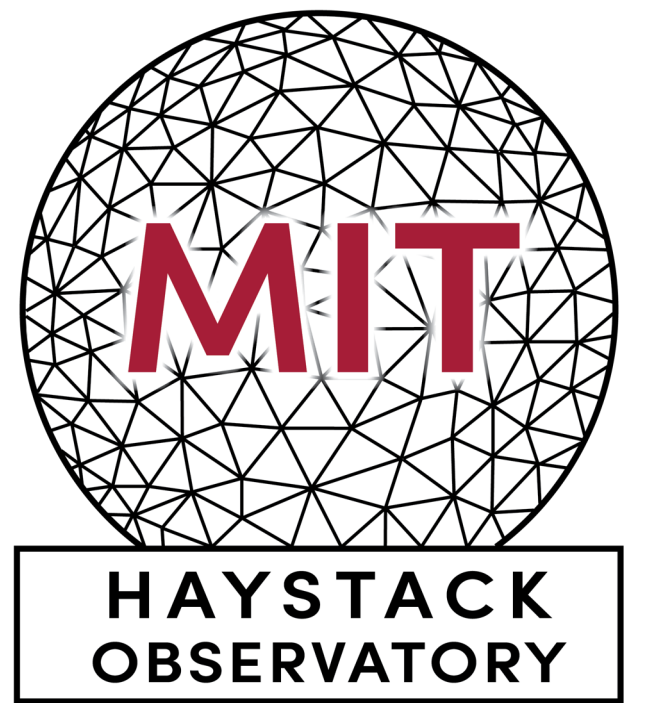


# ElectroMagnetic Vector Sensor Ionospheric Sounder (EMVSIS)



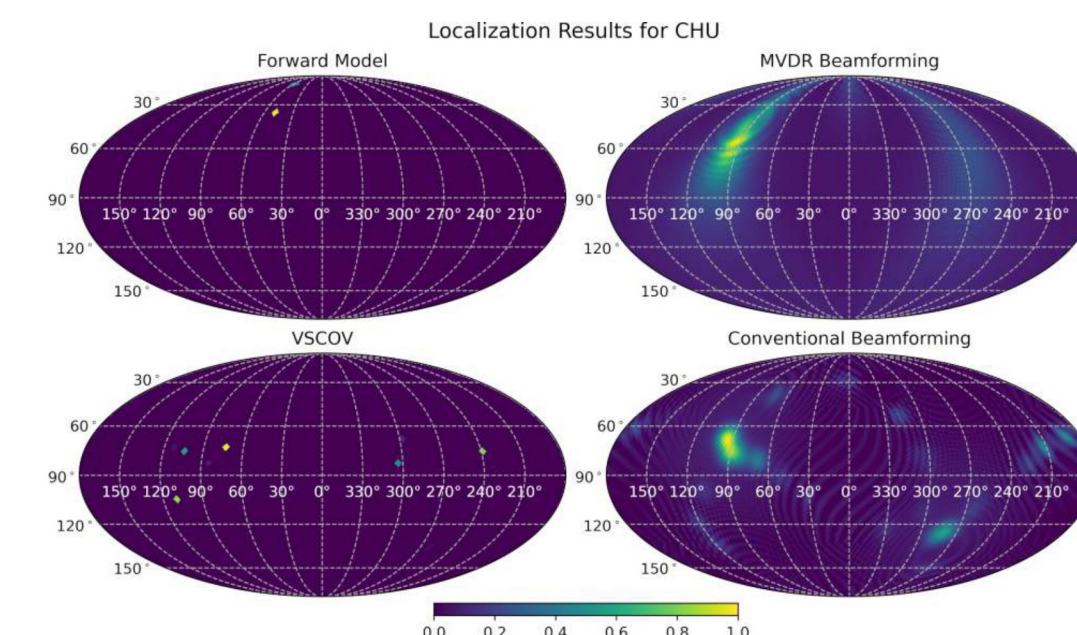
John Swoboda,<sup>1</sup> Ryan Volz,<sup>1</sup> Juha Vierinen,<sup>2</sup> Frank Lind,<sup>1</sup>

