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OFFICE OF THE DIRECTOR OF NATIONAL INTELLIGENCE

HFGeo Phase 0 and Phase 1B Test and Evaluation Smart Collection Office

LEADING INTELLIGENCE INTEGRATION

Frank C. Robey, D.Sc.

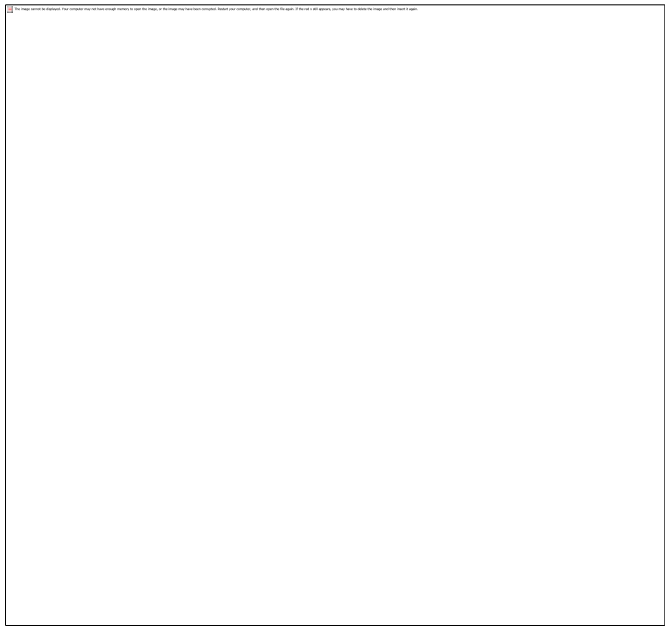
HFGeo Phase 1B Proposers' Day Briefing,
July 13, 2012

Agenda

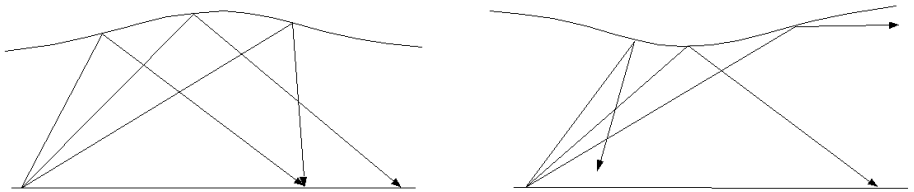
8:00 – 8:30 am	*Check-in*	
8:30 – 8:40 am	*IARPA Overview and Remarks*	Dr. Peter Highnam IARPA Director (acting)
8:40 – 9:10 am	*Contracting Officer Remarks*	Ms. Sarah Wiley IARPA Contracting Officer
9:10 – 10:30 am	*HFGeo Phase 1B Overview*	Dr. Frank Robey SC Deputy / Program Manager
10:30 – 10:45 am	*Break*	
10:45 – 11:30 pm	*HFGeo Phase 1B T&E*	Dr. Frank Robey SC Deputy / Program Manager
11:30 – 12:00 pm	*Q&A Session*	
12:00 – 12:45 pm	*No Host Lunch*	
12:45 – 3:00 pm	*Capability Briefings and Informal Teaming Discussions*	Non-Government Personnel Only

Phase 0 Testing

- **Ionospheric physics investigation**
  - Determine the temporal variation of the ionosphere
  - Determine the spatial variation & scale
  - Determine variation with frequency for geolocation
- **Sensor data for Phase 1 (vector)**
  - AM, single sideband, digital (PSK-31), and radar waveforms
  - Interference: local and long distance
  - Sky wave and surface wave radar intelligence data
- **Vector antenna proof of concept**

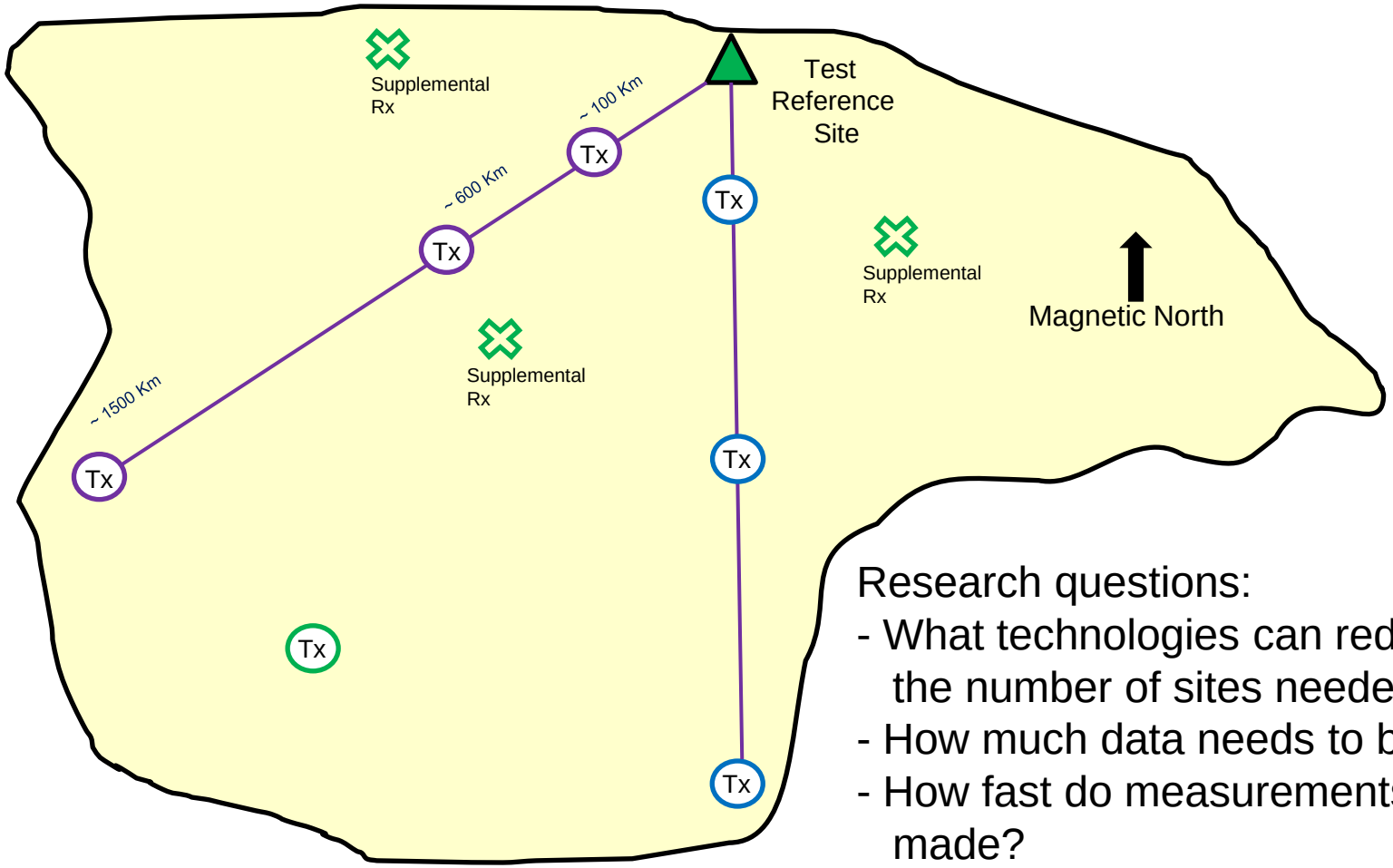


Ionospheric Electron Density Variation



Propagation Variation

Notional Test Layout for Phase 1B



Research questions:
- What technologies can reduce the number of sites needed?
- How much data needs to be shared?
- How fast do measurements need to be made?

