

STR Overview of HFGeo Phase 1A

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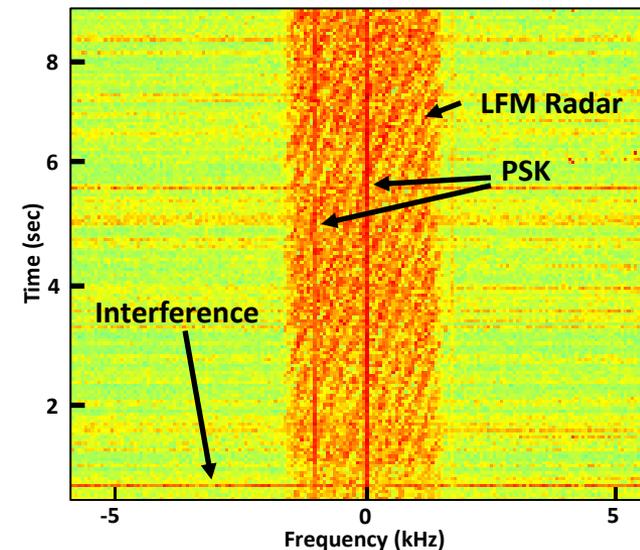
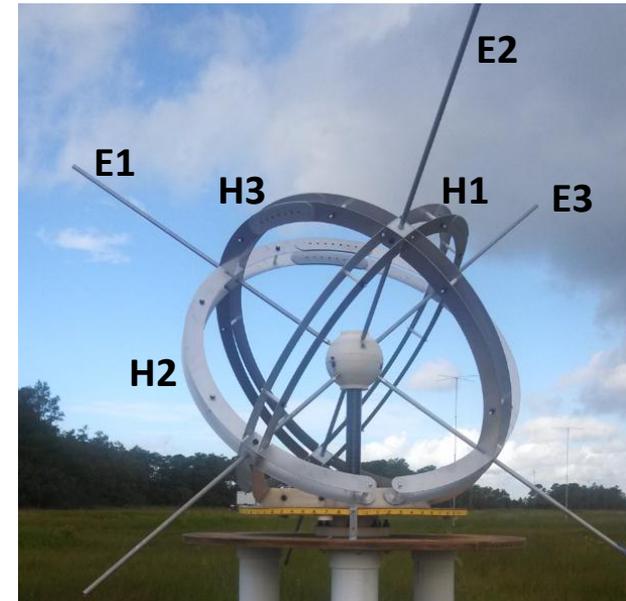
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- **Focus on innovative solutions to National Security challenges**
 - Broad and deep expertise in sensor technologies, target phenomenology, and complex system development
 - Experience developing and transitioning advanced sensing, automated processing, and decision support systems for DoD and Intel customers
- **Sensors and Signal Processing group led HFGeo Phase 1A team**
 - HF multi-channel beamforming and signal processing focus
 - Developed prototype automated processing system
 - Participated in HFGeo Phase 1A data collection and Quicklook processing
 - Teamed with Integrated Adaptive Applications (IAA)
- **Facilities**
 - Located in Woburn, MA
 - Secure computing, communications, and laboratory facilities

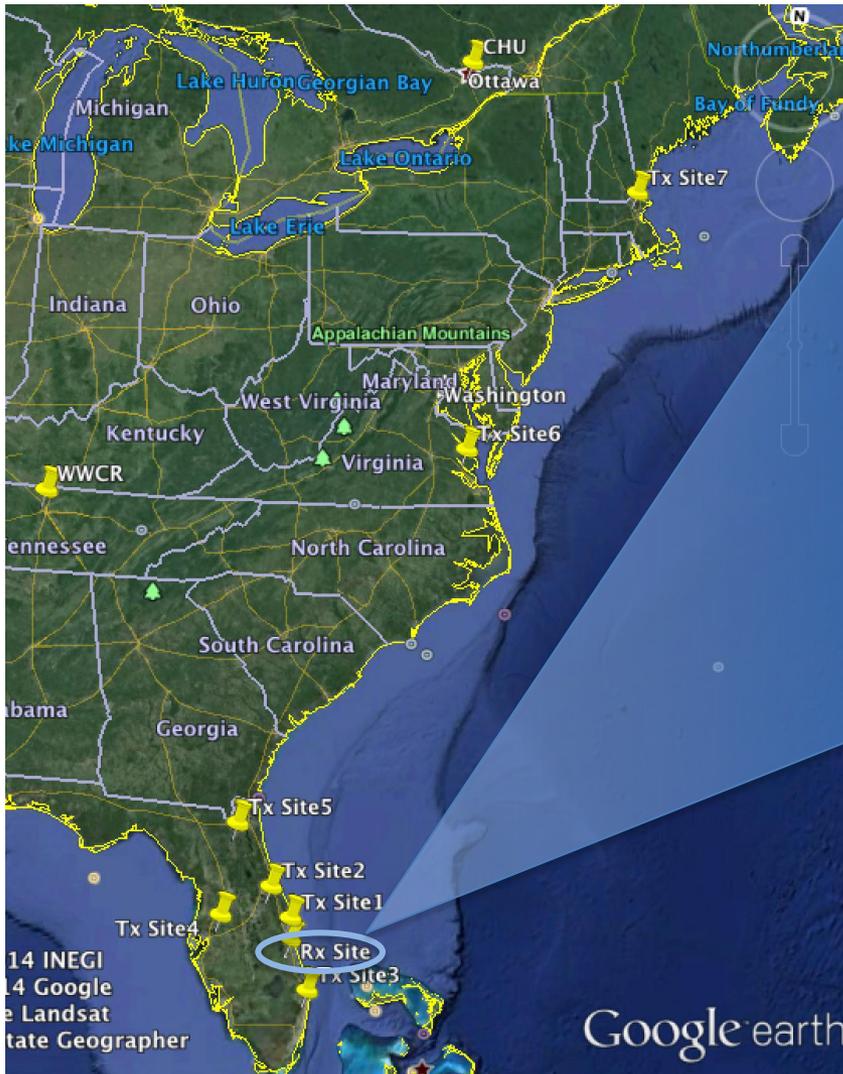
- **Process HF receiver data from electrically small Electromagnetic Vector Sensor (EMVS) array**
 - Detect and isolate HF signals of interest in complex signal environment (man-made and environmental noise, multipath, in-band communications broadcasts, etc.)
 - Estimate angle of arrival (AoA) in azimuth and elevation
 - Classify signals
 - Geolocation of SOI's
- **Demonstrate signal processing gains achieved by applying advanced algorithms to EMVS array**
 - Accurate AoA via beamforming
 - Detection threshold extension
 - SINR improvement
- **Phase 1A algorithms developed and tested with two program datasets**
 - Phase 0 dataset collected before program start, Phase 1A data at end of Phase1