<sup>1</sup> MIT Haystack Observatory, Westford, MA, 01886, USA

<sup>2</sup> Dept. of Physics, University of Tromsø, Tromsø, Norway

## Objective

- Combine new techniques and technologies to create volumetric measurement of the bottom-side electron density in a low power envelope
  - MIMO Radar—Enables volumetric imaging with low power
  - Advance CW waveform coding—Enables low power transmit
  - ElectroMagnetic Vector Sensor (EMVS)—Angle of arrival estimation in small form factor



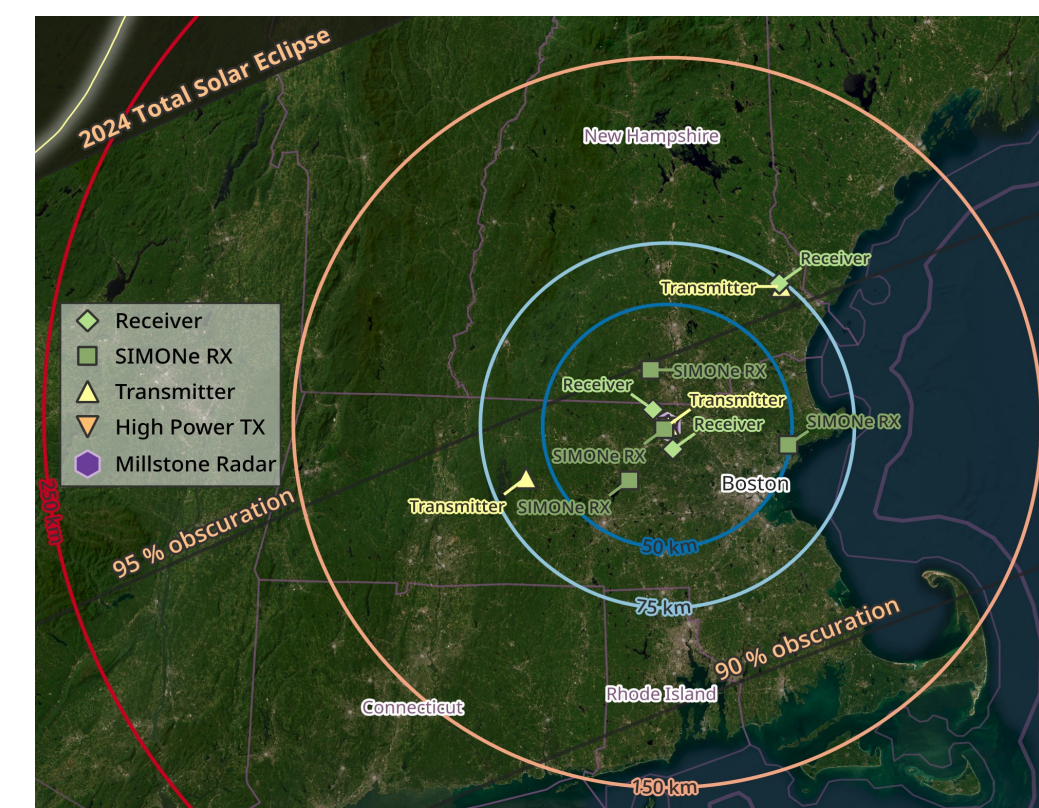
Kononov 2024

## Desired Scientific Products

- Electron Density Measurement
  - ~2–10 km vertical resolution (BW dependent)
  - ~25–50 km horizontal resolution
  - ~1- to 10-minute time resolution
- Ion Velocity Measurement
  - Measurement of Doppler from each Tx/Rx pair
  - 0 mode and X-mode
  - Use polarization filtering in EMVS
- Common Ionosonde Parameters
  - Fof2
  - hmf2
  - MUF