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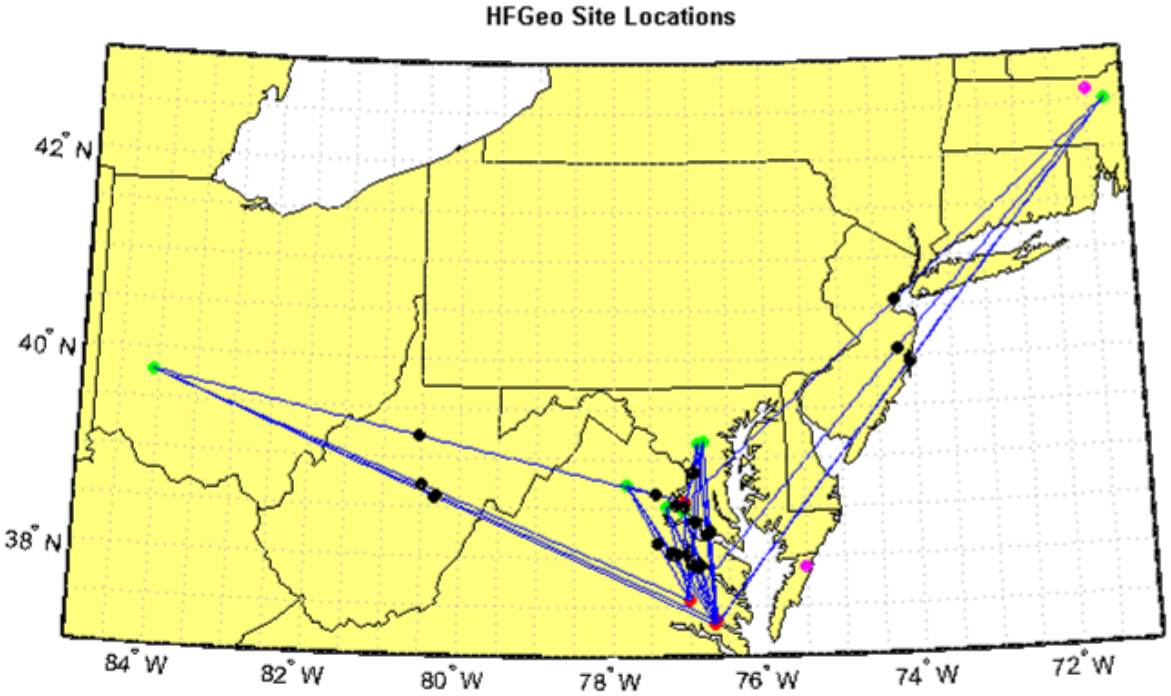
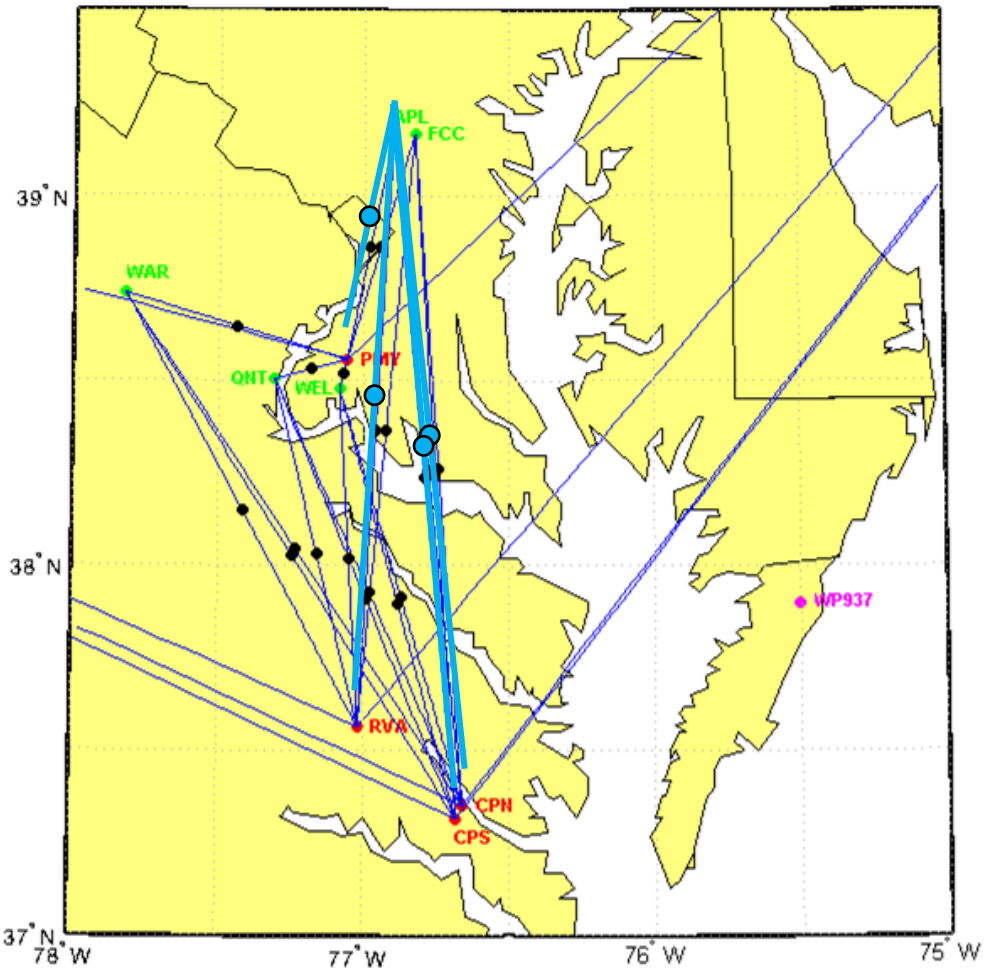
HFGeo Phase 1A Link Distribution



- Receiver
- Transmitter
- Midpoint
- Digisondes (UMass-Lowell)

- 28 Receiver – Transmitter links
- 6 separate campaign intervals (~ 5 x 12 hrs, 1 x 24 hrs)
- Successfully conducted between 01 – 09 Mar 2012
- Participation by 13 additional FCC sites not illustrated above

Phase 1A HFGeo Local Link Distribution



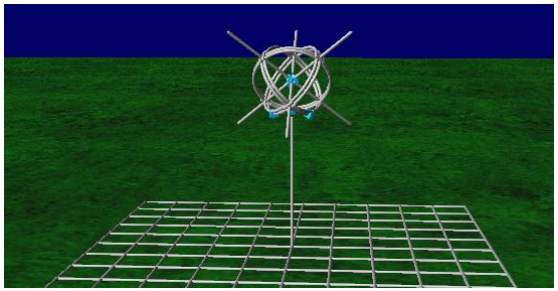
- Receiver
- Transmitter
- Midpoint
- Digisonde (UMass-Lowell)

APL links (example)

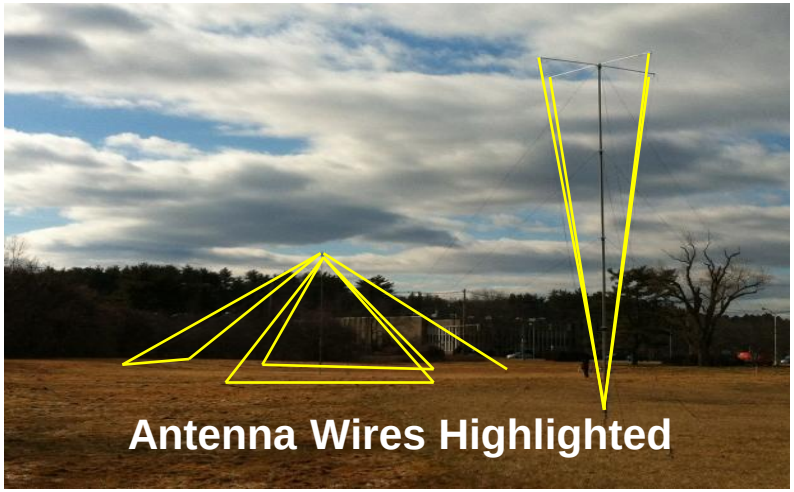
Dense midpoint distribution contains spatial variation from < 1 km to ~100 km

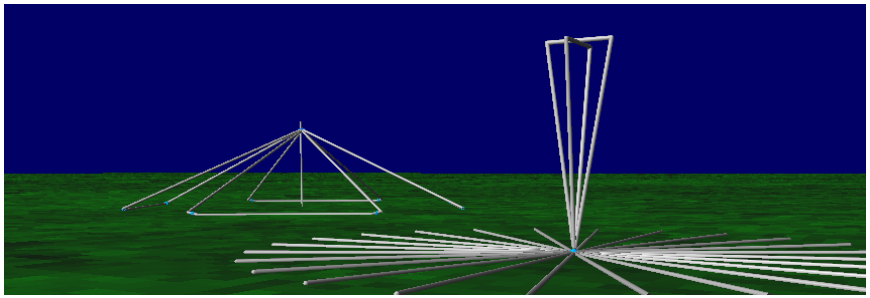
Antenna Equipment

Naval Research Laboratory
6-Axis Vector Sensor
Used for Receive Only
Total of 3 Antennas Fielded



MITRE Corporation
3-Axis Wire Antenna
Used for Transmit and Receive
Total of 18 3-Pol Antennas Fielded

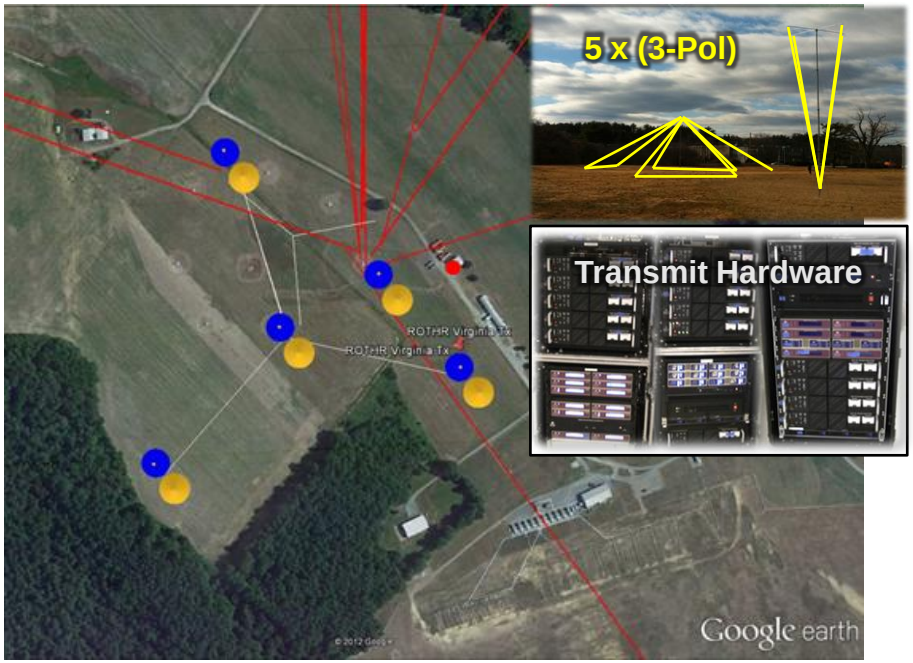




Layouts for Sites with Arrays

15-Channel Transmit System

ROTHR: New Kent, Virginia (RVA)
1 x 3-Polarization Sounder
4 x 3-Polarization Radar/Comms Emitters



18-Channel Receive System

FCC HFDF Enforcement Site: Laurel, MD
4 x 3-Polarization Wire Antennas
3 x Vector Sensors

Equipment from across the wider HF/OTHR community was reconfigured to support this HFGeo testing campaign

Particular thanks to OSD/AFRL NGOTHR Technology Risk Reduction Initiative for use of transmit equipment

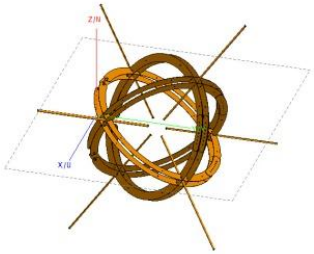
Vector Sensor Development

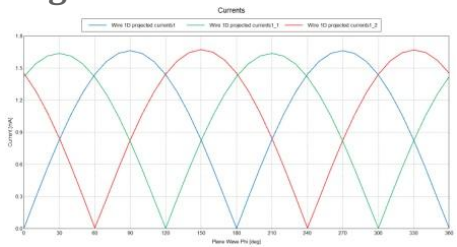
Vector Sensor Characteristics

- Ground symmetric
- 3 orthogonal loop construction
- 3 orthogonal dipole construction
- Operates over 3 to 10 MHz
- Twin loop mechanically supports dipoles
- Active matching networks

