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Results from a prototype tetrahedral array for tracking sound sources in shallow water

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Motivation

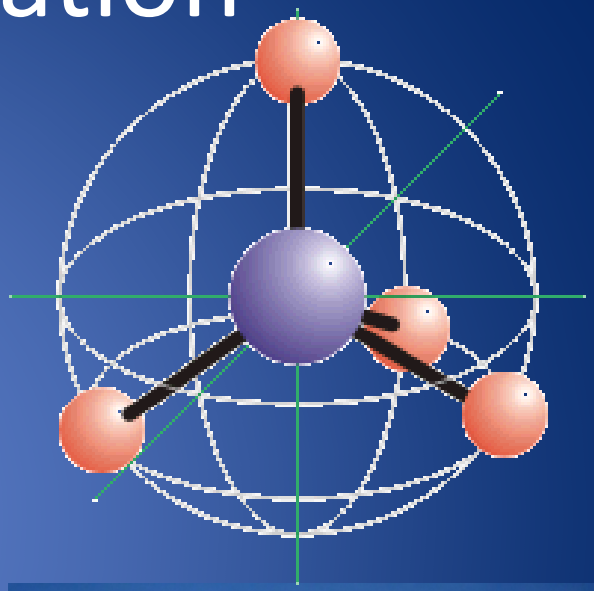
- Use passive acoustics in a near shore environment to detect sources by their characteristic sound (signature)
  - No environmental impact
  - Sources don't know they are being detected
  - Broadband, mid- to high frequency sources (1kHz to 40 kHz)

- Goals
  - Detect, classify and track underwater broadband sources
  - Robustness over accuracy
  - Develop a computational inexpensive model
  - "Small scale" (few hydrophones)
  - TDOA, Likelihood function*, Beamforming

* 5aEA12. Diver Monitoring using the Hawaii Experimental Acoustic Range

Hydrophone Configuration

- 4 hydrophones for each Array
  - 3 in the horizontal plane
  - 1 raised from the center
  - Can be steered both vertically and horizontally



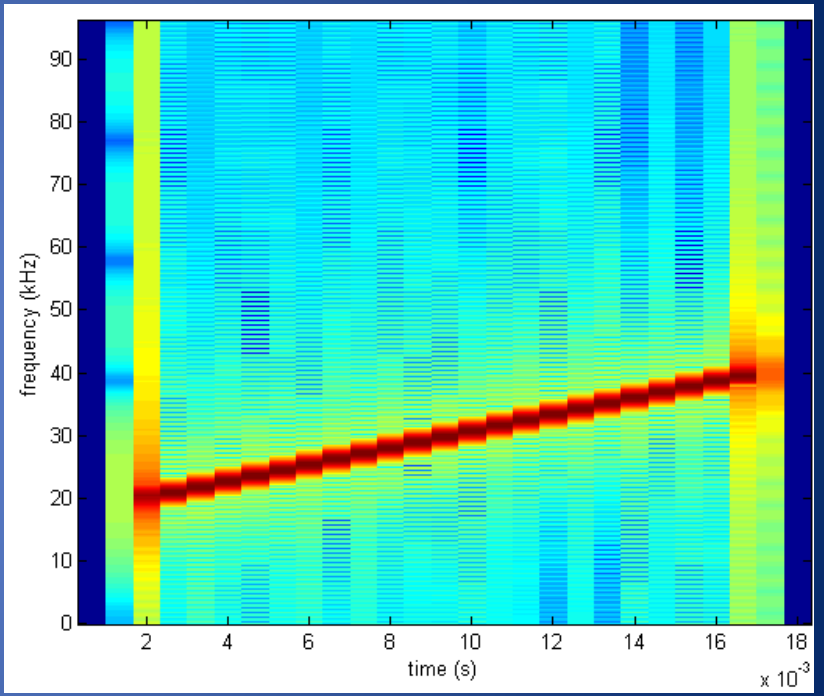
- Phase center is center of spherical coordinate system
  - Azimuth: Theta [0-360] deg
  - Elevation: Phi [0-180] deg