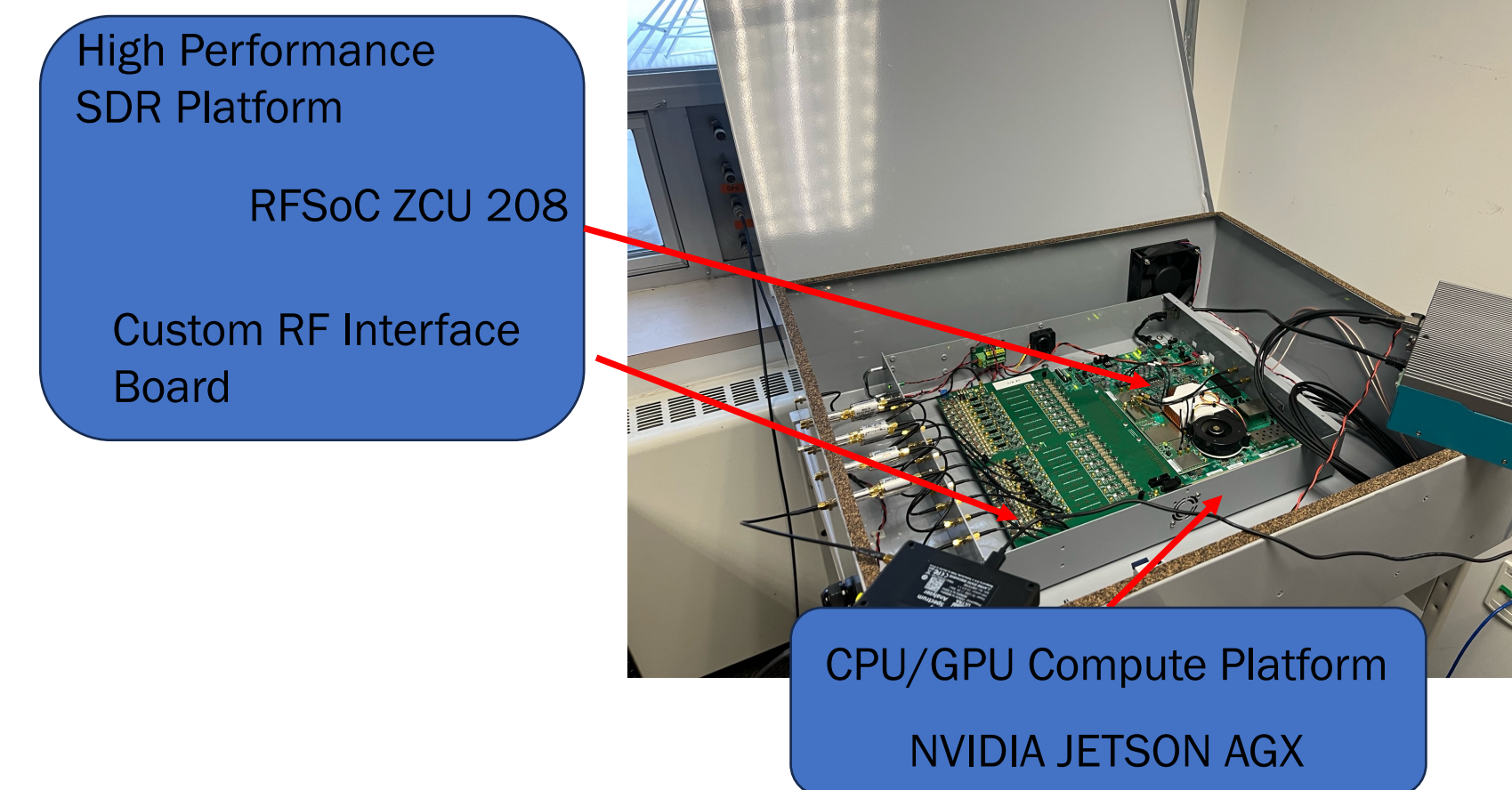
## Eclipse 2024 Deployment

- Deployed throughout New England
- Plan to deploy up to 5 transmitters and 8 receivers around MIT Haystack Observatory
- Partial deployment was completed: 3 receivers and 3 transmitters were deployed
- Received data is being processed and analyzed
- Deployed with Zephyr Meteor Wind Radar system
  - HF radar system with complementary capabilities and similar requirements
  - Used common receivers and jointly designed transmitters with many overlapping components



Map of partial deployment during the 2024 eclipse in New England.