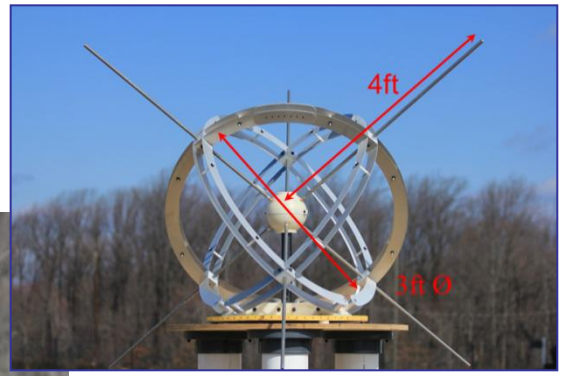
EM Modeling of Sensor

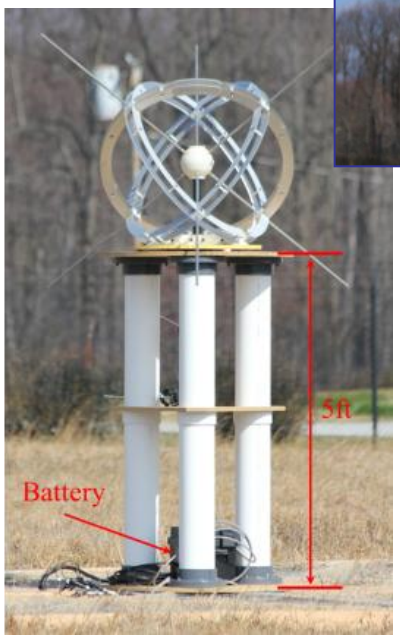
- Initial model of simple loops and dipoles done with NEC and based on method of moments
- Planned: Antenna range measurements





Fielded Vector Sensor





Transmit and Receive Equipment

15-Channel Transmit System

18-Channel Receive System

3-Channel Transmit System

(3 Total)

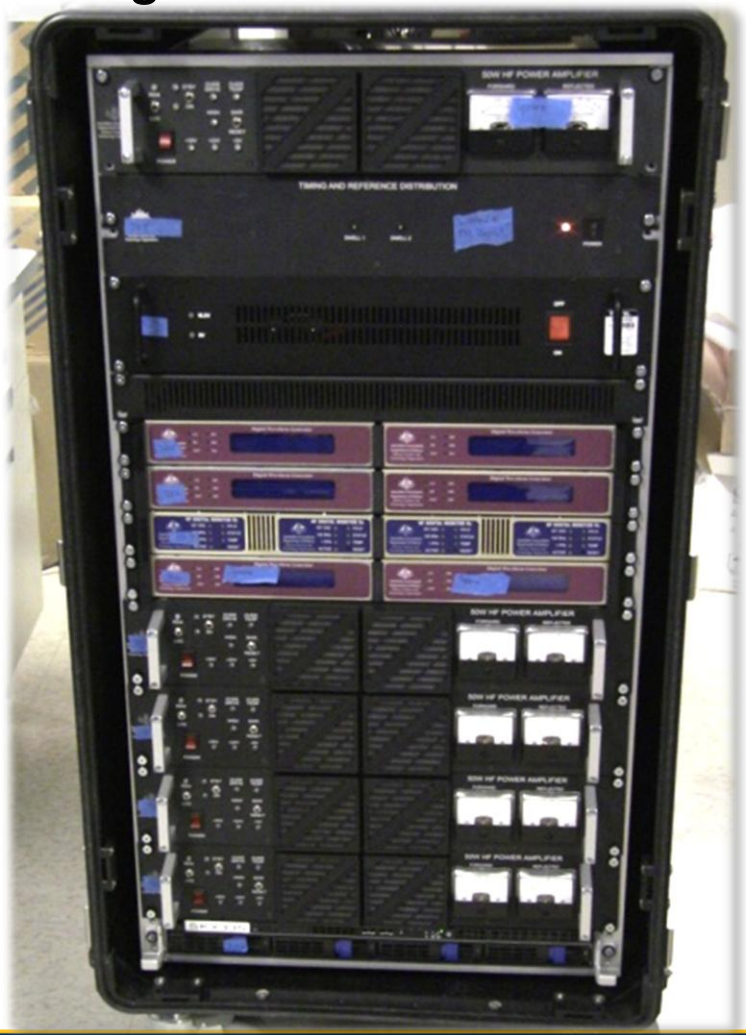
4-Channel Suitcase Receive System

(6 Total)

4-Channel Transmit Rack

Total of Three Systems Configured

- Combination of Components
  - Half-Height rack chassis
  - 4 Active DWG, PA, MRx sets
  - Control computer, TRDU, Power
  - Spares: 2 DWG, 1 PA
  - Jackson Labs GPS unit (in rear)
- Operation
  - Independent sounder scheduling for each channel/site
  - Individual radar scheduling for each channel/site



Suitcase Receiver Systems

Total of Six Systems Configured

- 6 suitcase systems
  - Analog front-end (external)
  - 4 Monitor receivers
  - Internally Generated GPS Timing
  - 1 Laptop Control Computer

18-Channel Receiver System

- Combination of Components
  - Half-Height rack chassis
  - 18 BAE Systems (AUS) Direct Digital Receiver (DDRx MkIID)
  - Control computer
  - GPS timing
  - Precision frequency reference
- Operation
  - Direct sampling of HF spectrum
  - Three flexible channelizers per receiver
  - Simultaneous reception of three frequency bands or sounders

Outline

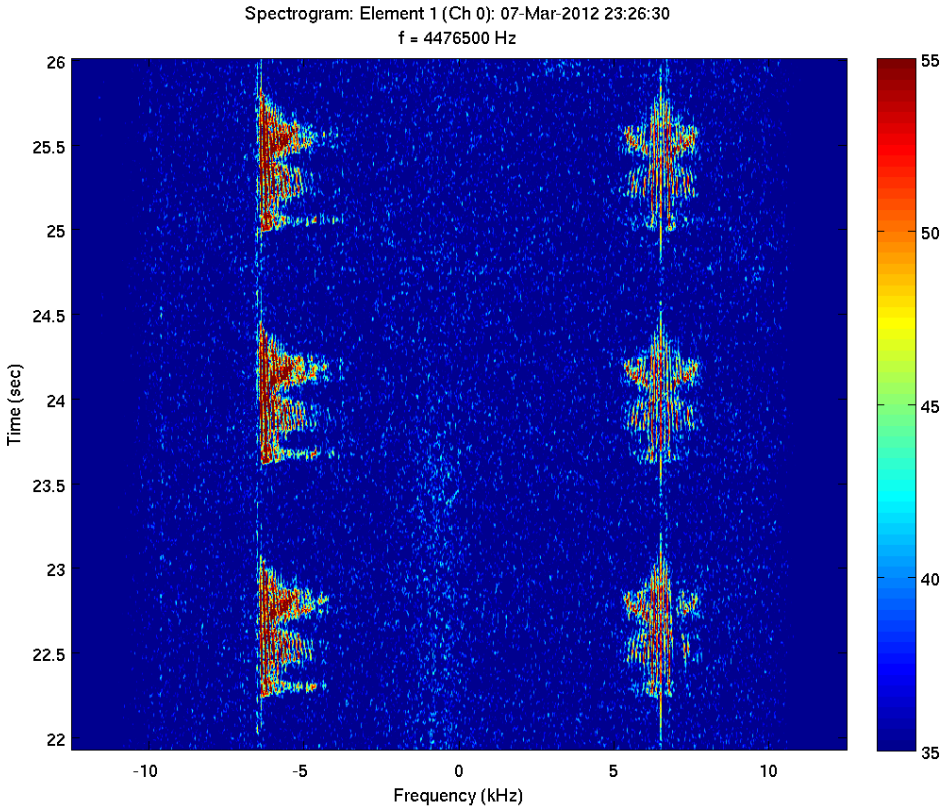
- Introduction
- Test Siting and Equipment
- Example Results
- Summary

Single Element Spectrogram

- Spectrograms (overlapped Short-Time Fourier Transforms) using built-in MATLAB function operating on raw data
- Example to right is of single sideband and AM signals

Communication Signal

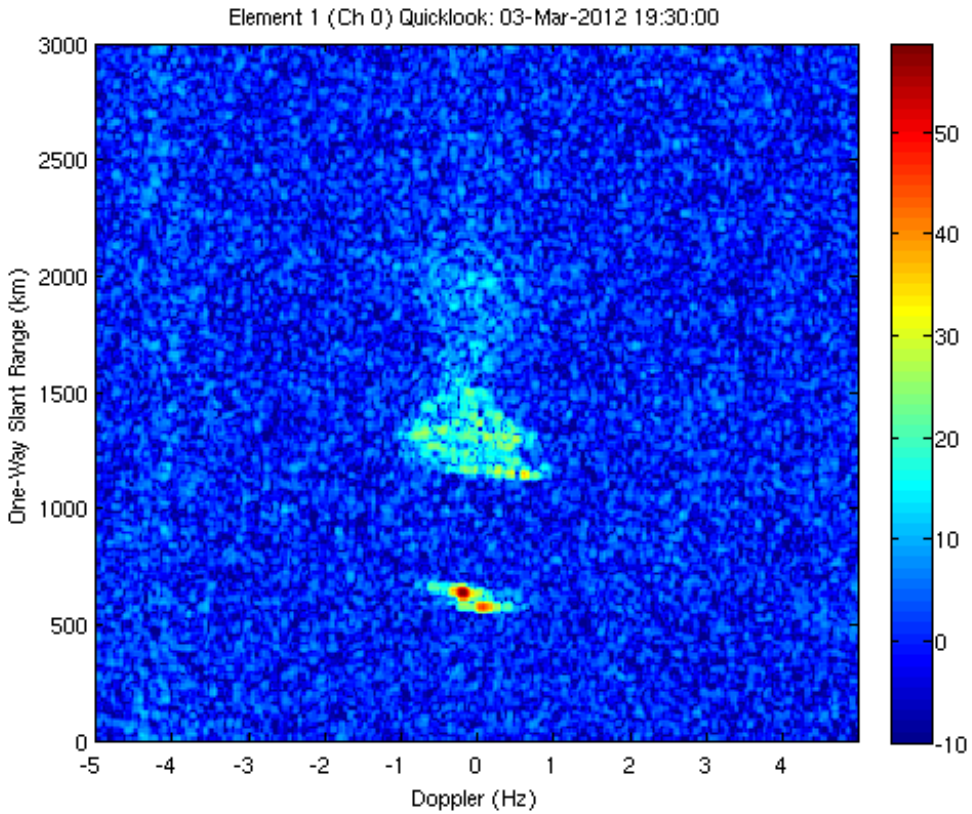
04 Mar 2012 23:26:00 UTC (17:26:00 Local)



