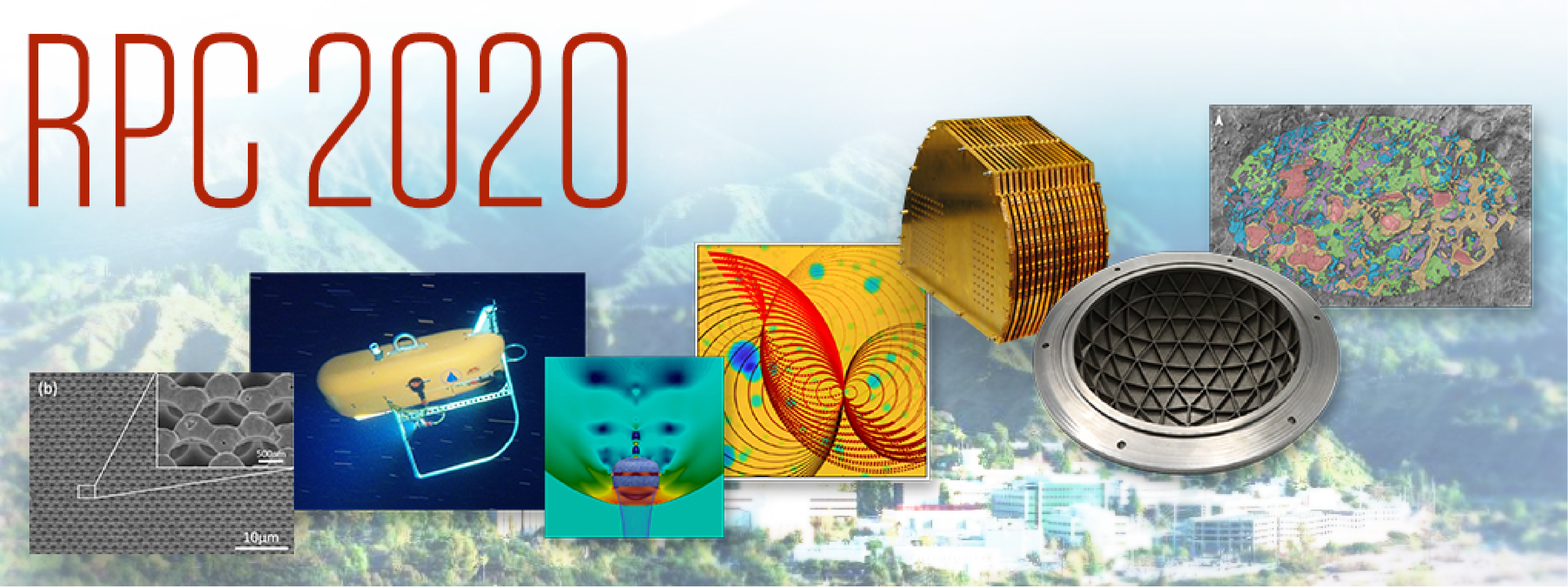

Virtual Research Presentation Conference

Rotating Beam Antenna Enabling Next Generation of Doppler Scatterometers

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Program: Topic
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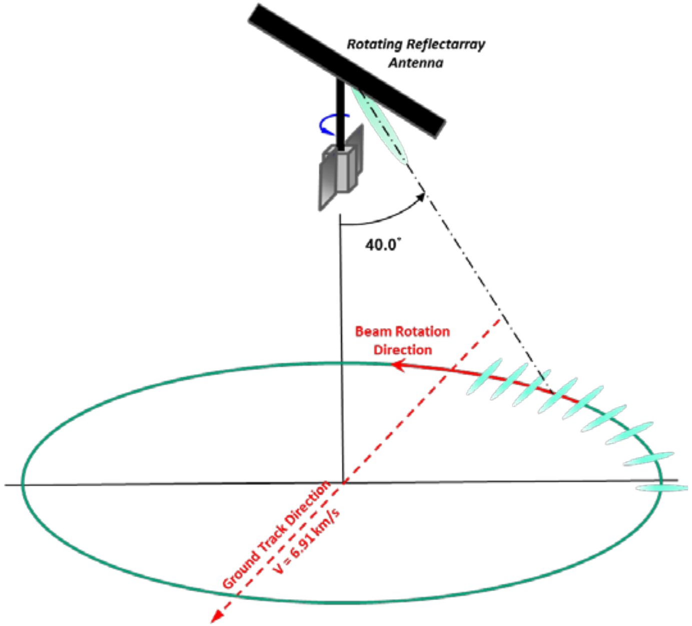
Tutorial Introduction

The 2017 NRC Decadal Review identified the simultaneous measurement of winds and currents as a measurement priority, and recommended that the measurement be achieved by a Doppler scatterometer as part of the $350M Earth Explorer competed mission candidates.