HFGeo Phase 1A Electromagnetic Vector Sensor (EMVS) Data

- **EMVS array produces 18 receive channels**
 - Each EMVS receives 6 channels - E1, E2, E3, H1, H2, H3
 - 3 EMVS sensors generate combined 18 channels for 18x1 sample vector per measurement time increment
- **Element size and sensor spacing much less than HF wavelengths**
 - ~ 15 m spacing between EMVS positions
 - 4 ft diameter dipoles relative to 10-100m HF wavelengths
- **Phase 1A datasets include communications and radar waveforms**
 - Receivers tuned to HF emitter frequencies and downsampled to 25 kHz baseband
 - Data includes sky / ground wave communications signals in interference and noise environment



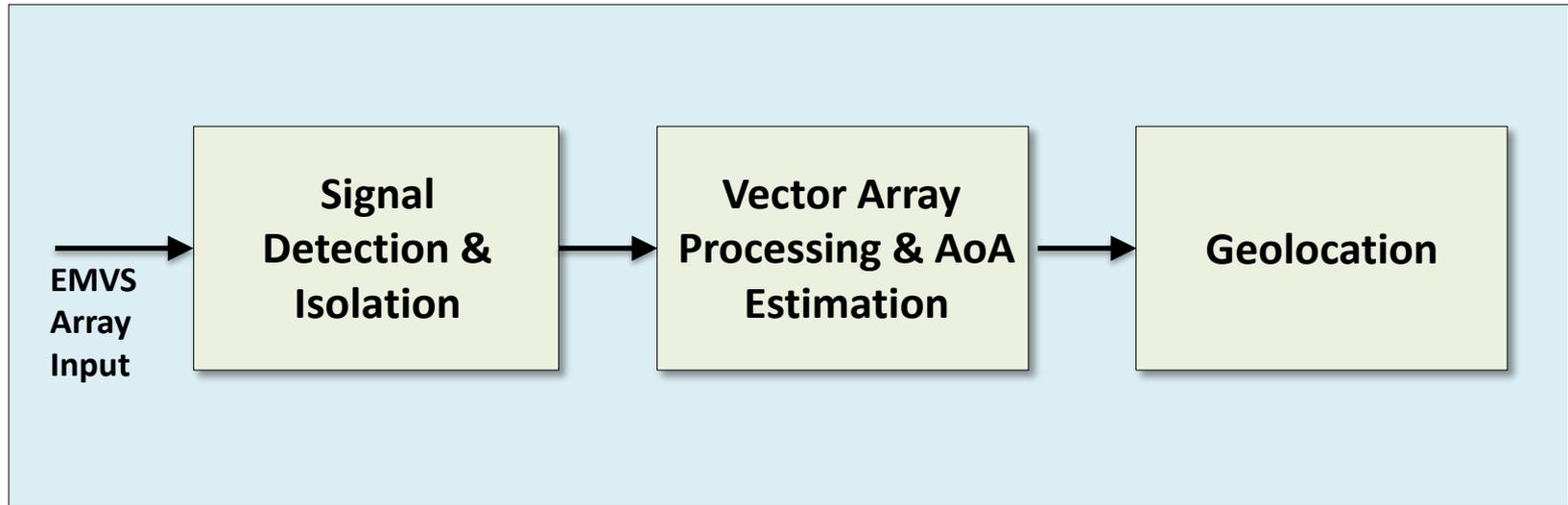
Phase 1A Testing in Vero Beach – Aug. 2013