Single Element Radar Processing

- Range-Doppler displays produced from radar transmission
- Example to right shows one-way radar signal measurement (channel scattering function)

Radar Range-Doppler Output
03 Mar 2012 19:30:00 UTC (14:30:00 Local)

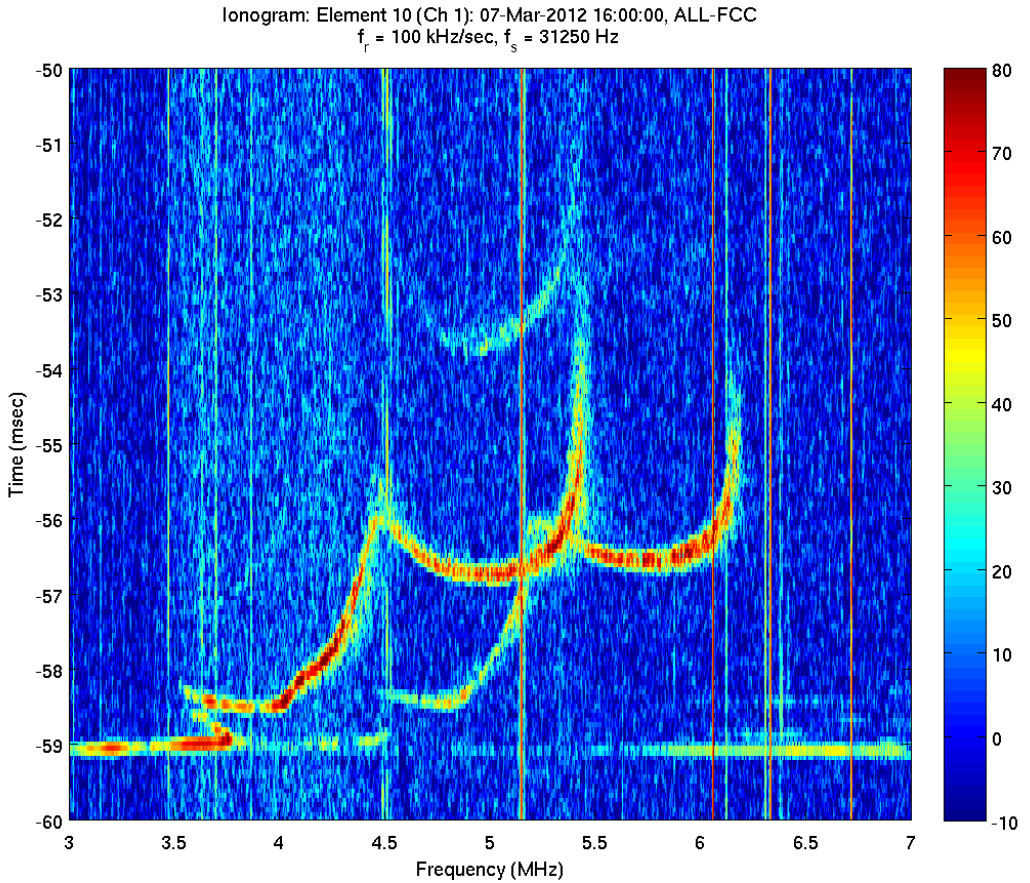


Single Element Ionogram

- Ionogram produced from linear-sweep transmitted signal
- Example to right shows near-vertical incidence with clear O/X traces and some 2-hop O returns

Ionogram Output

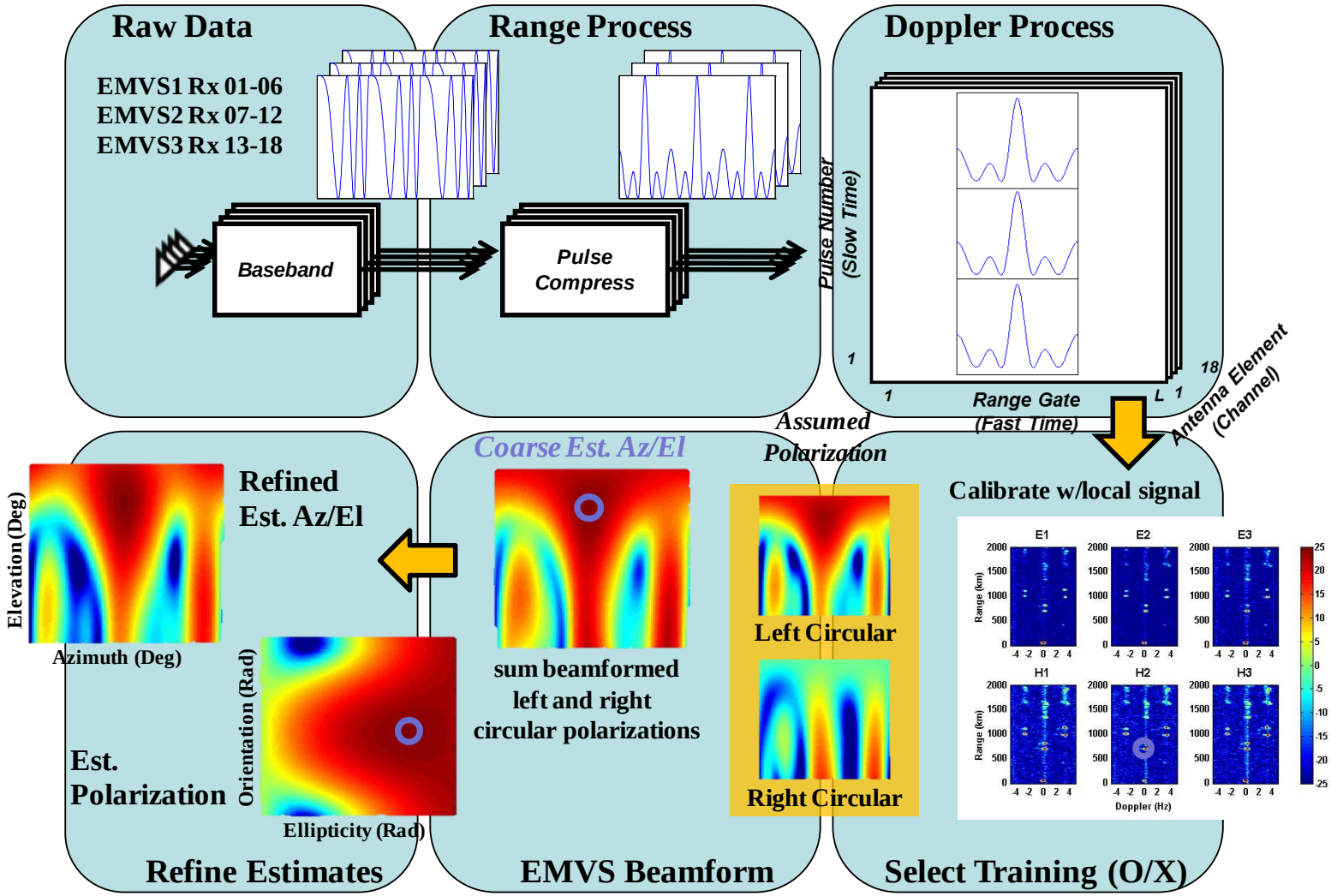
07 Mar 2012 16:00:00 UT (11:00:00 Local)