The DopplerScatt measurement concept was previously demonstrated from an airborne platform, but the antenna is the key technology and cost driver for a spaceborne mission.

The objective of this topical R&TD was to develop a Ka-band multi-beam, wide-swath, spinning antenna to enable a new spaceborne Doppler Scatterometer (DopplerScatt) mission for Earth Science:

- Develop an electrical design for a Ka-band antenna that can be deployed from a moderate cost launch vehicle, generates the required beams for the DopplerScatt performance, and achieves at least 50% efficiency.
- Develop a mechanical concept for the antenna structure and deployment, and assess the feasibility of deploying the antenna from a range of launch vehicles and fairings.
- Assess the expected performance of a Doppler scatterometer incorporating this antenna.



DopplerScatt Concept

Problem Description

The particular requirements driving the antenna design are:

Requirement	Driver
Narrow azimuth beamwidth (~0.10° – 0.12°) → Long antenna (~4m – 5m)	Needed to meet Doppler sampling requirements
High gain → Large aperture	Enables use of available commercial RF power sources, thereby reducing missions costs
Minimum antenna efficiency of ~50%	Needed to achieve high gain
Separate Tx and Rx beams, separated by the angle the antenna rotates in a round-trip radar bounce	Needed to compensate for the scan loss due to rotation
Beams pointed ~40° off nadir	Trade between swath size and return power strength
Able to spin at ~14 RPM	Needed to meet ground coverage requirements
Antenna pointing control better than 10% of 3-dB beamwidth in azimuth and elevation	Needed to meet radar performance requirements
Antenna elevation pointing knowledge better than 10% of 3-dB beamwidth	Needed to meet radar performance requirements
Antenna azimuth pointing knowledge after calibration better than 0.115 mdeg	Needed to meet radar performance requirements
Deployable from a compact configuration	Enables use of a moderate cost launch fairing
Moderate cost	Needed to fit into cost caps of NASA Earth Explorer Missions, Earth Ventures Missions, etc.

State of the Art Comparison

The closest antenna architecture that meets the requirements set above is the SWOT antenna, which is a deployable Ka-band reflectarray. The SWOT antenna achieves the driving Doppler scatterometer azimuth beamwidth requirement through a 5 m long aperture. The SWOT antenna has two beams, scanned in elevation, but it does not scan in azimuth, which is more challenging with this antenna geometry.

The following modifications would need to be made to the SWOT design:

- Increase the antenna width to achieve narrower elevation beams and increased gain
- Incorporate separate transmit and receive feeds
- Modify the design if needed to meet stability and torque requirements due to spinning
- Consider modifying the antenna f/D ratio to allow for a more compact structure
- Assess whether changes are needed to the existing SWOT antenna deployment mechanism

In order to reduce cost, maximize TRL, and achieve a deployable light structure, we chose to use the SWOT antenna design as the starting point for the DopperScatt design.

Methodology

Towards the end of FY19, we started focusing on whether DopplerScatt could be proposed as an instrument on a NASA Earth Ventures Mission (EVM) or Earth Ventures Instrument (EVI). We discussed the SWOT antenna and boom costs with several key players from SWOT. It became apparent that in order to have any hope of staying within an EVM or EVI budget, we needed the antenna to be as close to a build-to-print of the SWOT antenna as possible. With this realization, the target milestones of our FY20 work became:

1. Determine beam stability and beam pointing knowledge requirements
2. Update the reflectarray design to use SWOT-sized panels, and update the look angle so to something that would work with the gain achieved with SWOT-sized panels
3. Evaluate the radar performance with the updated reflectarray design with SWOT-sized panels and new look angle
4. Evaluate the structural/thermal performance of the SWOT antenna and boom in the DopplerScatt spinning environment
5. Create and archive a summary package of key results in order to provide a starting point for upcoming proposals