Model Validation

- Linear up-chirp from 20-40 kHz @ 192 kHz
- Length: 0.015 s duration

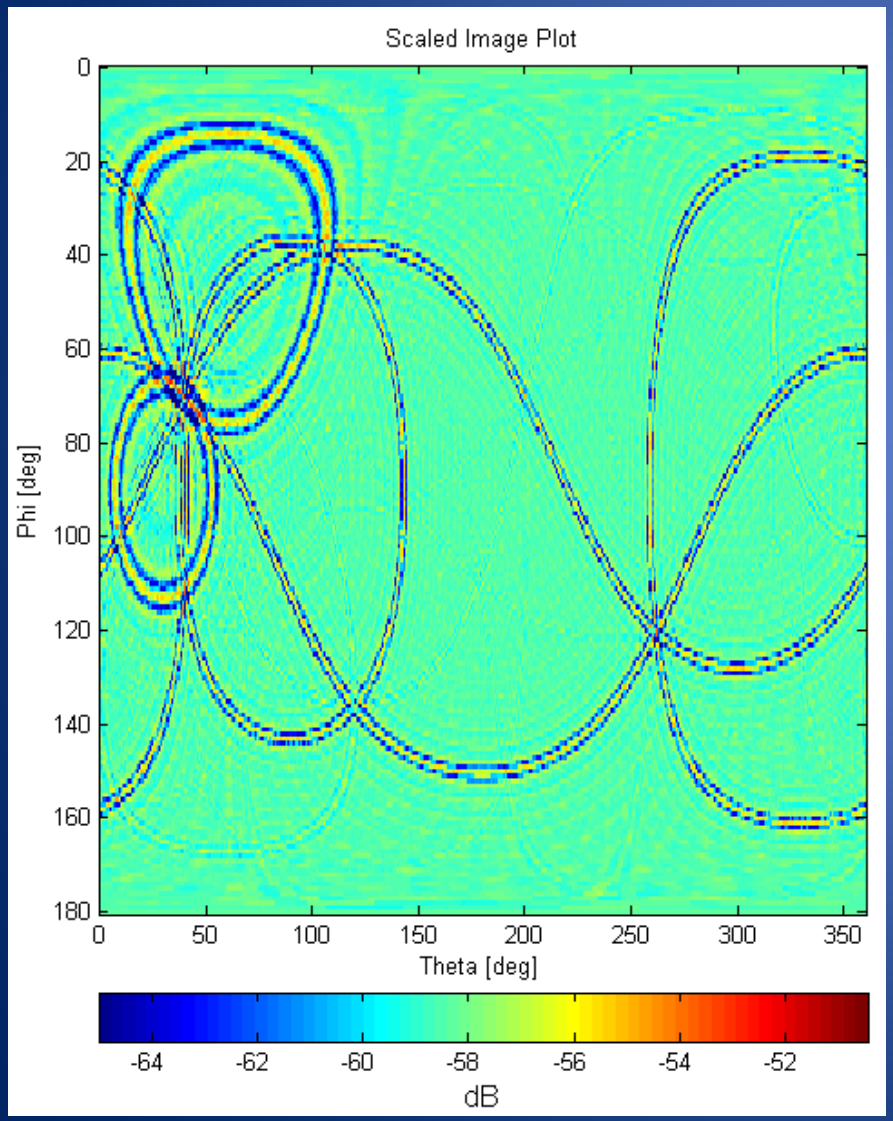
- Source Location: $\theta = 40°$, $\phi = 70°$, d = 100 m
  - Plane wave assumption* (radius = 0.9 m)

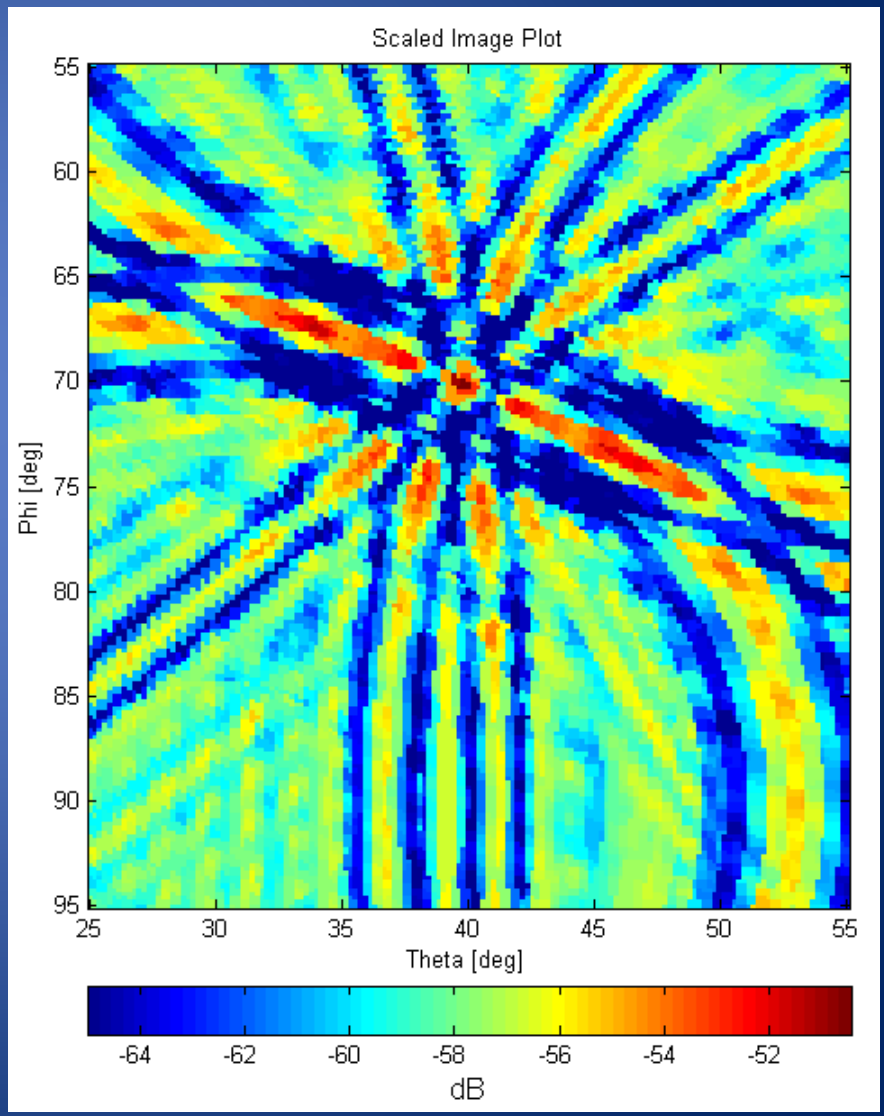
- $\lambda/2$ frequency: 850 Hz
  - General problem with grating lobes