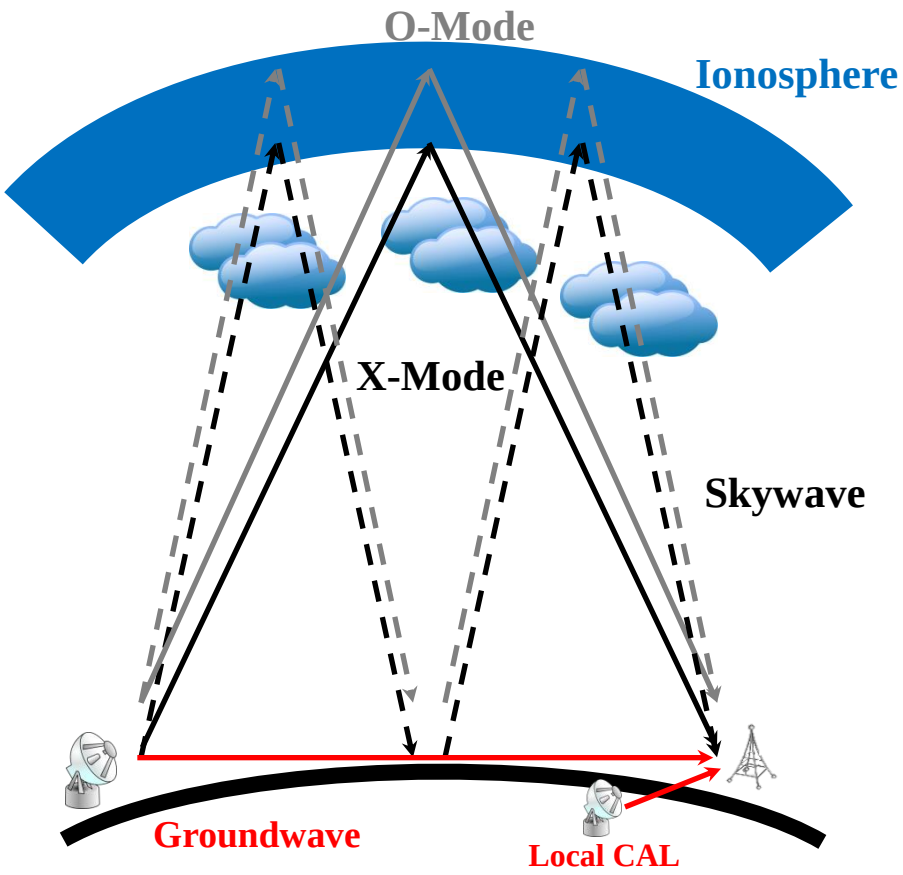
Vector Sensor Measurements

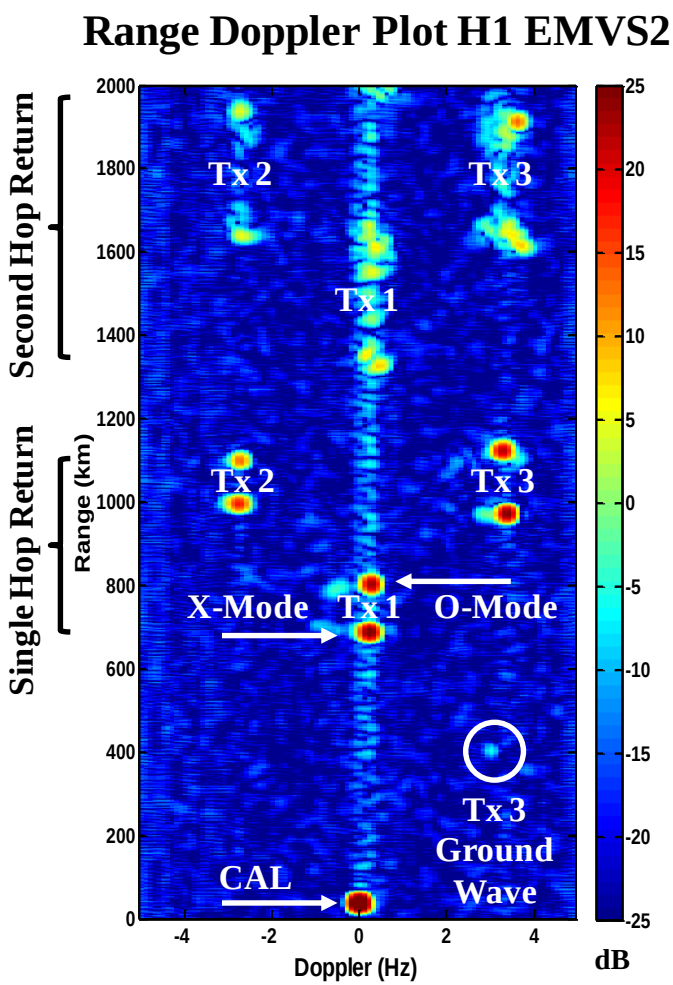
- Three element vector sensor deployed to FCC receive site
- Calibration efforts are significant
- Prior to deployment, NEC was used to model vector sensor
- Initial calibration is using local signal injection
- Further calibration will use SPAWAR outdoor antenna range

Quick Look Processing



Channel Scattering Function

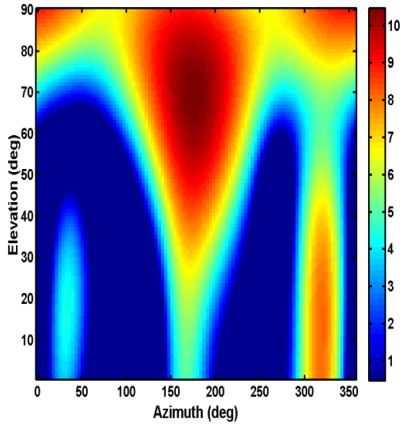




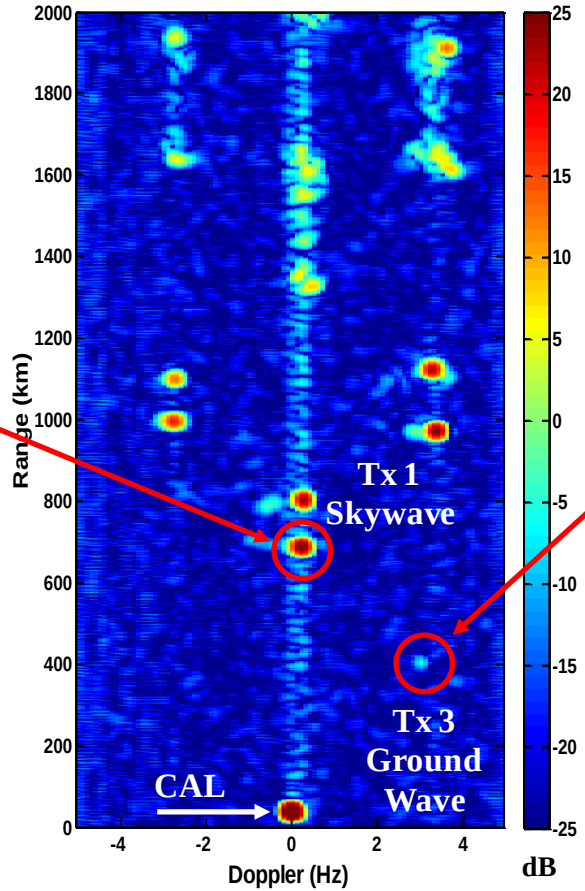
Radar Waveform - 20kHz Swept BW, 10Hz WFR, 10s Dwell, 5.48MHz fc, E3 → N **2012-03-03 023320 UTC**

2D EMVS Array Spatial, Polarization Processing

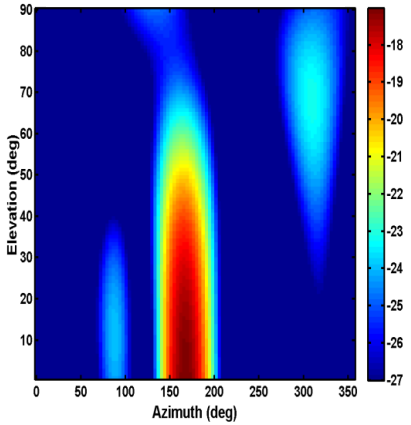
Tx 1 Skywave



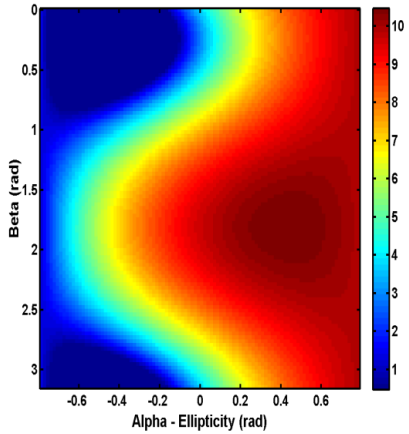
Range Doppler Plot H1 EMVS2



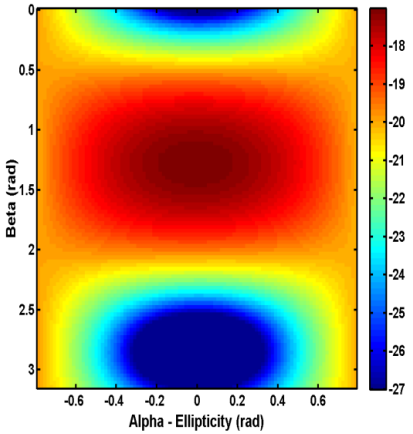
Tx3 Ground Wave



Tx 1 Left Circular Polarization



Tx3 Vertical Polarization



Est. ~176°Az, 69°El

Est. ~169°Az, 0°El

Radar Waveform - 20kHz Swept BW, 10Hz WFR, 10s Dwell, 5.48MHz fc, E3 → N

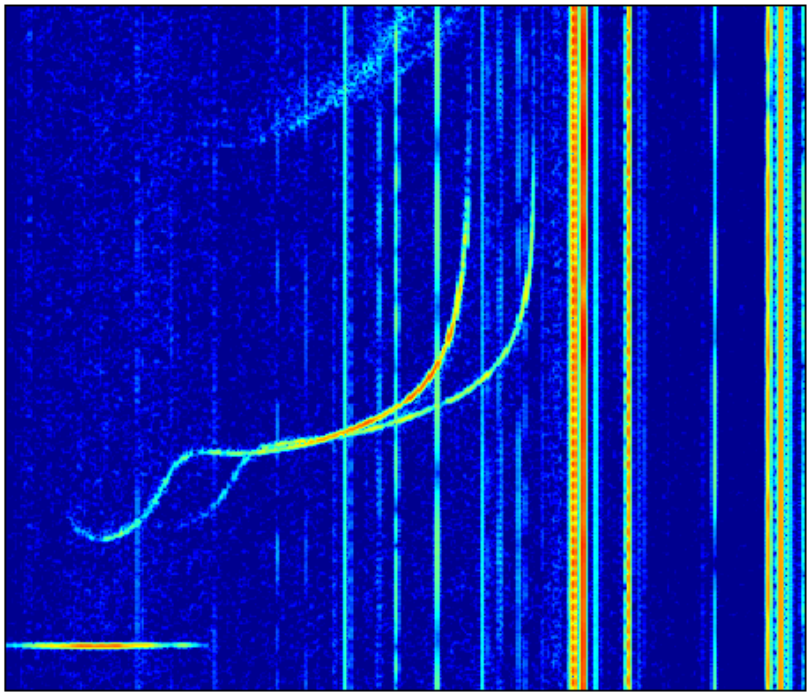
2012-03-03 023320 UTC

Ionogram RF Interference Removal

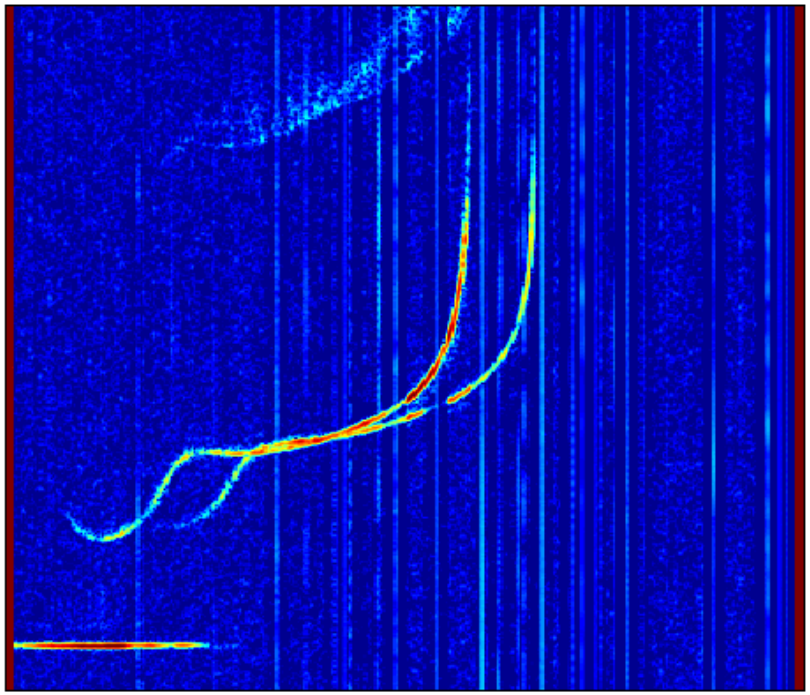
Exploitation of Polarization Data

- RF Interference (RFI) removed using polarization-based processing
  - Left plot is measurement on single H-pol dipole receive antenna
  - Right plot is combination of 3-polarization responses to reject interference sources in sounder data

