REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
18-01-2012	Conference Proceeding	-

4. TITLE AND SUBTITLE
Synthetic aperture acoustic imaging of canonical targets with a 2-15 kHz Linear FM chirp

5a. CONTRACT NUMBER
W911NF-09-1-0082

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
633606

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHORS
John Judge, Chelsea Good , Joseph Vignola, Steven Bishop, Peter Gugino, Mehrdad Soumekh

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
The Catholic University of America
The Catholic University of America
620 Michigan Avenue, N.E.
Washington, DC 20064 -

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
55997-CS.1

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
Synthetic aperture image reconstruction applied to outdoor acoustic recordings is presented. Acoustic imaging is an alternate method having several military relevant advantages such as being immune to RF jamming, superior spatial resolution, capable of standoff side and forward-looking scanning, and relatively low cost, weight and size when compared to as compared to 0.5 – 3 GHz ground penetrating radar technologies. Synthetic aperture acoustic imaging is similar to synthetic aperture radar but more akin to synthetic aperture sonar technologies owing to the

15. SUBJECT TERMS
Synthetic aperture acoustic, acoustic imaging, image reconstruction

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Joseph Vignola
UU	UU	UU	UU		19b. TELEPHONE NUMBER
					202-319-6132

Report Title

Synthetic aperture acoustic imaging of canonical targets with a 2-15 kHz Linear FM chirp

ABSTRACT

Synthetic aperture image reconstruction applied to outdoor acoustic recordings is presented. Acoustic imaging is an alternate method having several military relevant advantages such as being immune to RF jamming, superior spatial resolution, capable of standoff side and forward-looking scanning, and relatively low cost, weight and size when compared to as compared to 0.5 – 3 GHz ground penetrating radar technologies. Synthetic aperture acoustic imaging is similar to synthetic aperture radar but more akin to synthetic aperture sonar technologies owing to the nature of longitudinal or compressive wave propagation in the surrounding acoustic medium. The system's transceiver is a quasi mono-static microphone and audio speaker pair mounted on a 5-meter rail. Received data sampling rate is 80 kHz with a 2-15 kHz Linear Frequency Modulated (LFM) chirp with a pulse repetition frequency (PRF) of 10 Hz and an inter-pulse period (IPP) of 50 milliseconds. Targets are positioned within the acoustic scene at slant range of two to ten meters on grass, dirt or gravel surfaces and with and without intervening metallic chain link fencing. Acoustic image reconstruction results in means for literal interpretation and quantifiable analyses. A rudimentary technique characterizes acoustic scatter at the ground surfaces. Targets within the acoustic scene are first digitally spotlighted and further processed providing frequency and aspect angle dependent signature information.

Conference Name: SPIE Defense Sensing

Conference Date: April 25, 2011

Synthetic Aperture Acoustic Imaging

25 April 2011

Joseph Vignola, John Judge, and Chelsea Good
The Catholic University of America

Mehrdad Soumekh
Soumekh Consulting

Steven Bishop and Peter Gugino
US Army RDECOM CERDEC NVESD

Acoustic Imaging

The backscatter of pulses directed at a stationary target, launched and received from a moving transceiver, can be processed to form images.

The resolution of these images is set by the travel range of the moving transceiver rather than by the physical size of the components.

Image resolution can be quite good because the travel range or synthetic apertures can potentially be quite large.

Acoustic Imaging

The backscatter of pulses directed at a stationary target, launched and received from a moving transceiver, can be processed to form images.

The resolution of these images is set by the travel range of the moving transceiver rather than by the physical size of the components.

Image resolution can be quite good because the travel range or synthetic apertures can potentially be quite large.

Acoustic Imaging

The backscatter of pulses directed at a stationary target, launched and received from a moving transceiver, can be processed to form images.

The resolution of these images is set by the travel range of the moving transceiver rather than by the physical size of the components.

Image resolution can be quite good because the travel range or synthetic apertures can potentially be quite large.