- **3 NRL EMVS systems and MITRE truth array**
 - Calibration whip antenna ~ 60 m away
- **Several days of multi-emitter HF collections**
 - Variable-power communications signals
 - Test cases included in-band noise and multiple interference sources

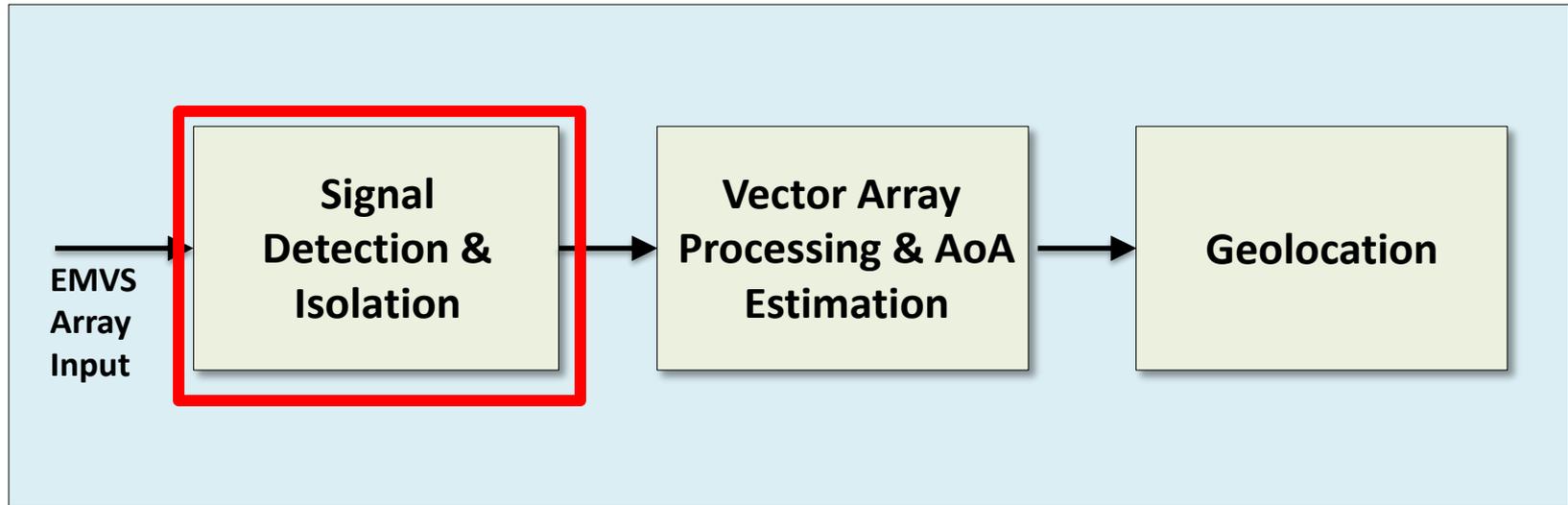
- **Array manifold**
 - Government team provided NEC-model generated manifold for 18-channel array
 - Model generated for specific 3-EMVS test configuration
 - Calibrated model using whip antenna
- **Calibration sources for Phase 1A data collection**
 - Calibration whip antenna placed on receive site near EMVS array
 - Helicopter flew two days with cable-deployed antenna
- **STR team developed beamforming signal processing algorithms**
 - Final Phase 1 system integrated modified Robust Capon Beamformer
 - Truth angle of arrival (AoA) data not released to performers – our internal performance assessment based on known (after the fact) transmit locations and estimating truth AoA

Block Diagram of Data Processing System



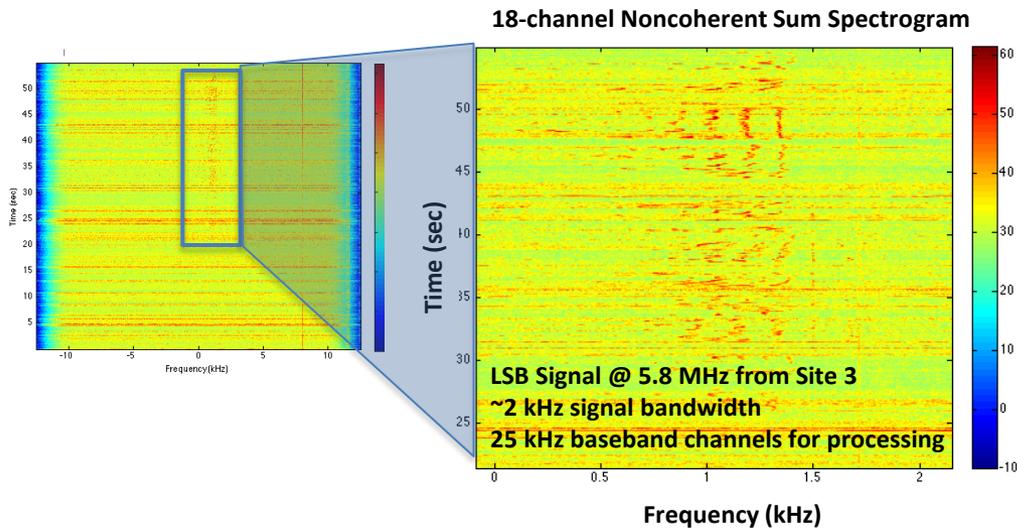
- Signal detector isolates signal of interest, increases signal isolation relative to background noise or interference signals
- Vector array processor calibrates data and estimates AoA angles
- Geolocation processor associates detections and estimates geo-coordinates of signals of interest