H-Pol 1



Cleaned Ionogram

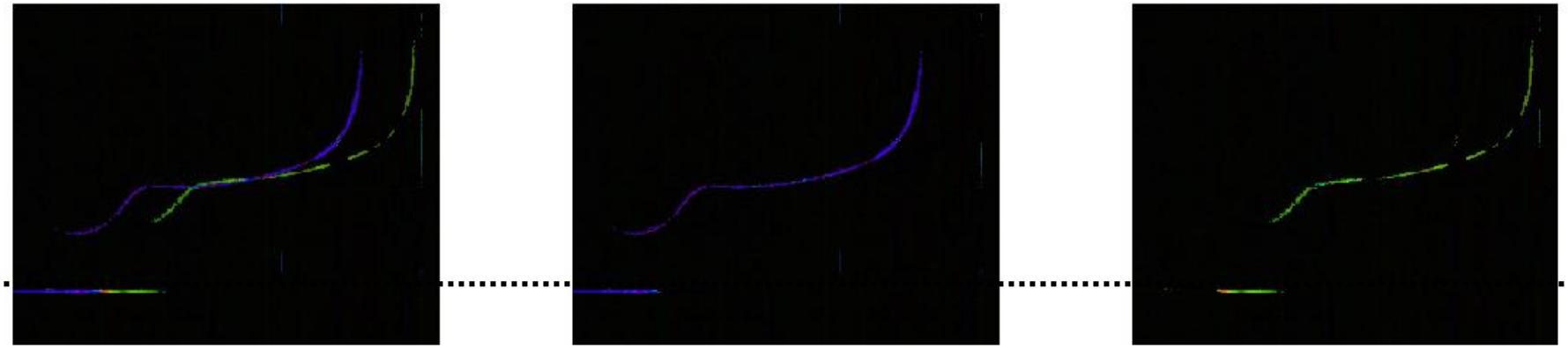


Ionospheric O-X Separation

Receive Antenna Quick-look Result

Color Indicates Ionospheric Mode: O (purple) or X (green)

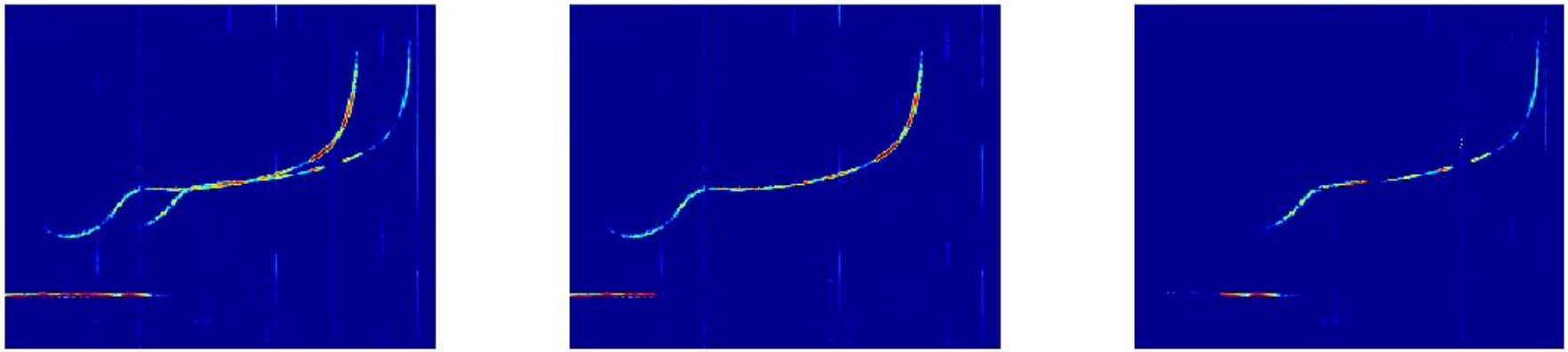
Cleaned Ionogram | O Mode | X Mode



Color Indicates Amplitude Level (dB)

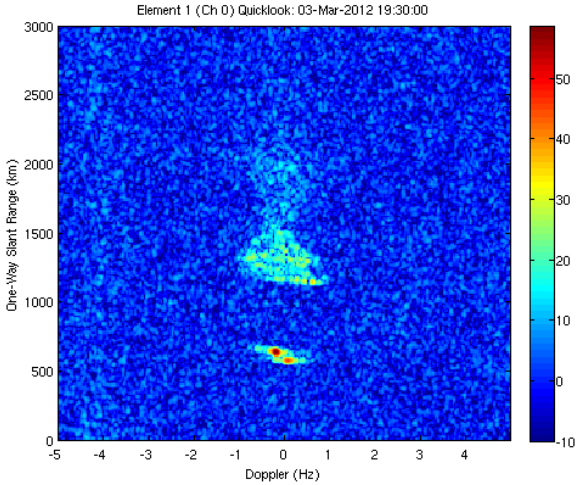
Initial result indicates potential separation of F-layer O and X modes