Acoustic Imaging

Imaging can be done with light, RF, sound or, potentially, other forms of radiation

Acoustic radiation is worth considering because

•Objects that are opaque to light or RF might be translucent or transparent to sound

•Safety issues are limited and relatively easy to mitigate

•System costs are low

Acoustic Imaging

Imaging can be done with light, RF, sound or, potentially, other forms of radiation

Acoustic radiation is worth considering because

- Objects that are opaque to light or RF might be translucent or transparent to sound
- Safety issues are limited and relatively easy to mitigate
- System costs are low

Acoustic Imaging

Imaging can be done with light, RF, sound or, potentially, other forms of radiation

Acoustic radiation is worth considering because

•Objects that are opaque to light or RF might be translucent or transparent to sound

•Safety issues are limited and relatively easy to mitigate

•System costs are low

Acoustic Imaging

Imaging can be done with light, RF, sound or, potentially, other forms of radiation

Acoustic radiation is worth considering because

•Objects that are opaque to light or RF might be translucent or transparent to sound

•Safety issues are limited and relatively easy to mitigate

•System costs are low

Acoustic Imaging

Imaging can be done with light, RF, sound or, potentially, other forms of radiation

Acoustic radiation is worth considering because

•Objects that are opaque to light or RF might be translucent or transparent to sound

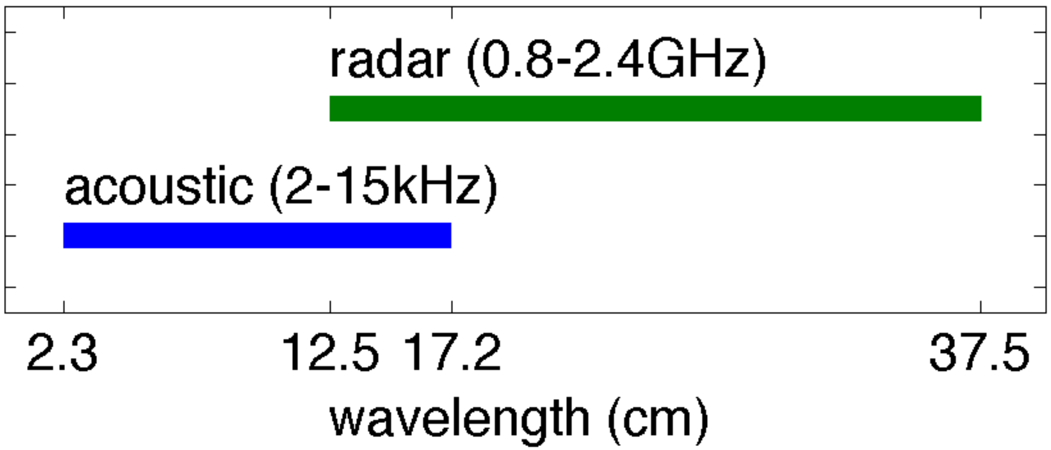
•Safety issues are limited and relatively easy to mitigate

•System costs are low

SAA images leads to 2D acoustic ***signature*** of an individual target which is determined by structural attributes including stiffness, density, shape and orientation

Wavelength and Resolution

Acoustic imaging can produce different information than other approaches because structures interact differently with sound than other forms of radiation



SAA wavelengths are smaller than SAR wavelengths: enhanced resolution

2010 Progress

Refined existing side-looking Synthetic Aperture Acoustic (SAA) imaging system

Analyzed more realistic data with relevant targets and clutter

- Outdoor and indoor measurements at CUA

Completed a field data collection

- Outdoor measurements at an Army test site

Measurement System

Side-looking rail mounted SAA transceiver

Outdoor test sites include a variety of surfaces, background structures and environmental conditions