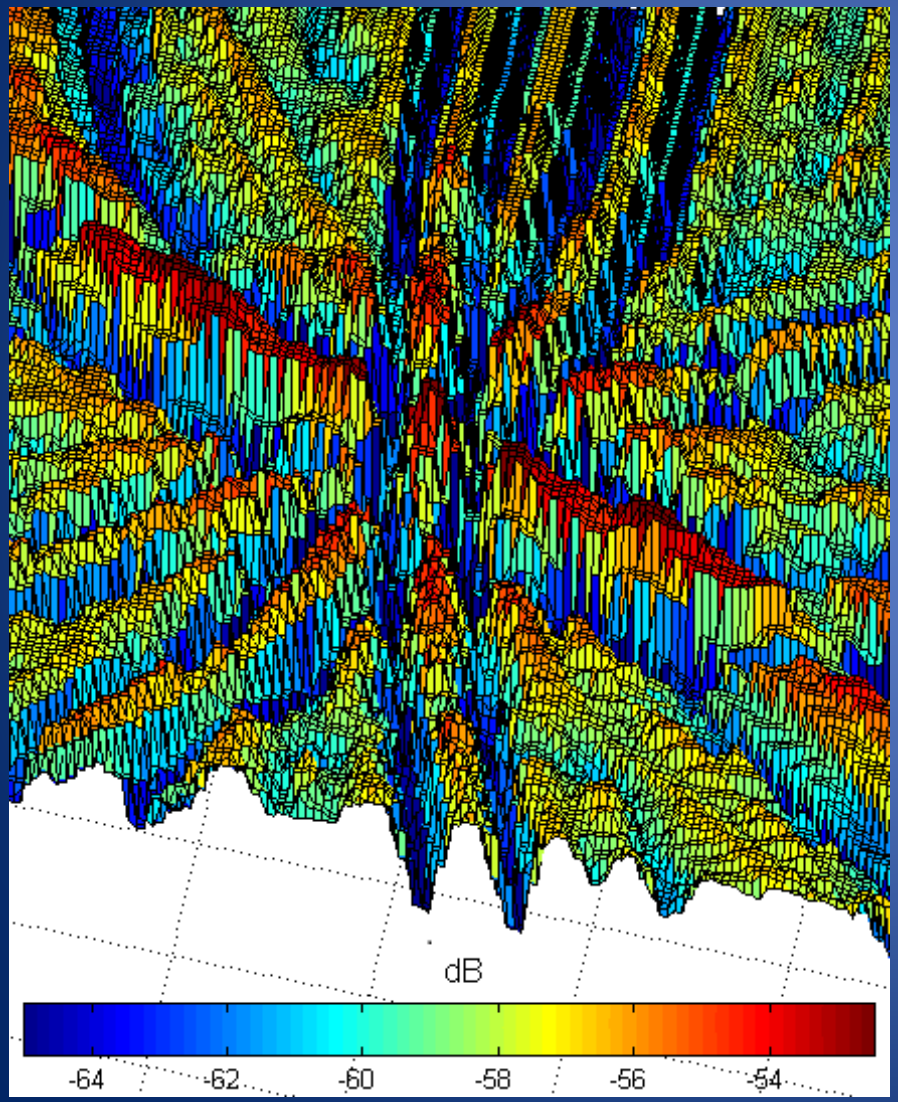
* Array Signal Processing by Don H. Johnson: ≈60 x radius