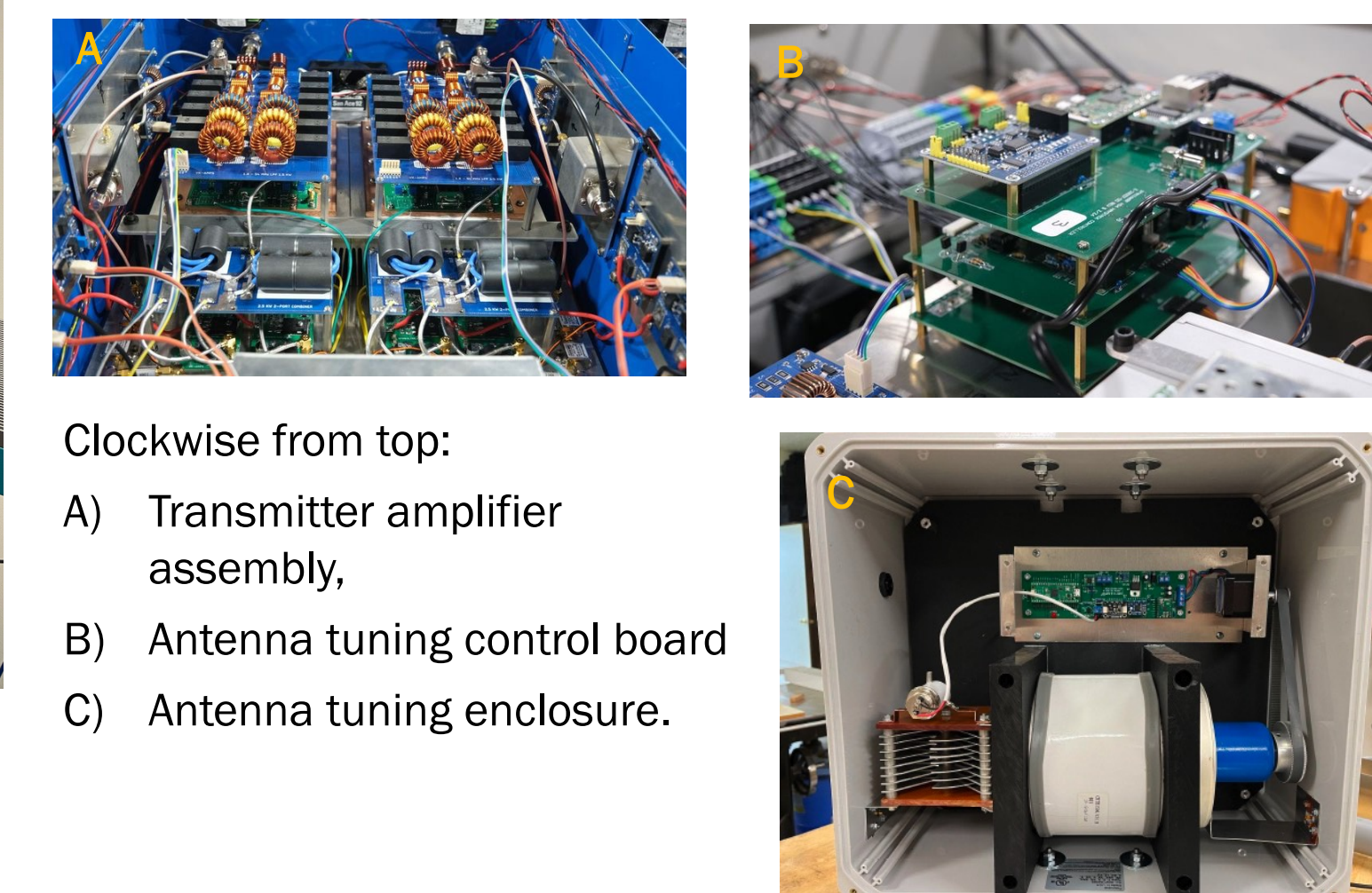
## Receiver System



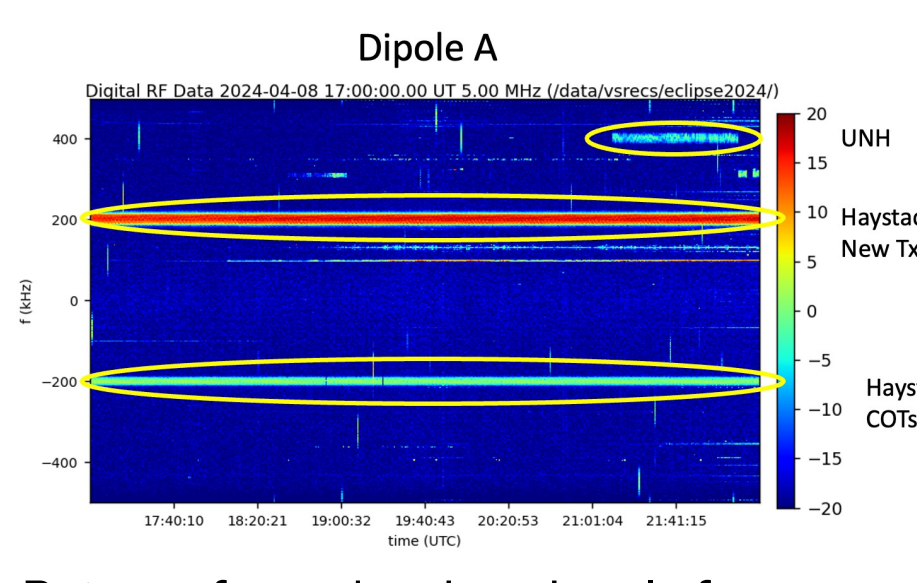
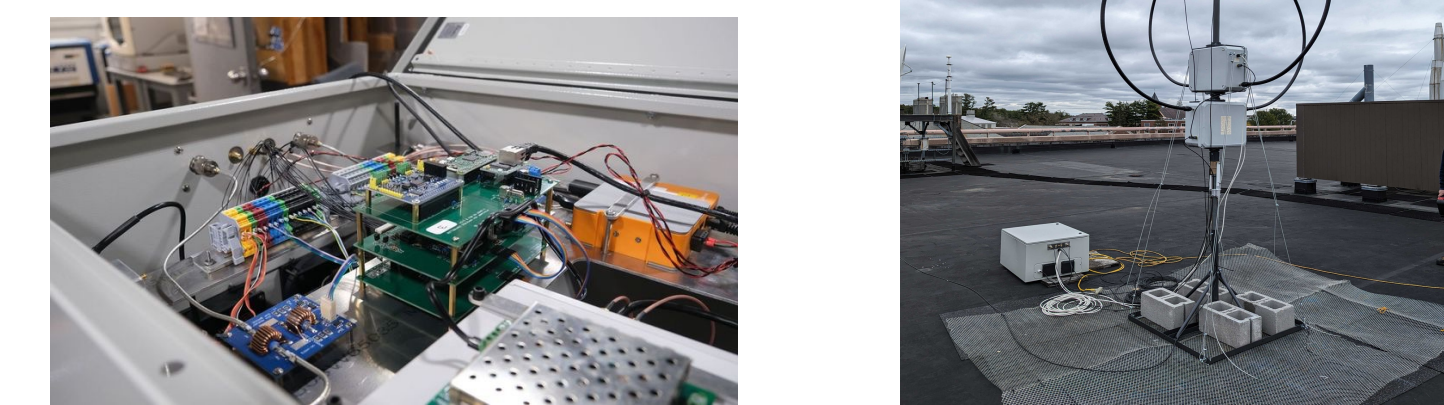
Below on the left, the radio and power system enclosures for the receiver. The right-hand side shows the EMVS antenna for this system.