Block Diagram of Data Processing System

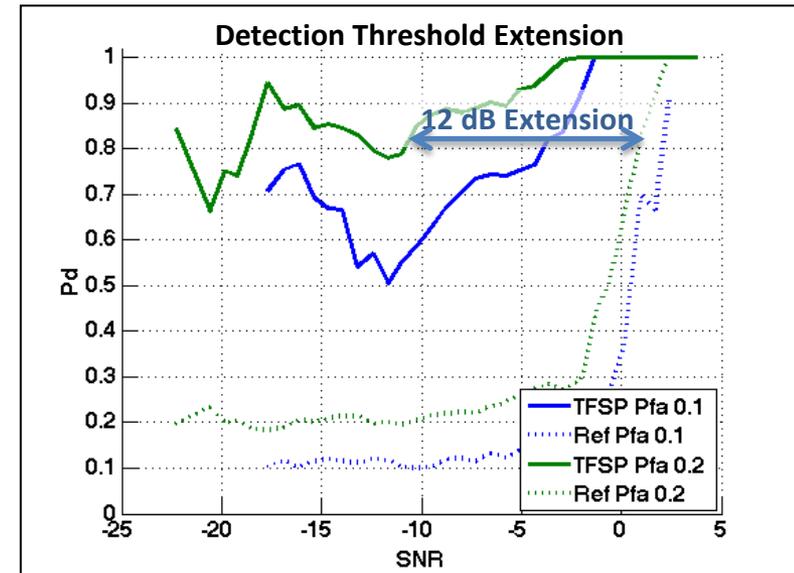
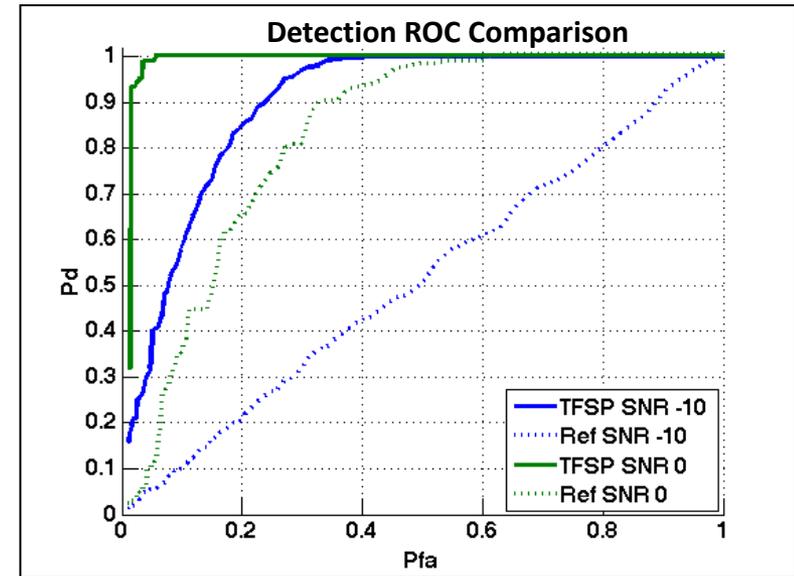


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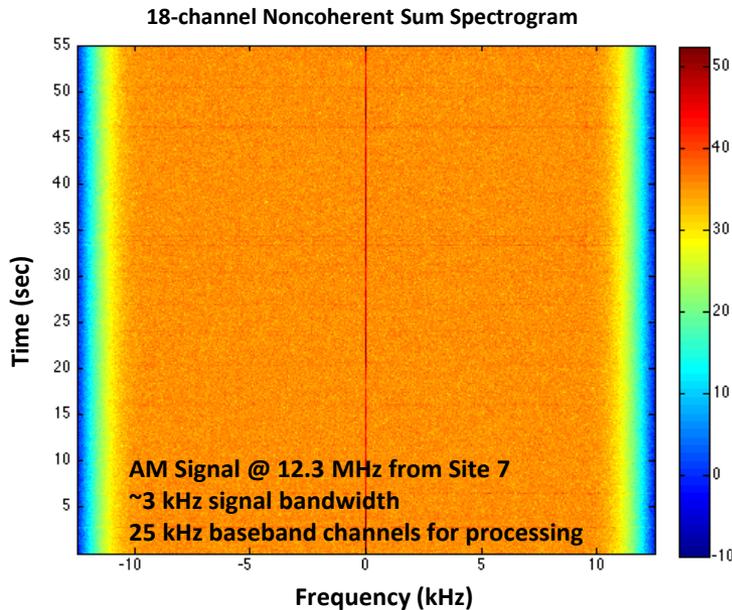
Detection Threshold Extension Relative to Energy Detector