Specifications & Parameters

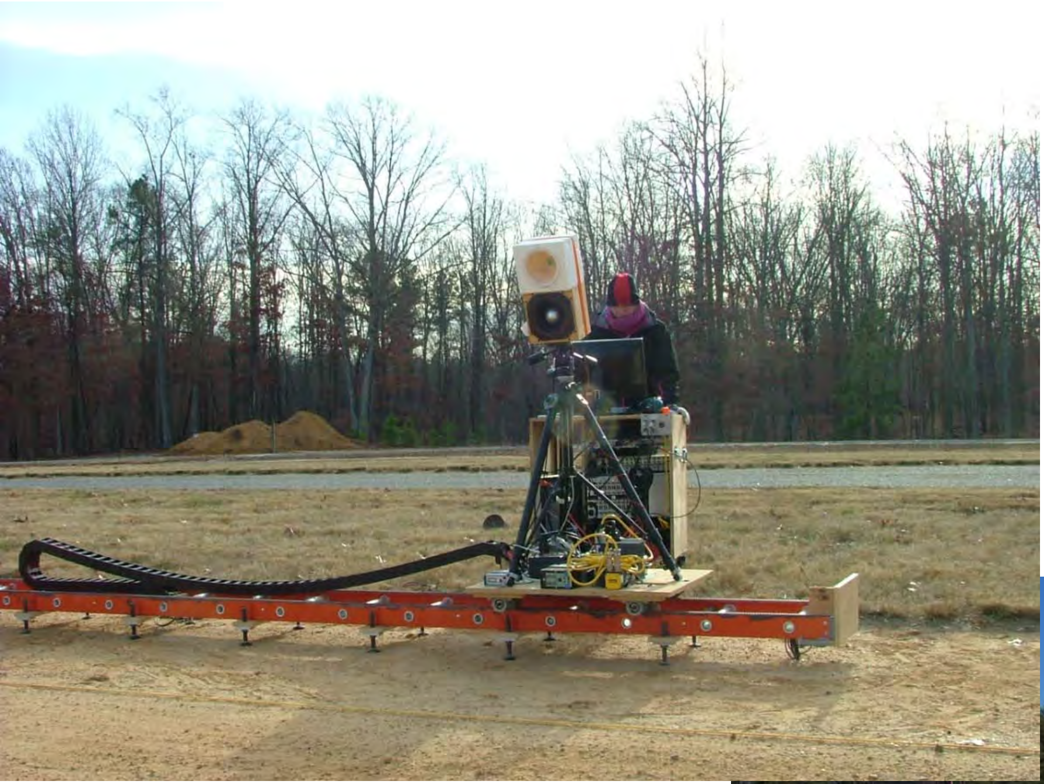
System Specifications

Travel range:	5 m
Chirp band:	2-15kHz
Slant range:	2-15m

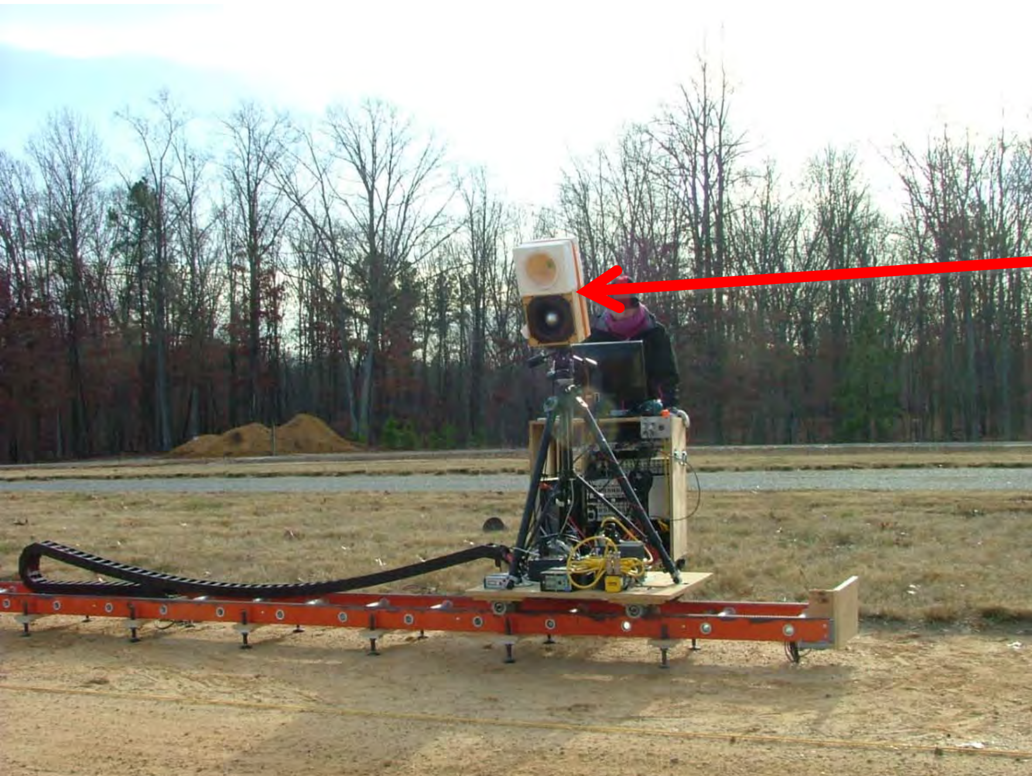
Study Specific Parameters

Repetition rate:	10Hz
Chirp duration:	10 & 40ms
SPL at target:	<105dB
Pulse diversification	0%
Depression angel	12.5°-30°