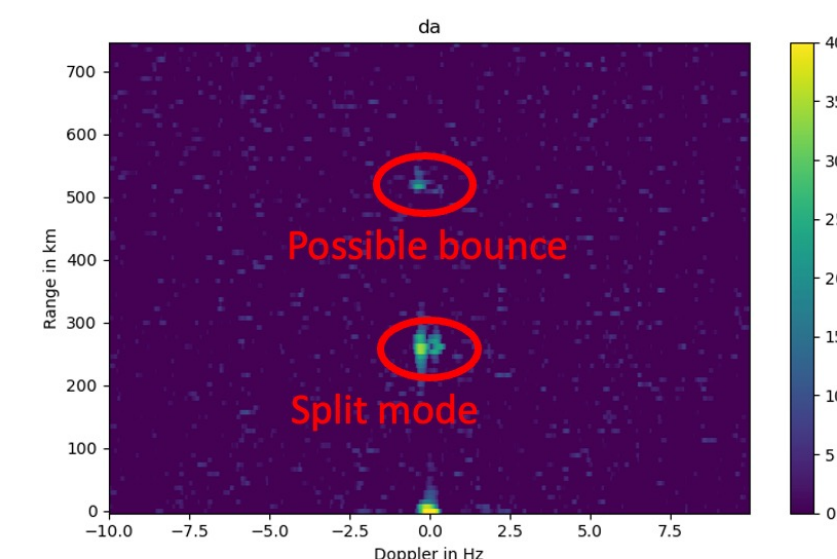
## Transmitter System



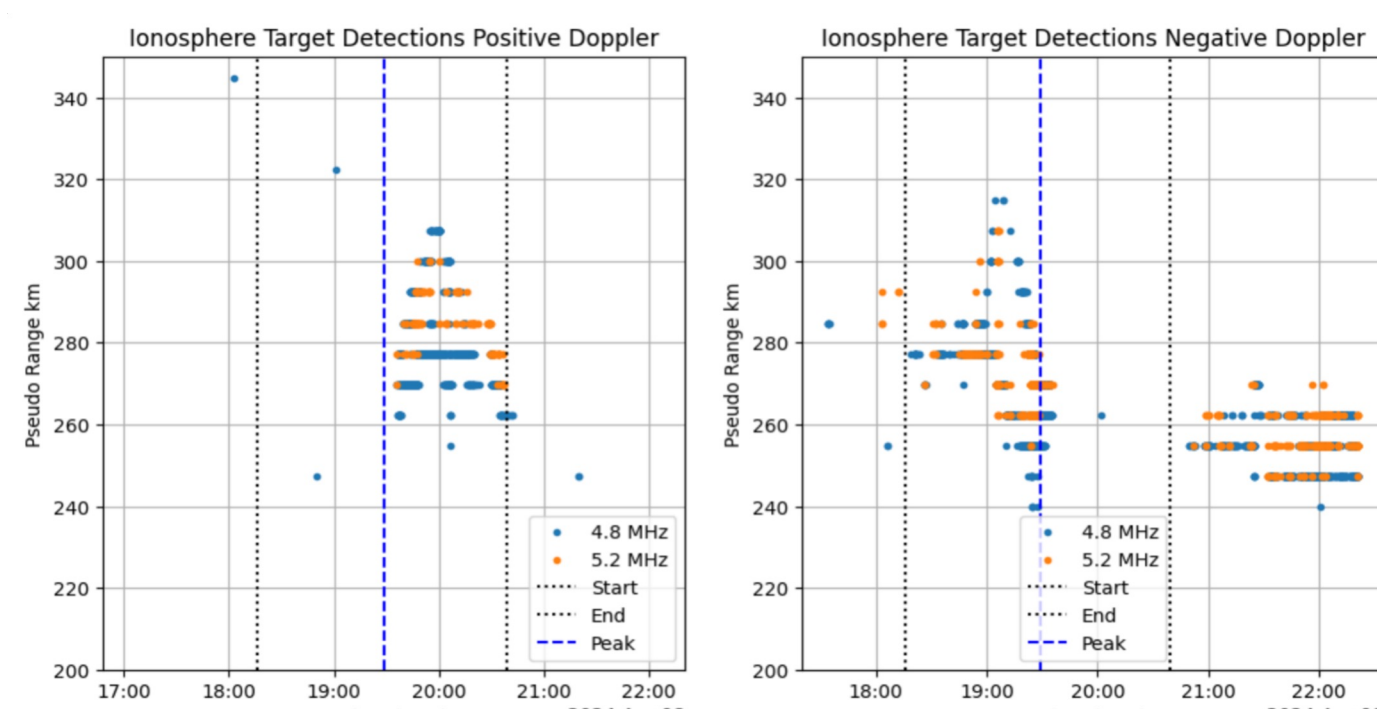
Right: The transmit dual polarized loop antenna. Below: Inside the transmitter enclosure.



Returns from showing signals from multiple transmitters during the eclipse.