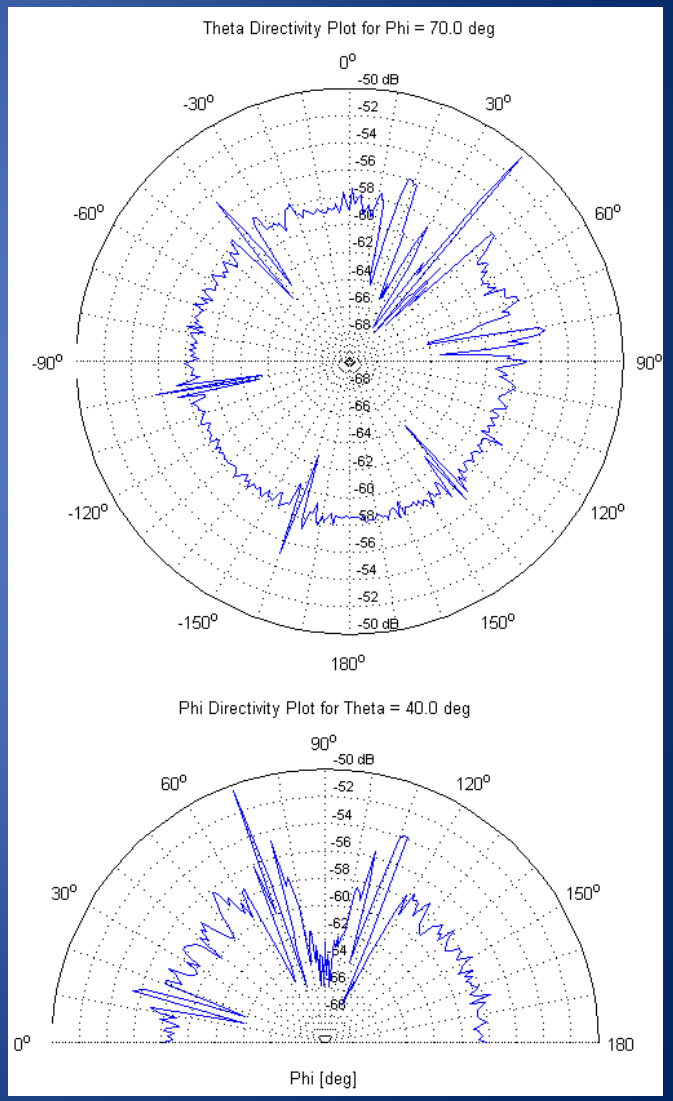
Model Results
Beamformer Output



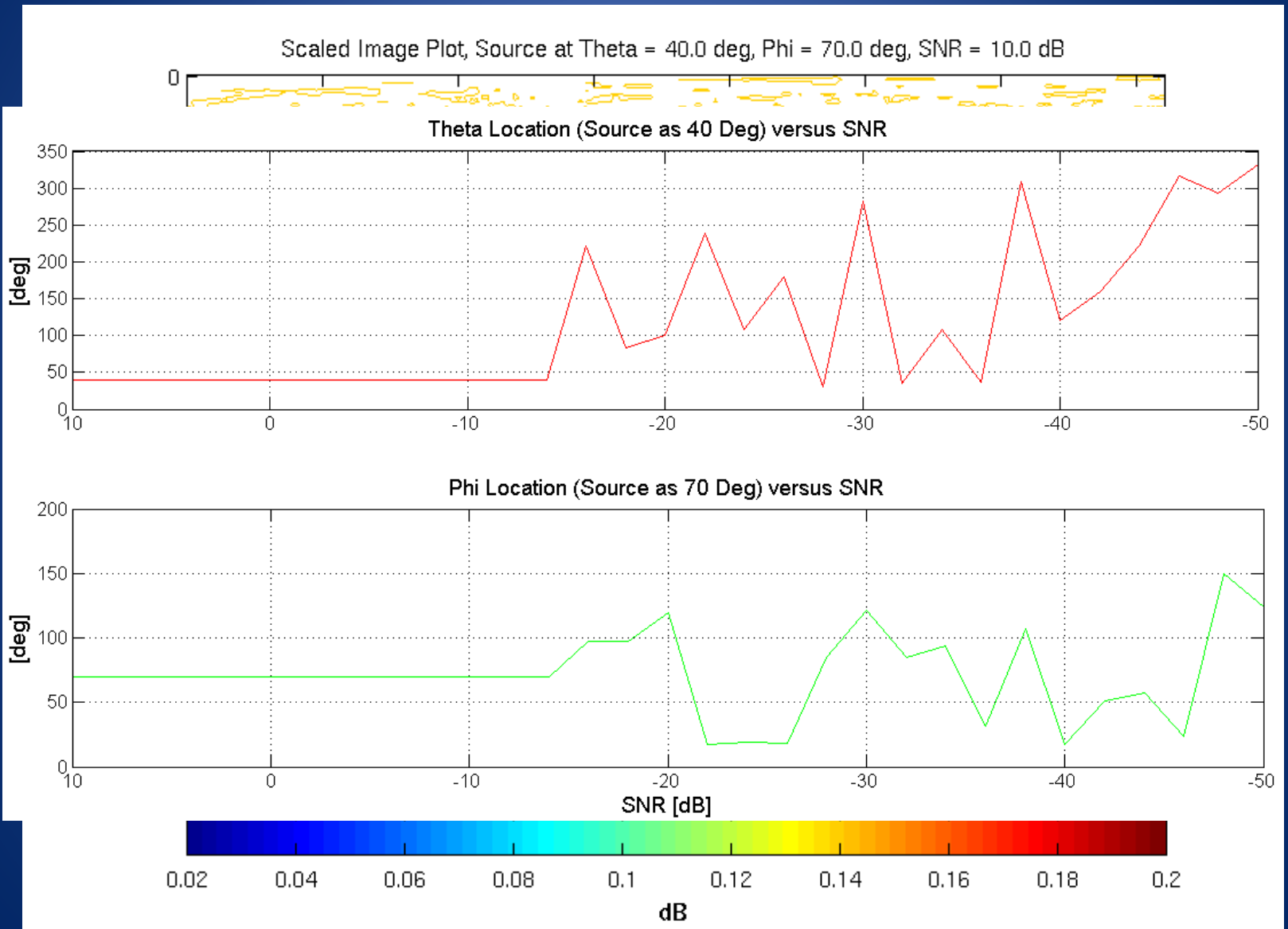


Model Results
Directivity Plot

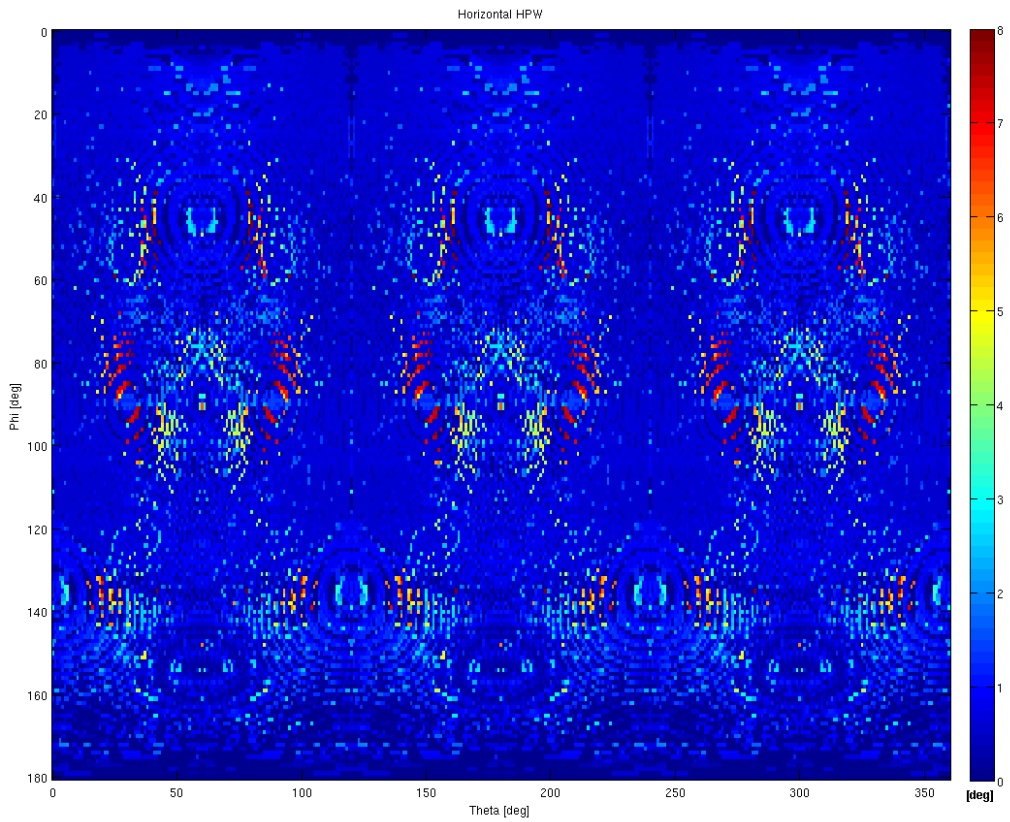