- Time Frequency Space Polarization (TFSP) detector evaluated with same detection thresholds computed for reference (Ref) energy detector
 - Lack of SNR diversity requires processing at very short time increments for statistical spread
 - 0.075 sec processing windows in this case

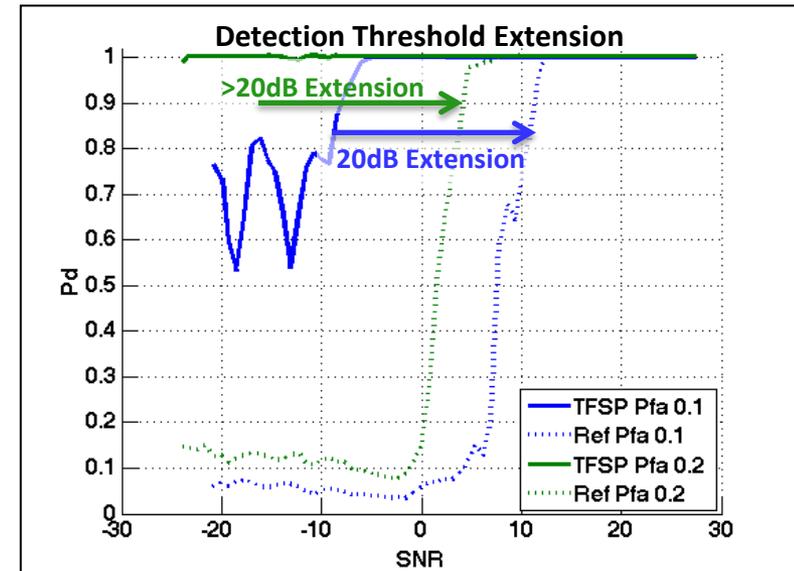
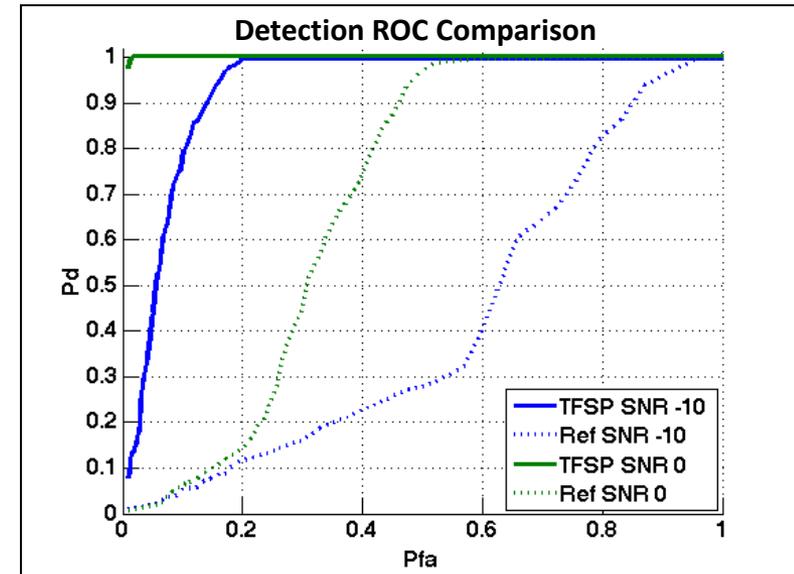


Detection Threshold Extension Relative to Energy Detector (cont.)

