High Frequency Geolocation (HFGeo)

Geolocating High Frequency Ionospherically Refracted Transmissions

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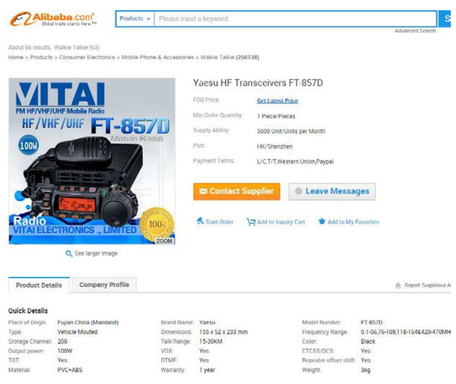
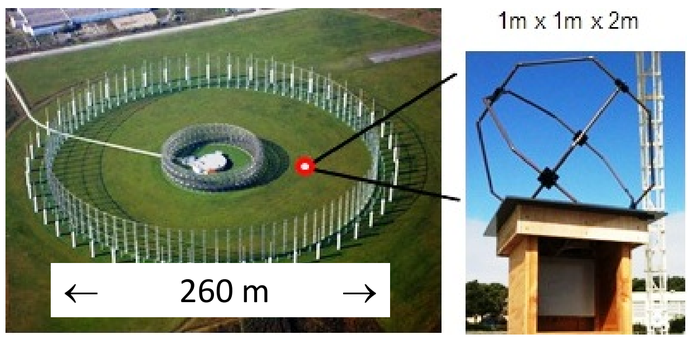
Why Care About HF?

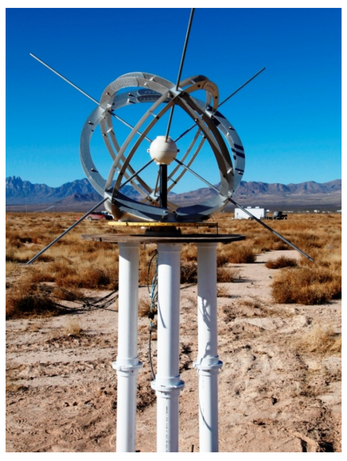
- HF Communications are an effective substitute to satellite communication (SATCOM) for voice and low data rate users
- Equipment is easy to get on Amazon or AliBaba and is inexpensive
- The ionosphere's effect on signal propagation complicates the problem
- Current solution use "brute force" though large antenna arrays tuned to these 10 - 100 meter wavelengths





How Can New Sensors Improve Geolocation?

- HFGeo Phase 1A proved electrically small (1.5 meter diameter) antennas can provide reliable estimates of arrival direction and polarization



- But the ionosphere is in constant motion; HF signals that "bounce" off it arrive at a variety of azimuth & elevation angles
- HF signal interaction with the ionosphere & Earth's magnetic field split the signal into two propagating modes with unique polarizations
- Electromagnetic Vector Sensors (EMVS) measure angles of arrival (AoA) & isolate each propagation mode

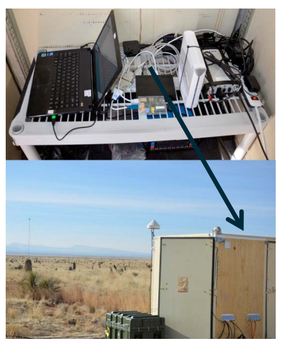
Measuring and Modeling the Ionosphere

- During the month of January 2014, the HFGeo team conducted an ionopspheric measurement campaign across the state of New Mexico
- The team included personnel from IARPA, MITLL, MITRE, AFRL, University of Texas ARL, and AFSPACE/SMC
- Instrumentation included HF transmitters, ionospheric sounders, optical emission sensors, low earth orbit satellite beacons and 67 HF receivers
- Collected more than 12 TB of data

Findings:

- Even on a calm day, the ionosphere can force 4°arrival angle changes
- Electrically small EMVS have the precision to isolate signals of interest from noise and interference
- Travelling Ionospheric Disturbances (TIDs) have wavelengths & electron density amplitudes that can be measured & modeled
- Modeling these density variations will enable the HFGeo system to correct ionospheric-driven errors

Receiving antenna at National Solar Observatory

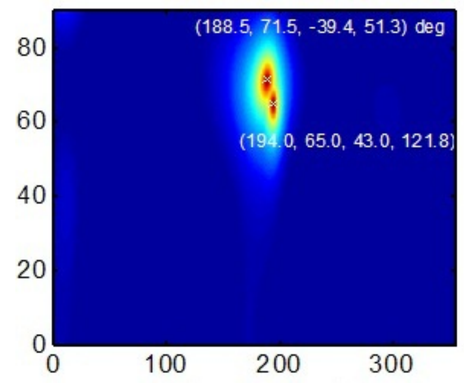


Equipment and Shelter at White Sands

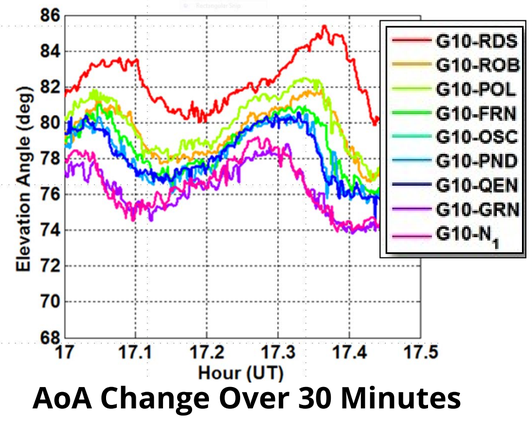
Ionospheric sounder antenna at White Sands