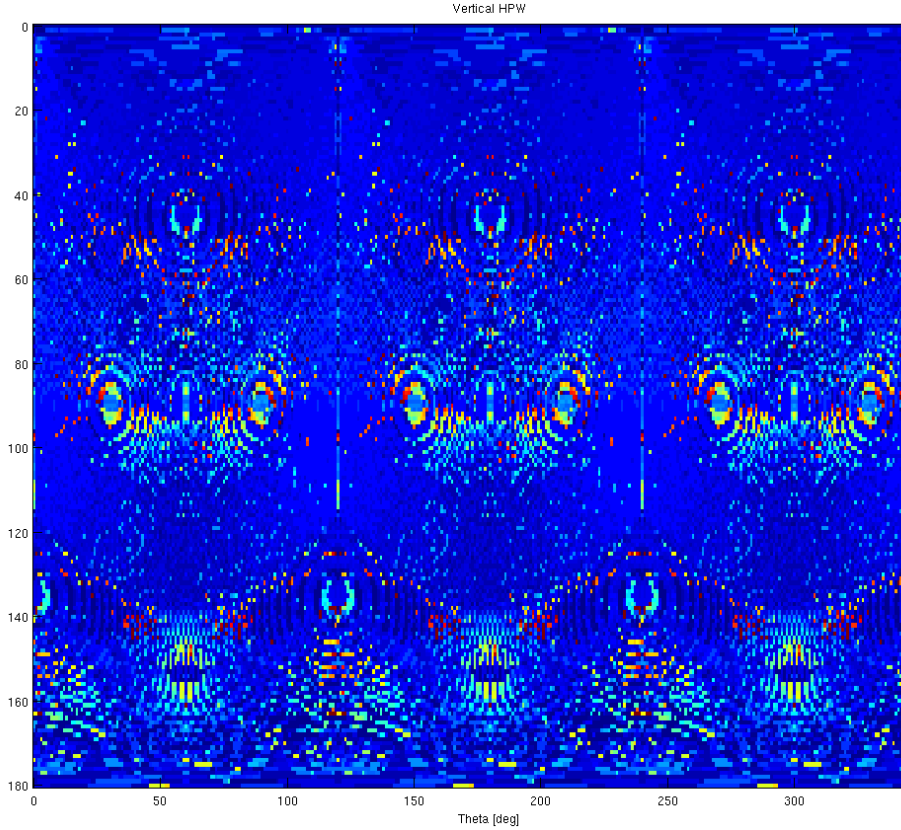


Source with white Noise



HPW - Resolution





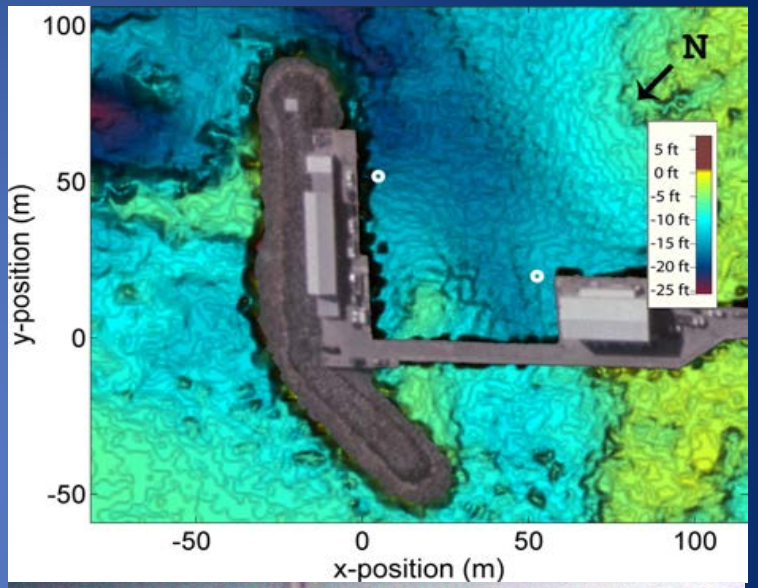
Horizontal HPW
Original Range: 0-12 deg