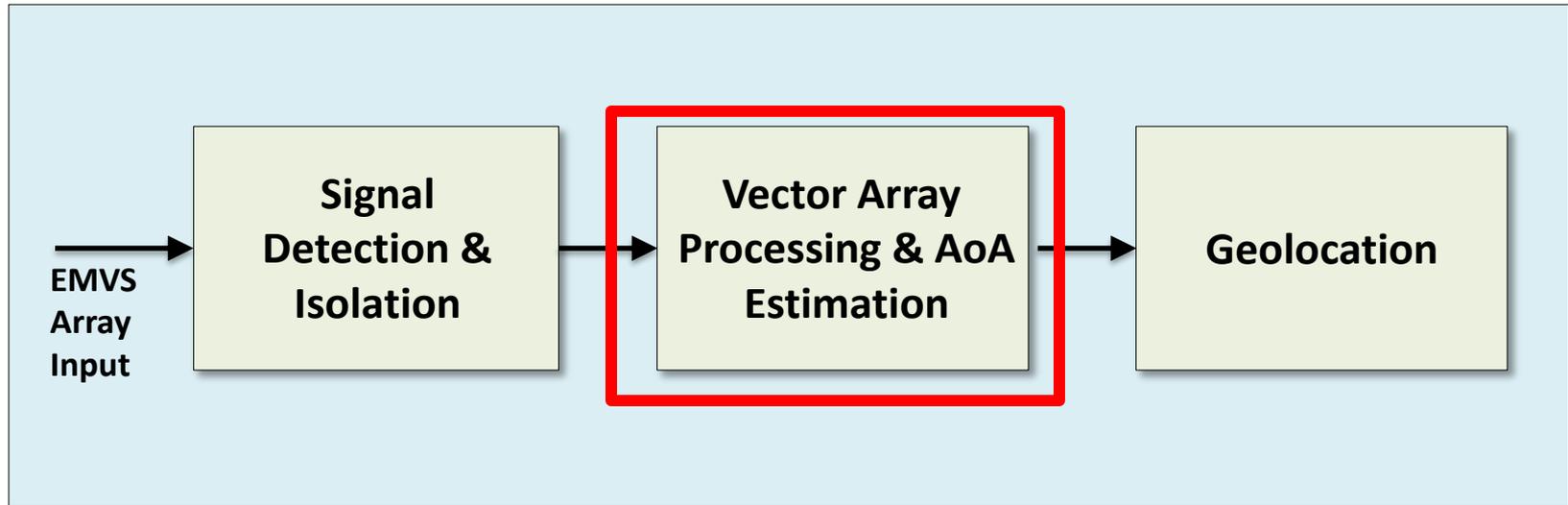


Phase 1A AM Signal

- TFSP detector evaluated with same detection thresholds computed for reference energy detector
 - Lack of SNR diversity requires processing at very short time increments for statistical spread
 - 0.02 sec processing windows in this case
- Achieved 100% Pd for evaluation intervals
 - Greater than 20 dB detection threshold extension

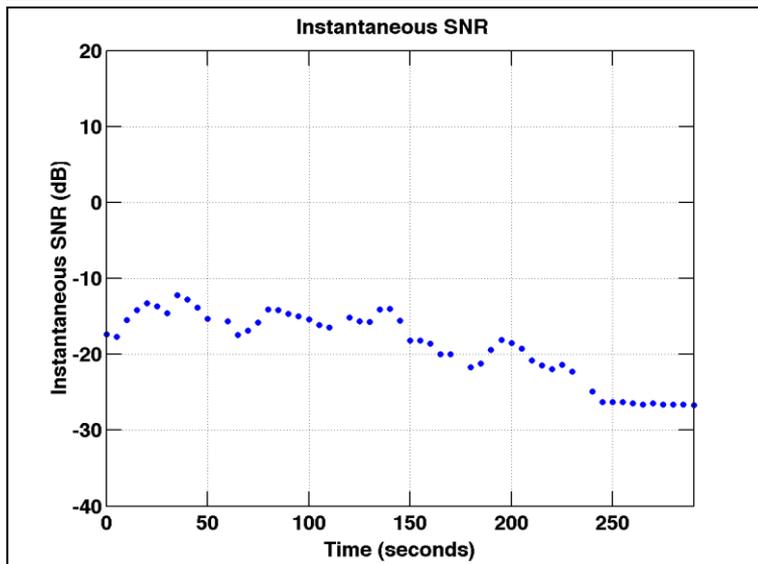
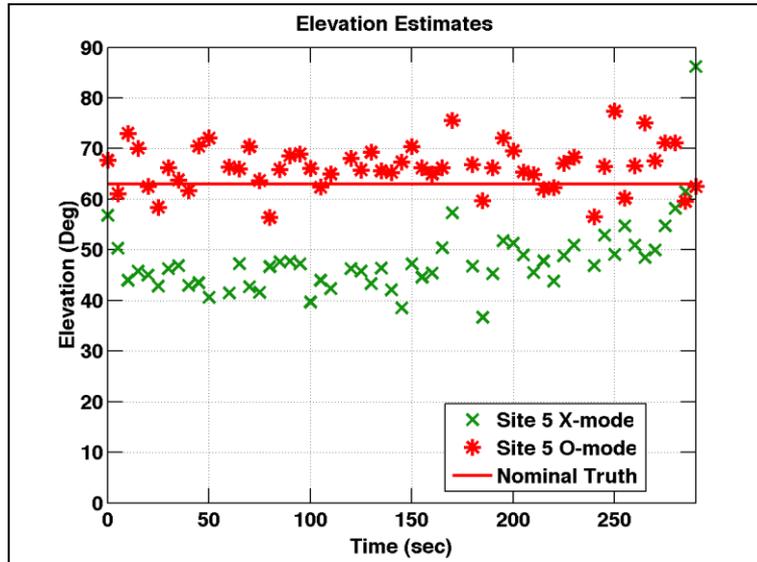
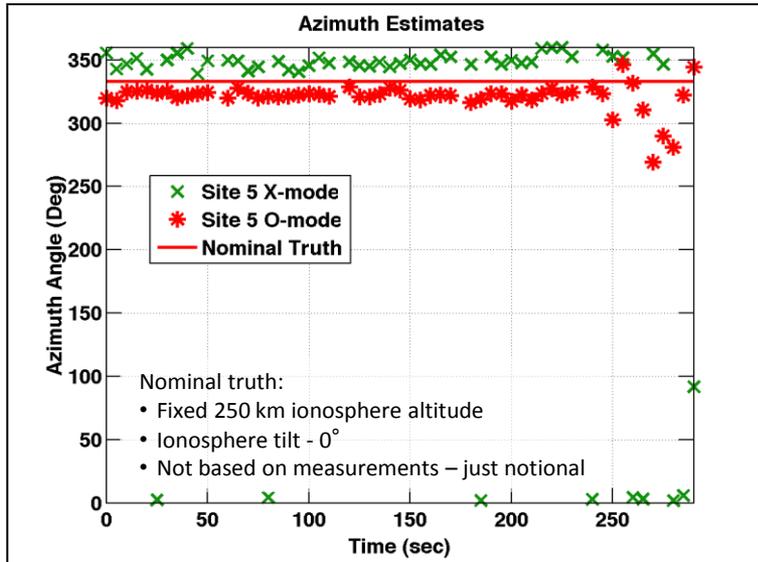