Results Thus Far

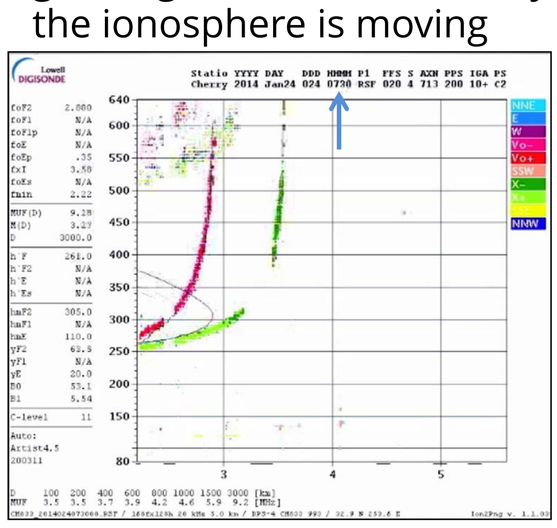
- An array of electrically small EMVSs can precisely separate both polarizations of an HF signal
- Systems without this capability mix the two together and induce angle estimation errors
- This same array of EMVS can precisely distinguish HF targets less than 6 km apart
- But even after midnight on a cold winter evening in New Mexico, with no tropospheric weather disturbance within 1000 miles and no significant geomagnetic or solar activity, the ionosphere is moving



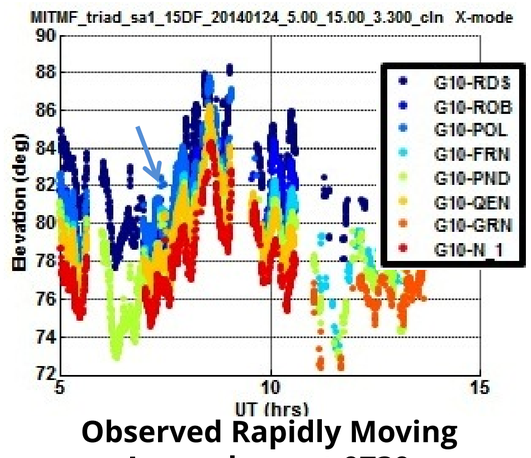
EMVS Array Can Separate Modes



AoA Change Over 30 Minutes



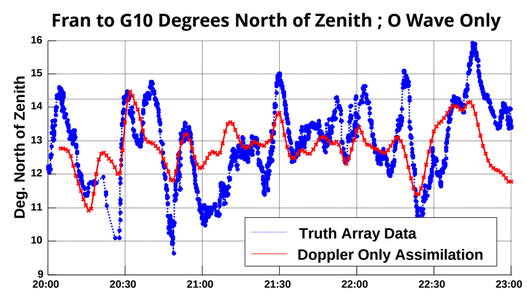
Sounder shows Calm Ionosphere at 0730



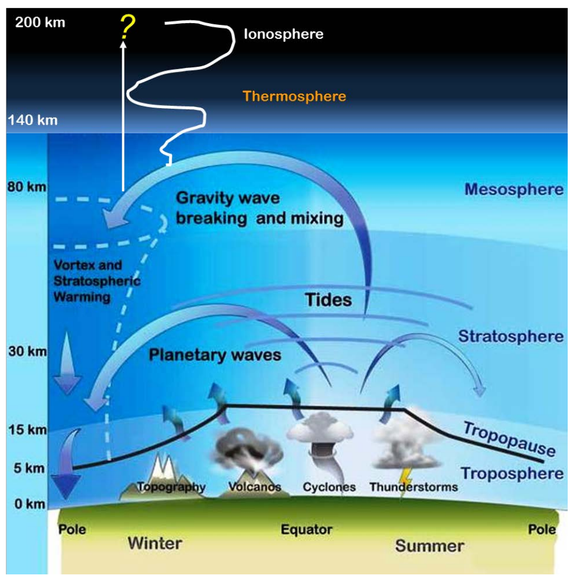
Observed Rapidly Moving Ionosphere at 0730

Upcoming Solicitation: Phase 2 and 3

- The next phases of HFGeo will design, build and test an integrated system incorporating:
  - Small antenna system
  - Ionospherically informed geo-location ability in the presence of ionospheric disturbances
- System performance will be demonstrated with a diverse set of use cases, under a variety of challenging ionospheric conditions
- Our test and evaluation team will continue to pursue experiments with rich, ground-truthed data, including a one year campaign to determine the effect of TIDs and other ionospheric disturbance on short range and long range propagation
- Longer-range goal: Model the effect tropospheric and stratospheric climate has on these ionospheric disturbances



Estimated (red) vs Truth (blue)



Adapted from: http://www.wmo.int/pages/publications/bulletin_en/archive/62_1_en

Transmit Site Equipment

Check Target site with GPS receiver

Optical Sensor

Receive Site Equipment