Cleaned Ionogram | O Mode | X Mode

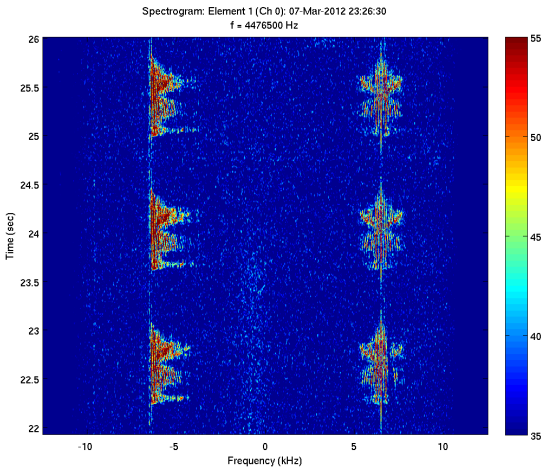


Data processing adapted from T. Harris, DSTO

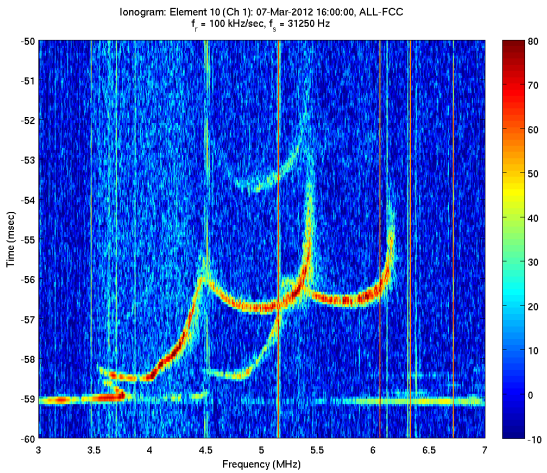
Data Supporting Ionospheric Analysis



Radar Range-Doppler



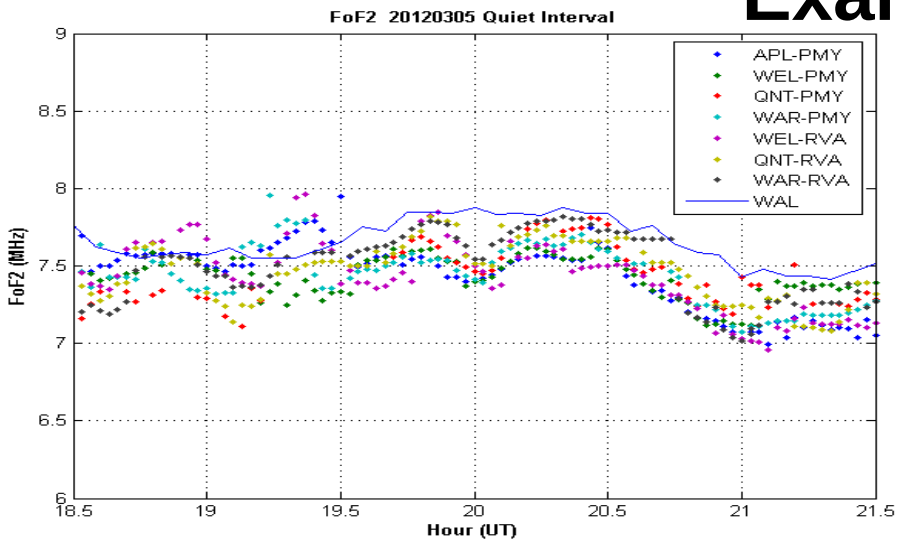
Communication Signal Spectrogram



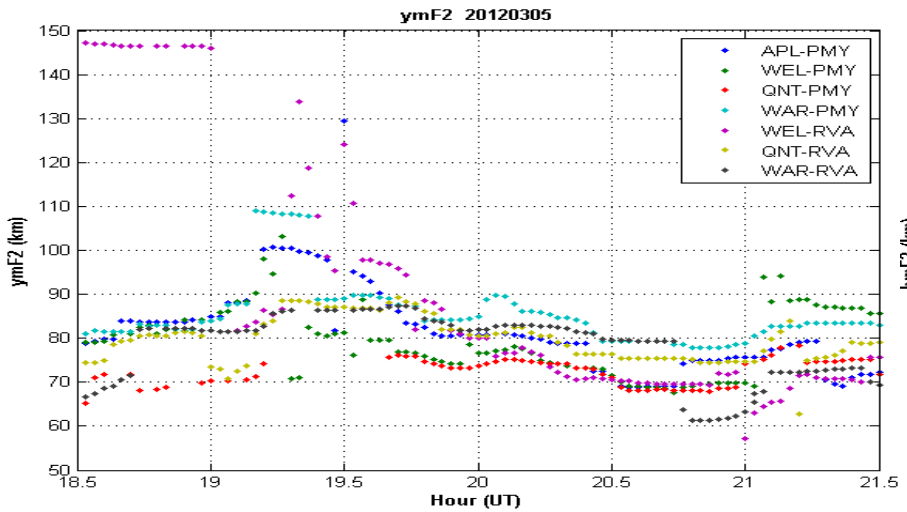
Ionospheric Sounders

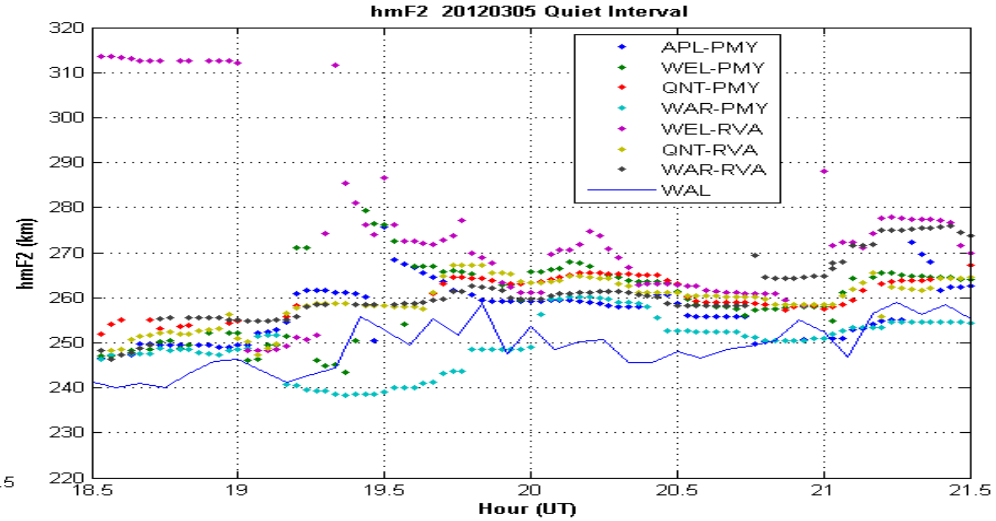
- Additional ionospheric data were collected by other sensors during test
  - Wallops Island Digisonde operated at 5 min intervals with enhanced “Skymap” mode at ~ 1 min intervals to determine tilt
  - Dual-frequency GPS data for TEC at RVA site (10 sec resolution)
  - Space weather measurements from NOAA, etc.

Examples

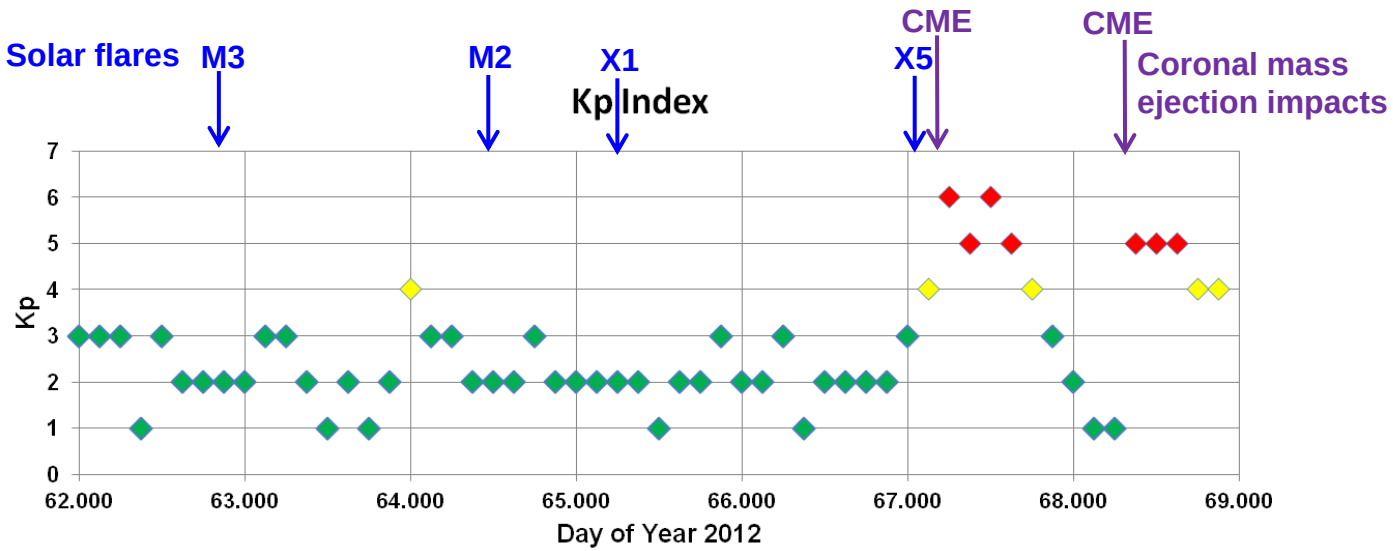


- These results illustrate the automated extraction challenge
- Short baseline control point parameters do not always precisely agree
- Agreement must be improved