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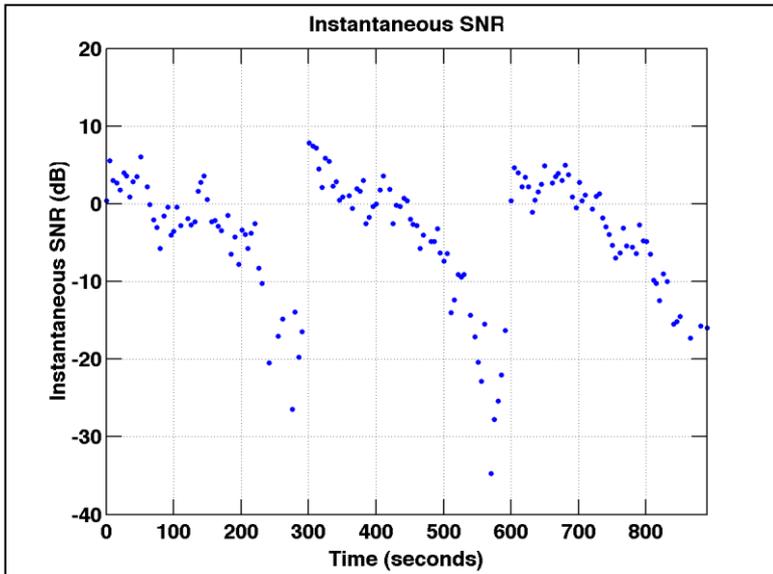
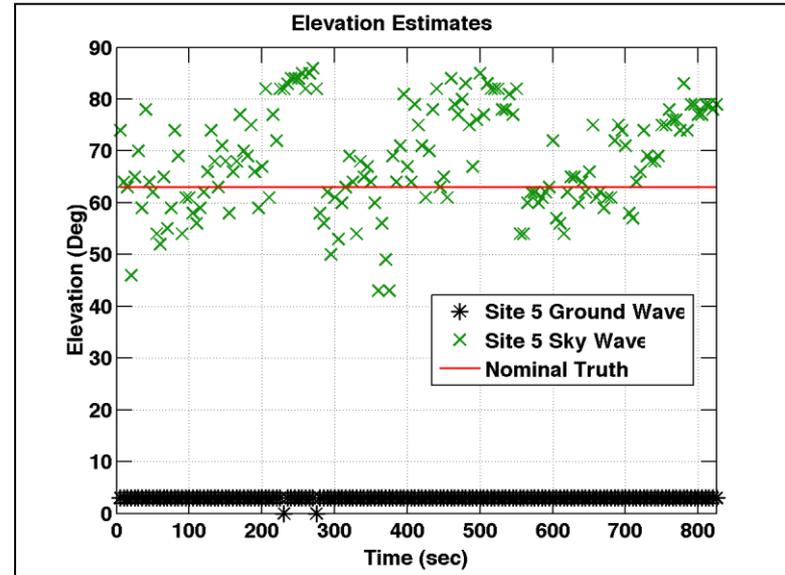
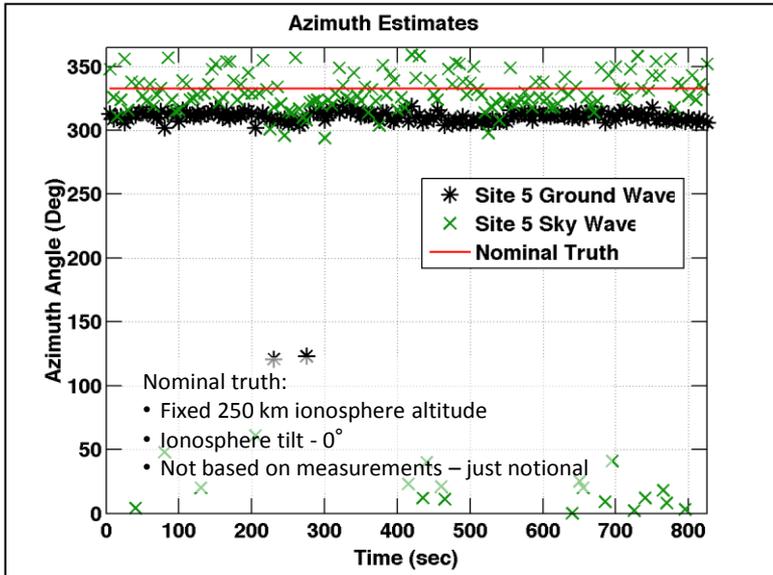
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Phase 1A AoA Estimation for Low-SNR Communications Signals