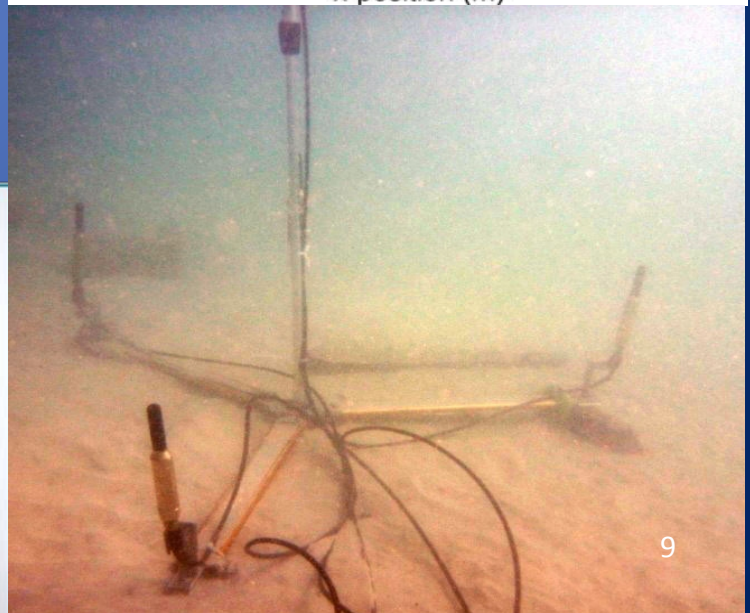
Vertical HPW
Original Range: 0-16 deg

Experimental Setup

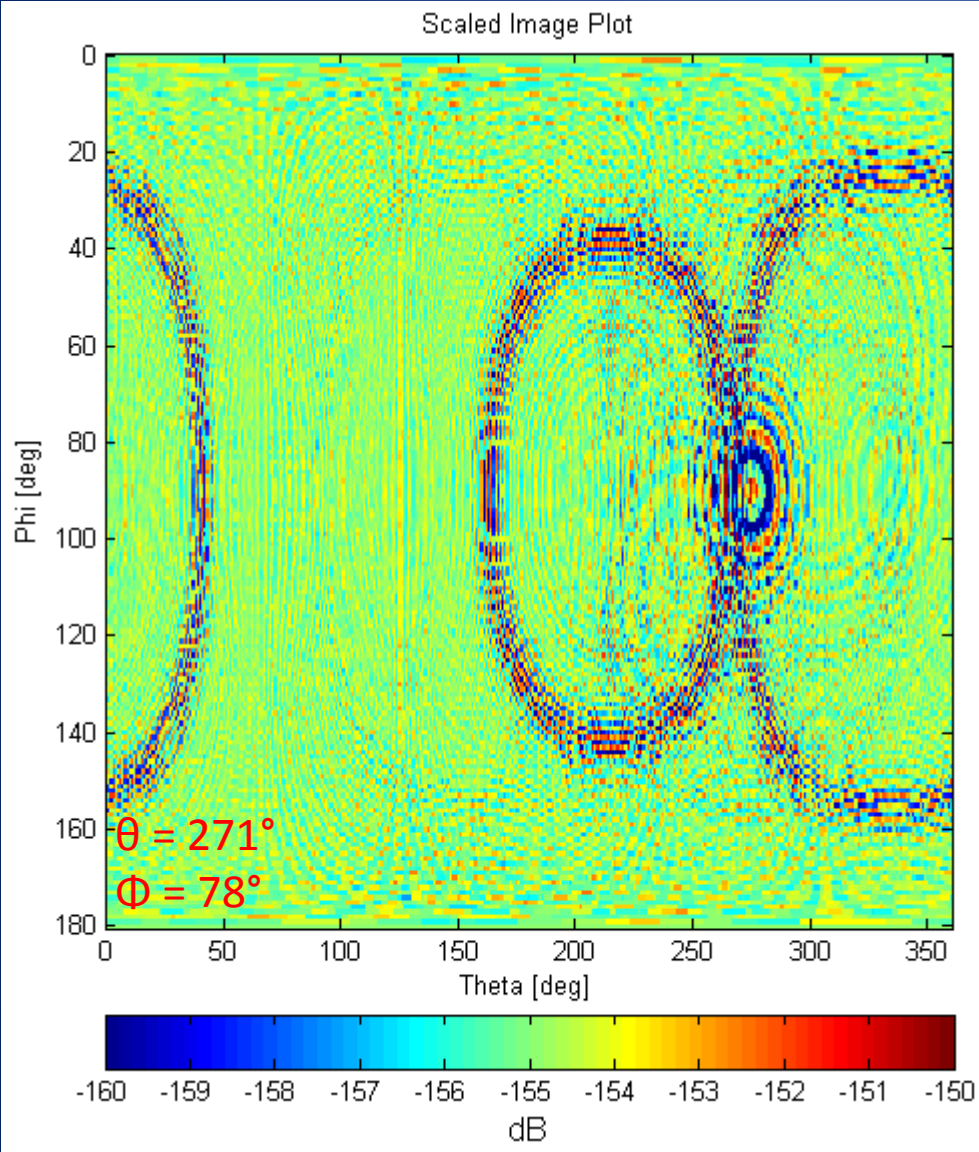
- Location: Makai Research Pier
- 2 Arrays (5 phones each)
  - Reson omnidirectional TC4032 Hydrophones, Frequency Response +/- 1 dB
  - Flexible configuration
  - 192 kHz digitized at 24 bit
  - Anti aliasing filter
  - 10 Hz high pass filter