Field Measurements

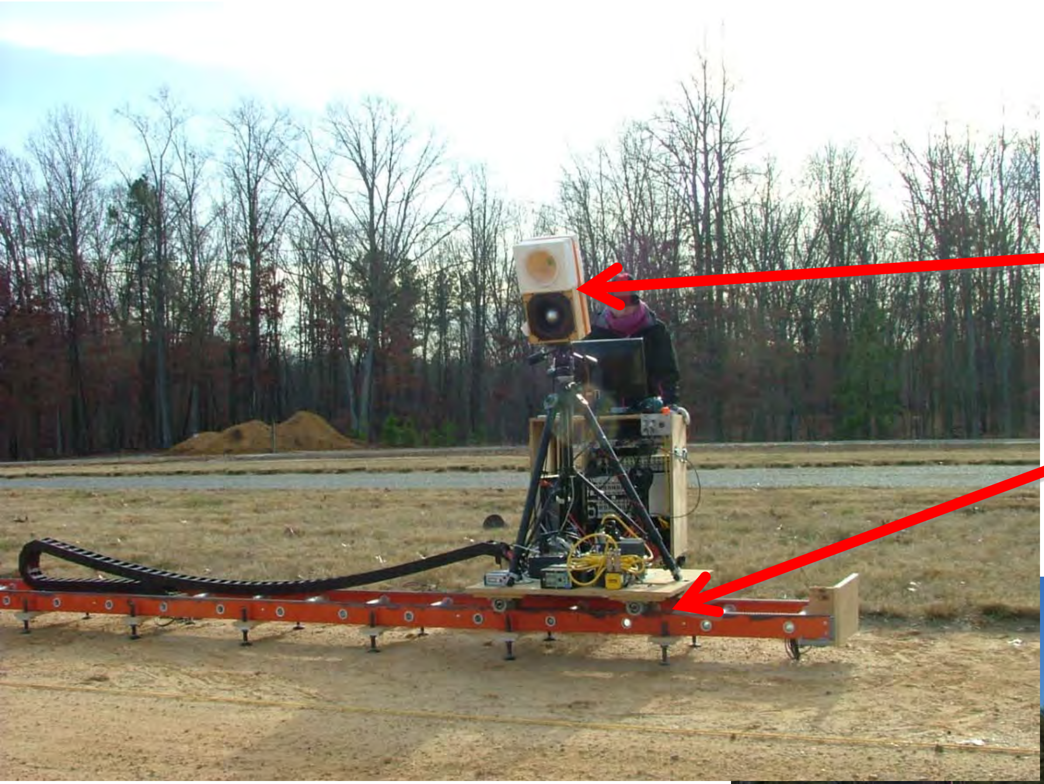


Field Measurements



Speaker/microphone combination transceiver

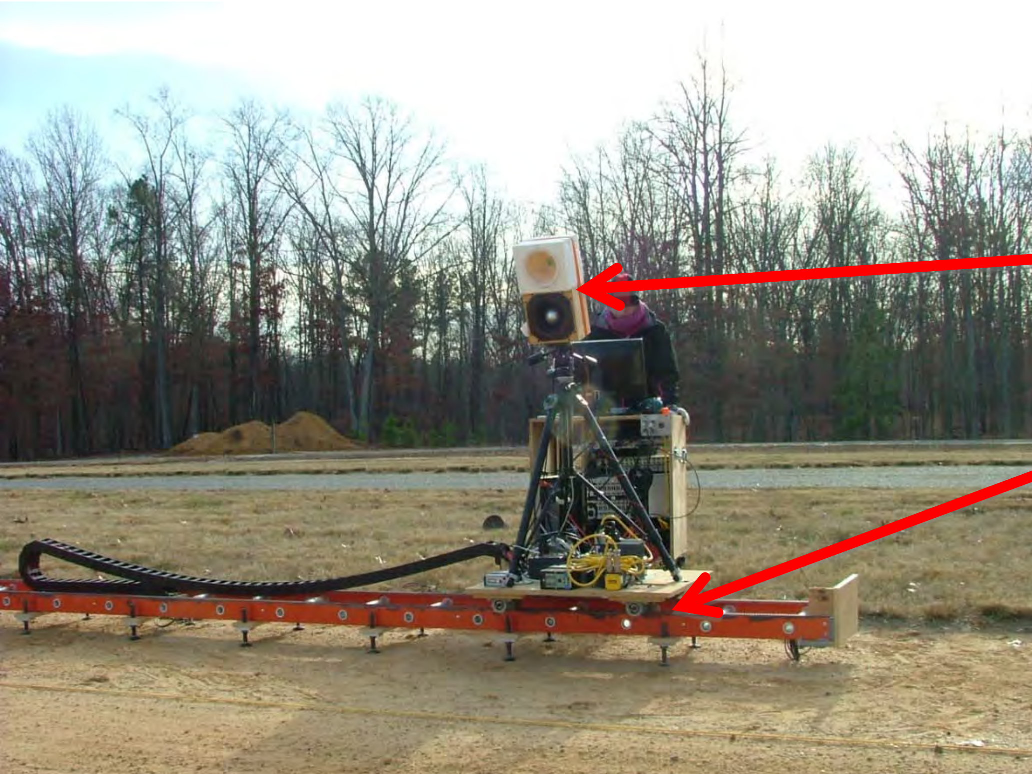
Field Measurements



Speaker/microphone combination transceiver

Carriage travels along 5 m rail

Field Measurements



Speaker/microphone combination transceiver

Carriage travels along 5 m rail

Targets were placed on dirt, gravel, and grass surfaces at 2-9 m range

Targets and Surfaces

a. Dirt and grass without any targets

b. Propped concave capped cylinder (CCC)
   - on dirt and grass
   - behind a metallic chain link fence

c. Spherical targets (bowling ball and softball)
   - on dirt and grass
   - behind a metallic chain link fence