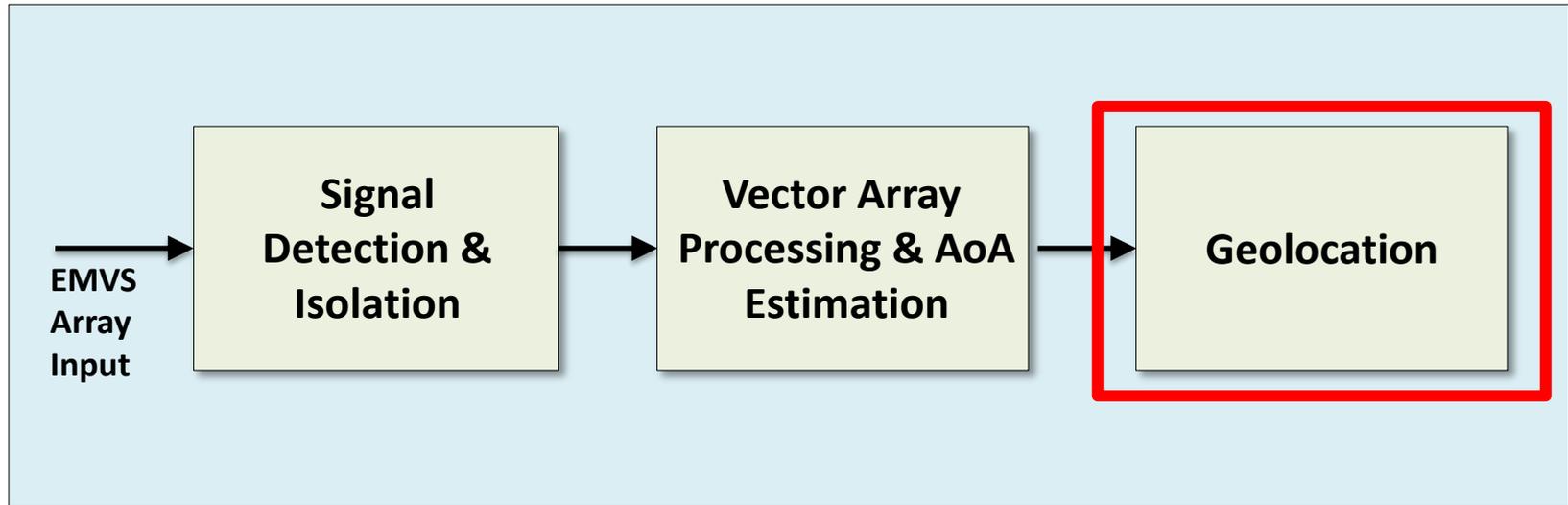
- PSK31 @ 5.8 MHz from Site 5 (NE Florida location, NW of Rx site)
- GLC-RCB processing with 5 sec integration time
- **Beamforming algorithm isolates X and O-mode sky waves**
 - X/O-mode skywaves propagate with distinct polarizations
 - Differing propagation paths result in unique AoA's for each skywave
- **Nominal truth positions provided only as relative reference – computed by STR based on fixed ionosphere height/tilt (not measured)**

Angle of Arrival Estimation as a Function of Signal to Noise Ratio (SNR)



- PSK31 signal from Site 5 (NE Florida location, NW of Rx site)
- Transmit signal SNR ramping test in presence of interference 3 kHz noise signal from Site 1
- GLC-RCB processing with 5 sec integration time
- **Site 5 transmit power varied over time**
 - Estimated azimuth angles stable as function of SNR
 - Mean elevation angle estimates shift with changes in SNR

Block Diagram of Data Processing System



- STR developed prototype geolocation algorithms and generated estimates on Phase 0 dataset
- Geolocation results not released at IARPA's discretion

- **Advanced signal detection algorithm extends threshold detection**
 - Enhances SOI's by filtering undesired interference signals
 - Extends SOI detection threshold by 10 – 20+ dB relative to reference energy detector

- **Adaptive beamforming algorithms applied to electrically-small HF EMVS array**
 - Detected and isolated communications signals from multiple transmit sites
 - Robust angle-of-arrival (AoA) estimates over long time intervals and variable signal-to-noise ratio (SNR) levels

- **HFGeo outcomes motivate capability maturation & system development**
 - Advance HF sensor system state-of-the-art
 - Integrate advanced sensing and signal processing into end-to-end system