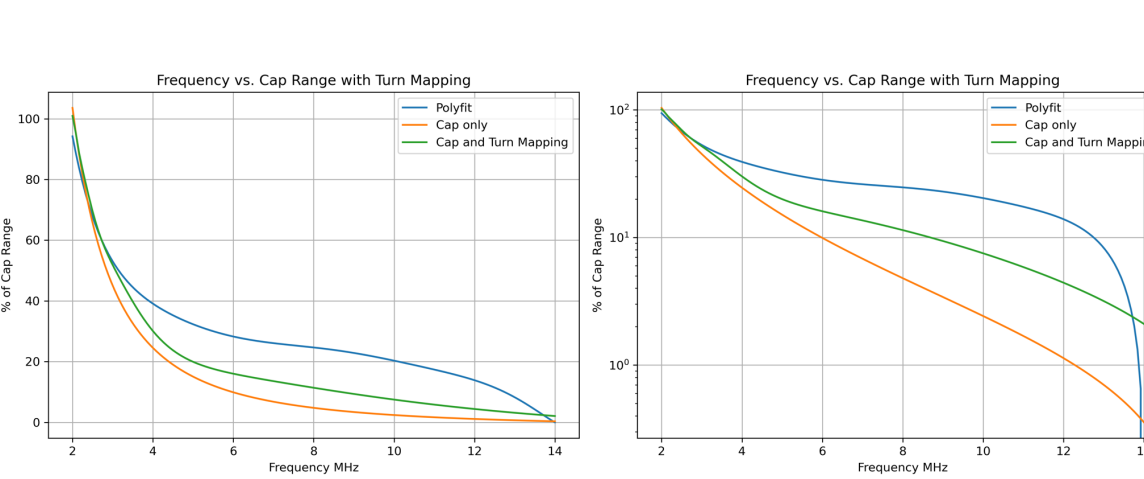
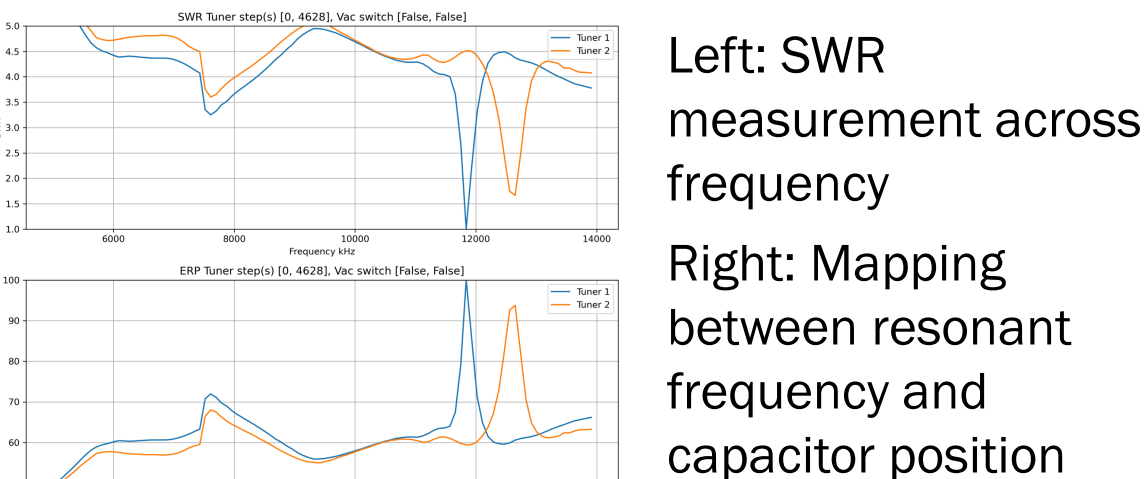
Partially processed returns showing possible bounce and mode splitting.