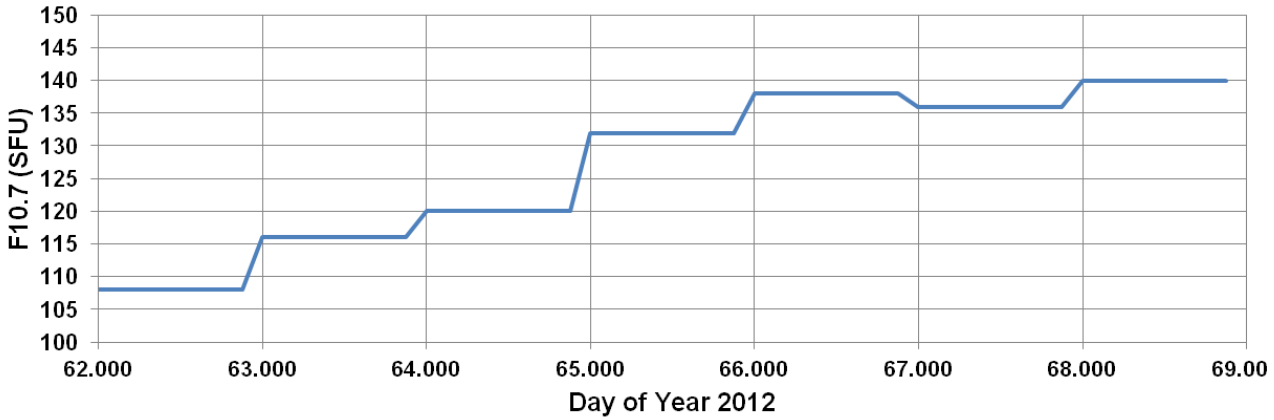


Space Weather During HFGeo Test



02 Mar 2012 = DOY 62

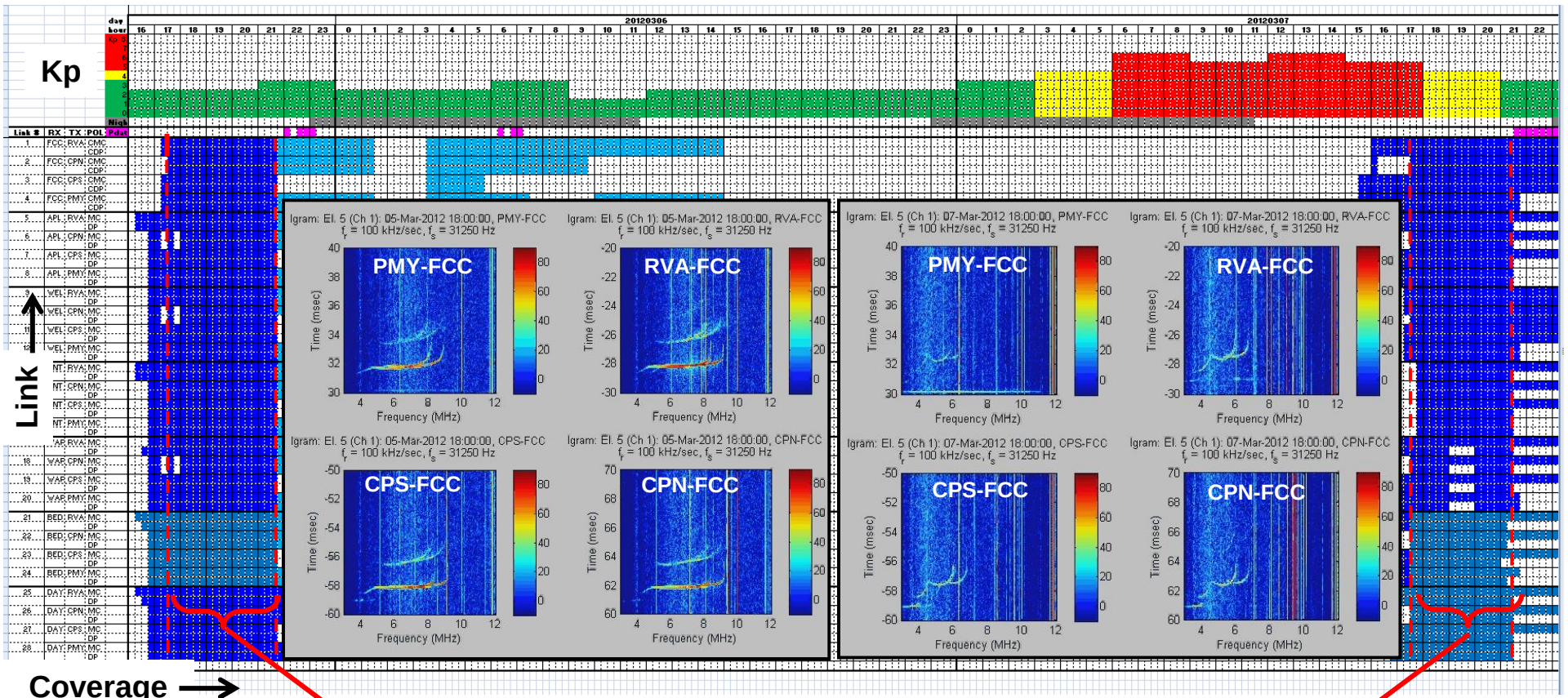
F10.7



- **A fortuitous mix of active and quiet conditions**

Results: Ionospheric Survey

← 05 Mar 2012 | 06 Mar 2012 | 07 Mar 2012 →



2 min resolution

4 min resolution

mixed resolution

Quiet Conditions
(FCC- RVA)
03/05/2012 ~ 1730 - 2145

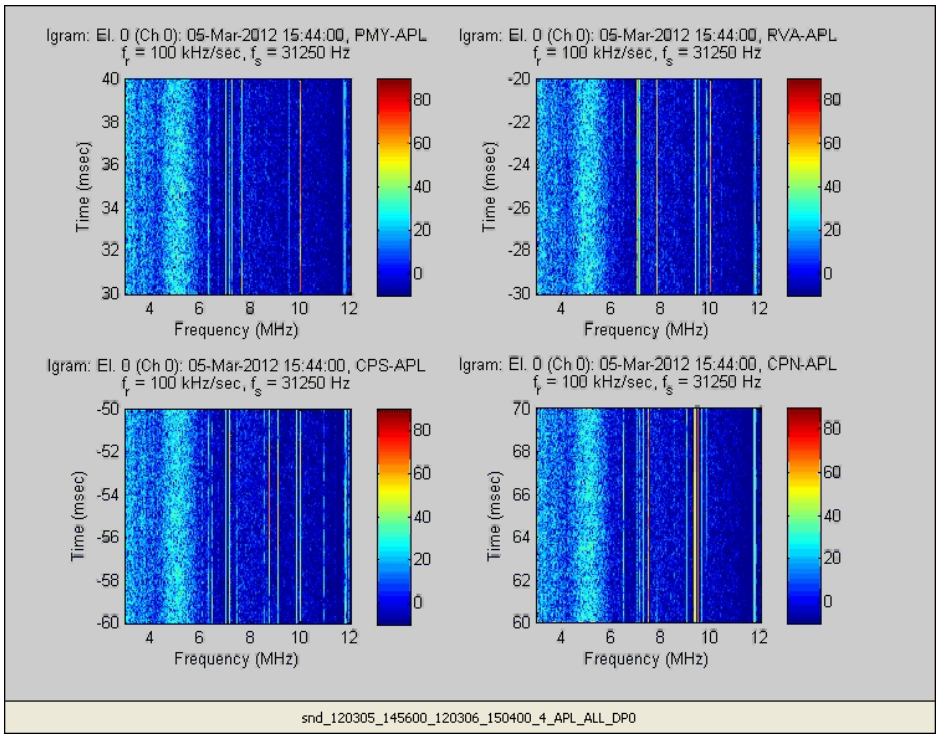
Active Conditions
(FCC-RVA)
03/07/2012 ~1730 - 2130

Sample Ionograms: Half-Day Movies

Quiet Conditions on 6 March 2012

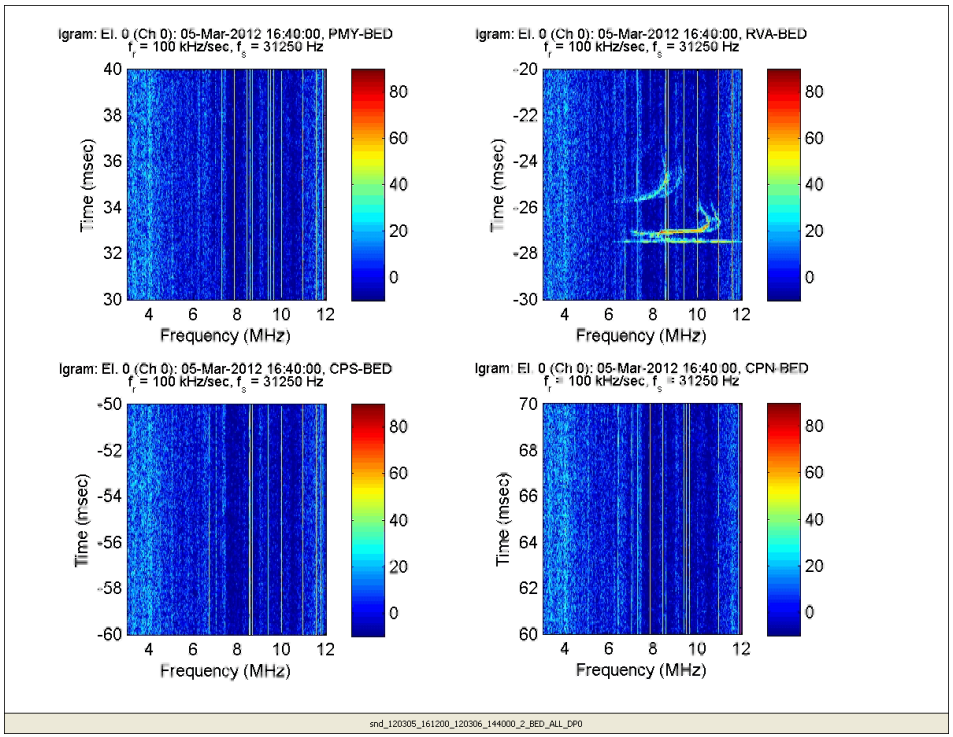
Short, Near-Vertical Baseline

APL Receive Site



Longer, Oblique Baseline

BED Receive Site

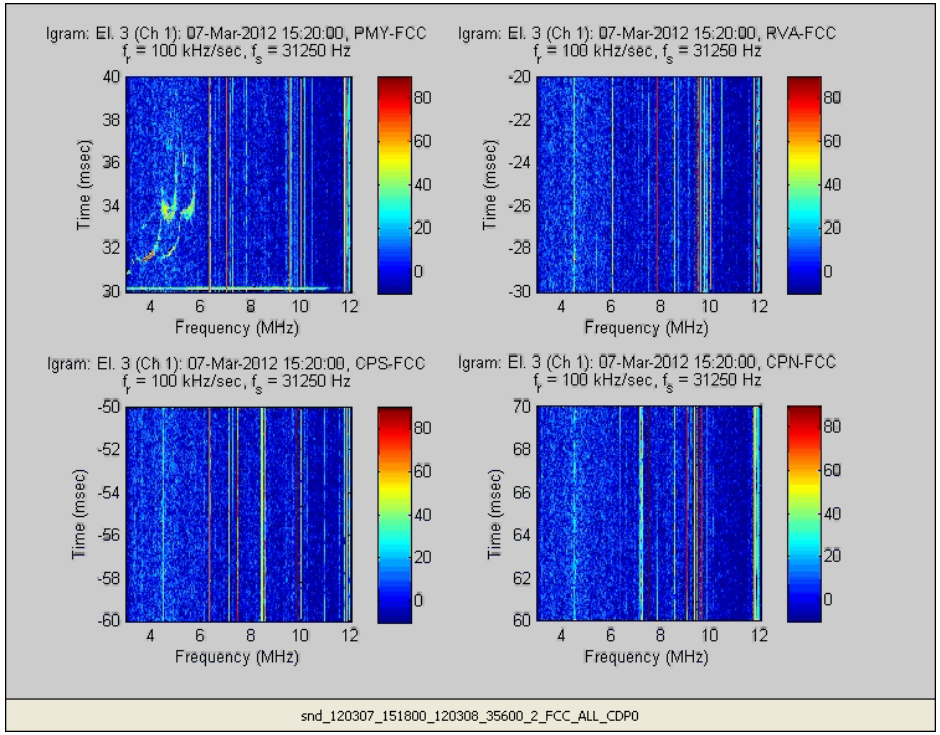


Sample Ionograms: Half-Day Movies

Active Conditions on 8 March 2012

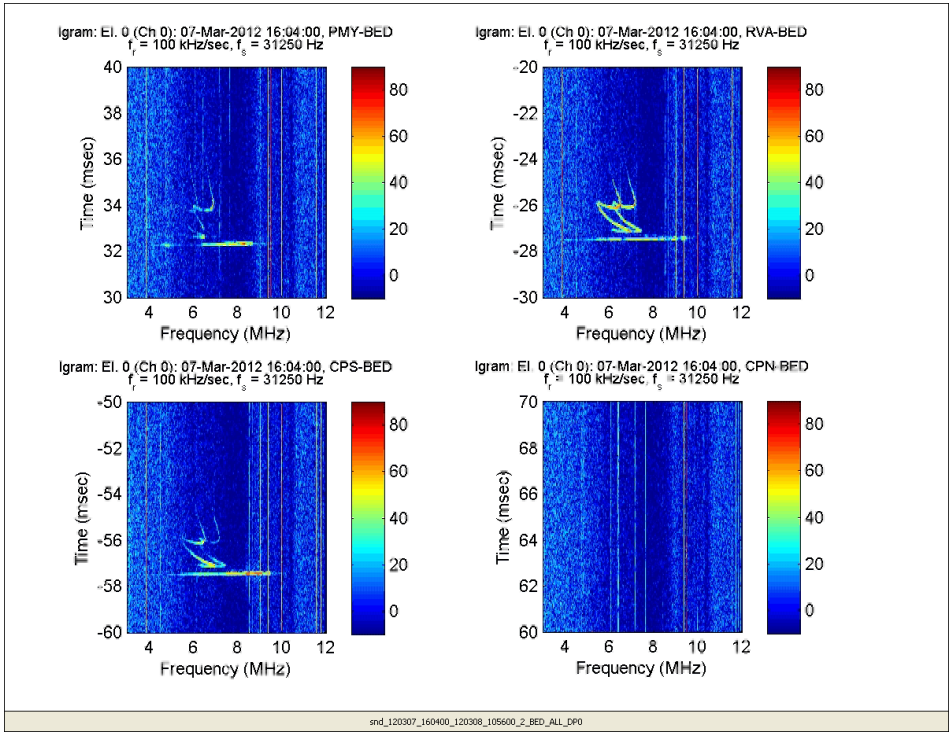
Short, Near-Vertical Baseline

FCC Receive Site



Longer, Oblique Baseline

BED Receive Site



Summary

- The HFGeo collection was a comprehensive, geographically distributed test fortuitously conducted under active and quiet geophysical conditions
- Initial polarimetric signal processing algorithms have been demonstrated to improve oblique ionogram interference rejection and trace extraction
- Some of this data could be provided if useful for Phase 1B