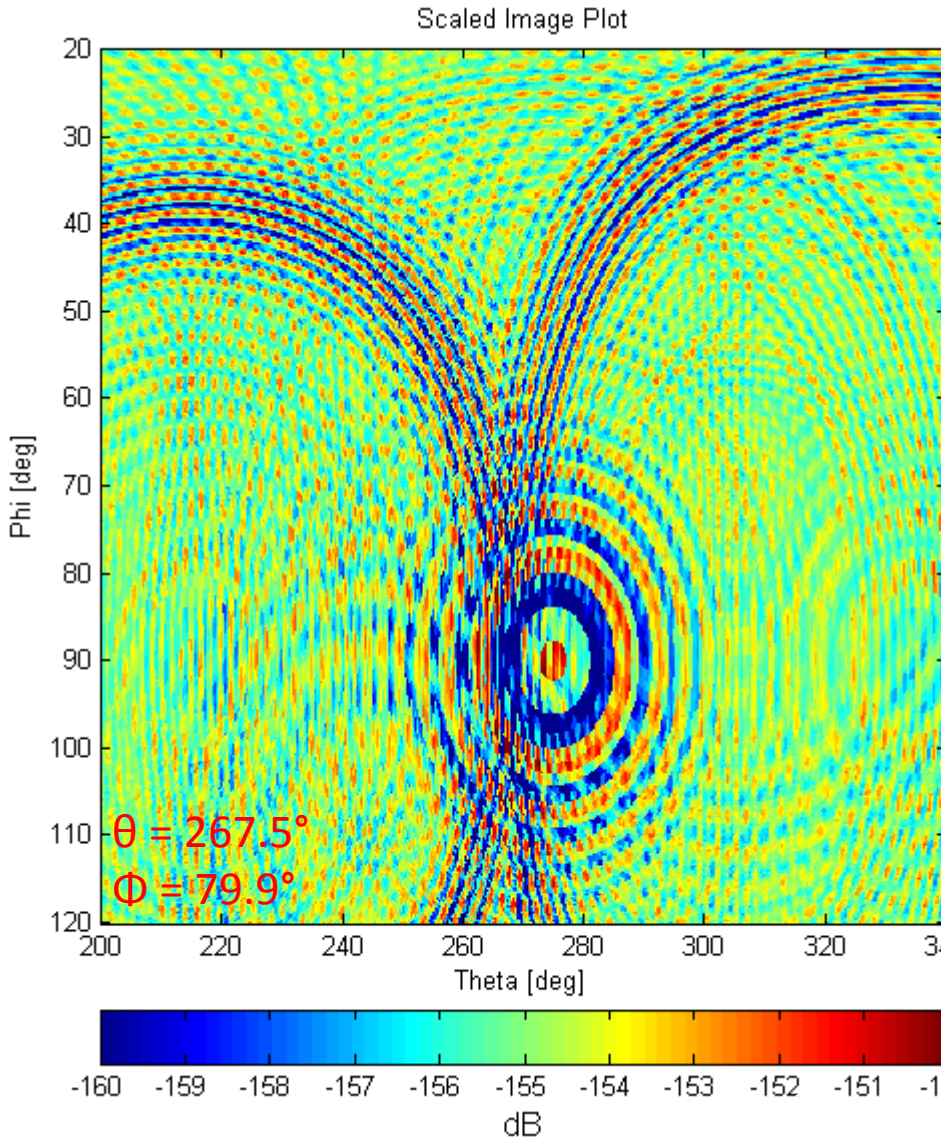
- Source:
  - Depth: 1 m
  - SL: ~ 90 dB re. 1 µPa
  - Chirp Length: 0.150 s
  - Sweep: 20 to 40 kHz





Results – Makai Exp.





Conclusions

- Beamformer is accurate as long as there are no side reflections
  - Horizontal source location can be determined with bottom or surface reflections (subject to environmental conditions)
- Change array configuration to a circular array (Application dependent)
  - triangulation
  - Reduce computational cost
  - Increase horizontal resolution
- Experiment with 3 arrays in an open shallow water environment
  - Location: South Shore Oahu, Kilo Nalu Ocean Observatory
  - Goal: Identify likely multipath models and construct a model utilizing a Likelihood function along with TDOA and focused beamforming
- Noisy environments
  - Energy Detectors (Teager-Kaiser Operator)
  - Edge detector in Spectrograms (e.g. Laplacian)