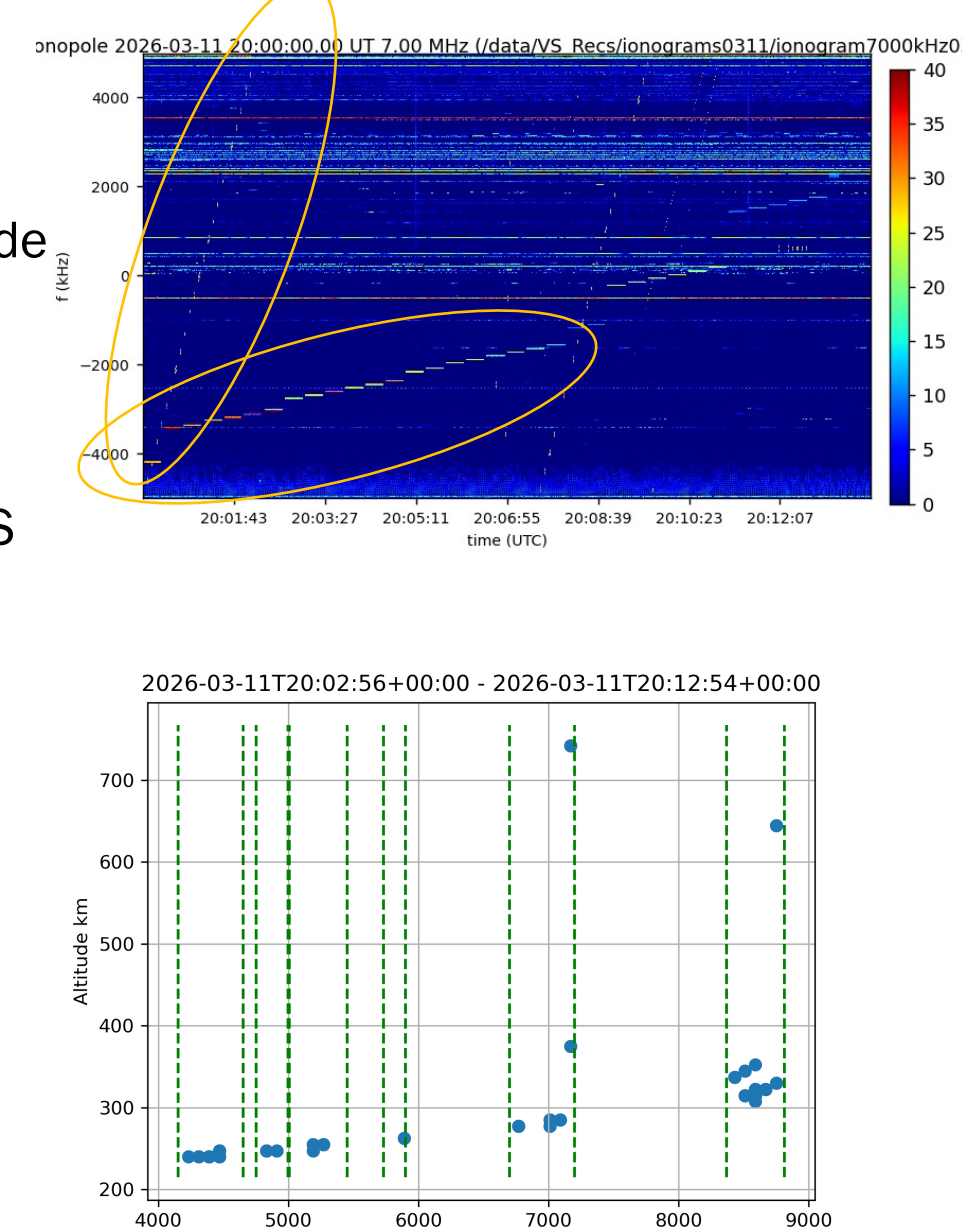
Fully processed detections tracking the virtual height of the ionosphere at multiple frequencies. Returns with positive and negative Doppler have been separated to try to discern bulk ionosphere motion during the eclipse.

## Recent Developments

- Created initial ionograms with frequency hopping method
- Improving stepper motor, timing belt and capacitor assembly
- Improving hard loop hardware components, better solder joints etc.
- Updated firmware and software for receiver system
- Performing RF system checks on receiver, linearity, etc.



Top: Spectral time intensity plot of transmit waveforms. Right: Partial ionograms from EMVSIS Transmit waveforms with licensed frequencies demarcated by green lines.



## Potential Future Steps

- Combine sensors for a large-scale space-weather network and grow from a regional scale to a national one
  - Zephyr Meteor Wind Radar
    - Thermosphere vector wind velocities
  - EMVSIS
    - Bottom-side ionosphere densities and drifts
  - GNSS TEC
    - TEC-based tomography to get top-side ionosphere
- Space mission for next-generation top-side sounding