Results (1)

Accomplishments versus goals: (1) Determine beam stability and beam pointing knowledge requirements

Status: Completed

Three requirements were developed:

a) The antenna pointing control shall be better or equal to 0.10 of the 3-dB beamwidth in both azimuth and elevation.

b) The antenna pointing knowledge in elevation shall be better or equal to 0.10 of the 3-dB beamwidth.

c) The antenna pointing knowledge in azimuth needs to be much better than the antenna pointing knowledge in elevation. The pointing knowledge can be calibrated to some extent. The residual azimuth jitter variance, which cannot be calibrated, must be less than 2×10^{-6} radians, or 0.115 mdeg.

Results (2)

Accomplishments versus goals: (2) Update the reflectarray design to use SWOT-sized panels, and update the look angle so to something that would work with the gain achieved with SWOT-sized panels and (3) Evaluate the radar performance with the updated reflectarray design with SWOT-sized panels and new look angle

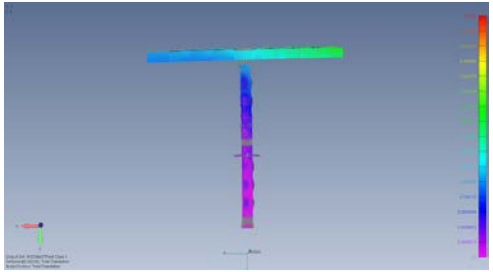
Status: Completed

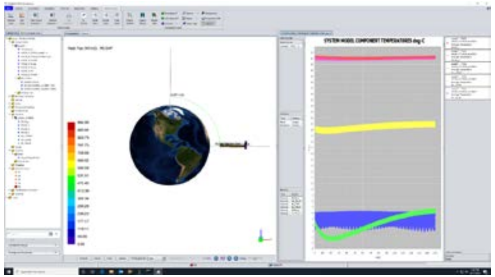
- It was determined that three additional rows of patches could be squeezed onto the top and bottom of the SWOT panels, while keeping the panel physical dimensions the same
- A new antenna RF design was generated with the additional rows using the previous look angle of 48°
- The resulting antenna patterns were analyzed with the Winds and Currents Mission (WaCM) radar performance model and determined that look angle needed to be reduced to 40° to compensate the reduction in gain due to the constraint of using the SWOT-sized panels
- The antenna RF design was iterated using the 40° look angle

Results (3)

Accomplishments versus goals: (4) Evaluate the structural/thermal performance of the SWOT antenna and boom in the DopplerScatt spinning environment

Status: Completed





- A reduced DopplerScatt antenna model was created from the SWOT NASTRAN model that was used for the Structural/Thermal/Optical/Performance (STOP) analysis
- Thermal analysis of the antenna while spinning was completed
- The thermal gradients were small due to the temperature averaging effect from the rotation
- The antenna panel distortions caused by the predicted on-orbit temperatures scanned the antenna pattern beam only slightly, and are not expected to be a concern
- Deformations due to spinning were relatively modest
- Z-deformations could be minimized by static balancing
- The antenna will be rotating around its minimum axis of inertia, which is a stable configuration

Results (4)

Accomplishments versus goals: (5) Create and archive a summary package of key results in order to provide a starting point for upcoming proposals

Status: In process

- The main findings are detailed in the R&TD final report
- A Docushare site was set up to archive internal reports and models. The team is in the process of uploading their information to the site.

Results (5)

Significance:

- The completed work shows that a DopplerScatt instrument can be implemented using a very close to build-to-print implementation of the SWOT antenna, thereby minimizing the cost of the large deployable antenna needed for a spaceborne version of the instrument
- An antenna RF design using the SWOT reflectarray panels was completed
- The predicted radar performance was evaluated and was shown to be acceptable with the antenna patterns
- The structural/thermal deformation of the rotating antenna was evaluated and found to have minimal impacts to the antenna RF performance
- This work lays the groundwork for JPL to be able propose a DopplerScatt instrument on a future mission

Next steps: Find a proposal opportunity for a DopplerScatt Instrument!

Publications and References

None