d. Material study
   - open and closed cell foam
   - ceiling panels
   - slate

e. Large artillery shell

f. Human

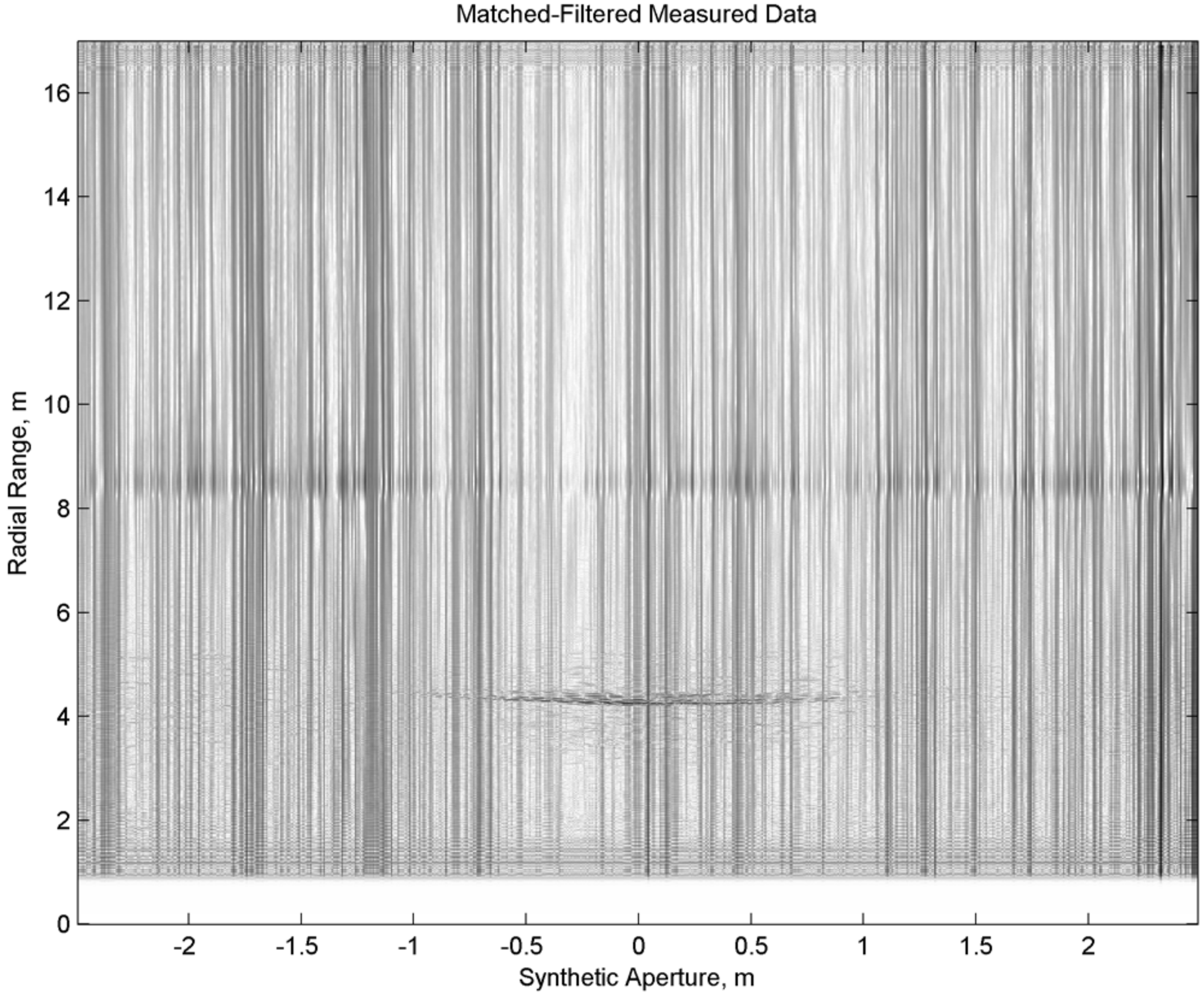
Field Measurements

- ***Test Environment Conditions:***
  - no recent rain
  - temperature was below freezing point
  - strong winds were present
  - background noise from nearby sites

Adaptive frequency domain filtering was used to suppress the acoustic noise signature of the wind and background noise.

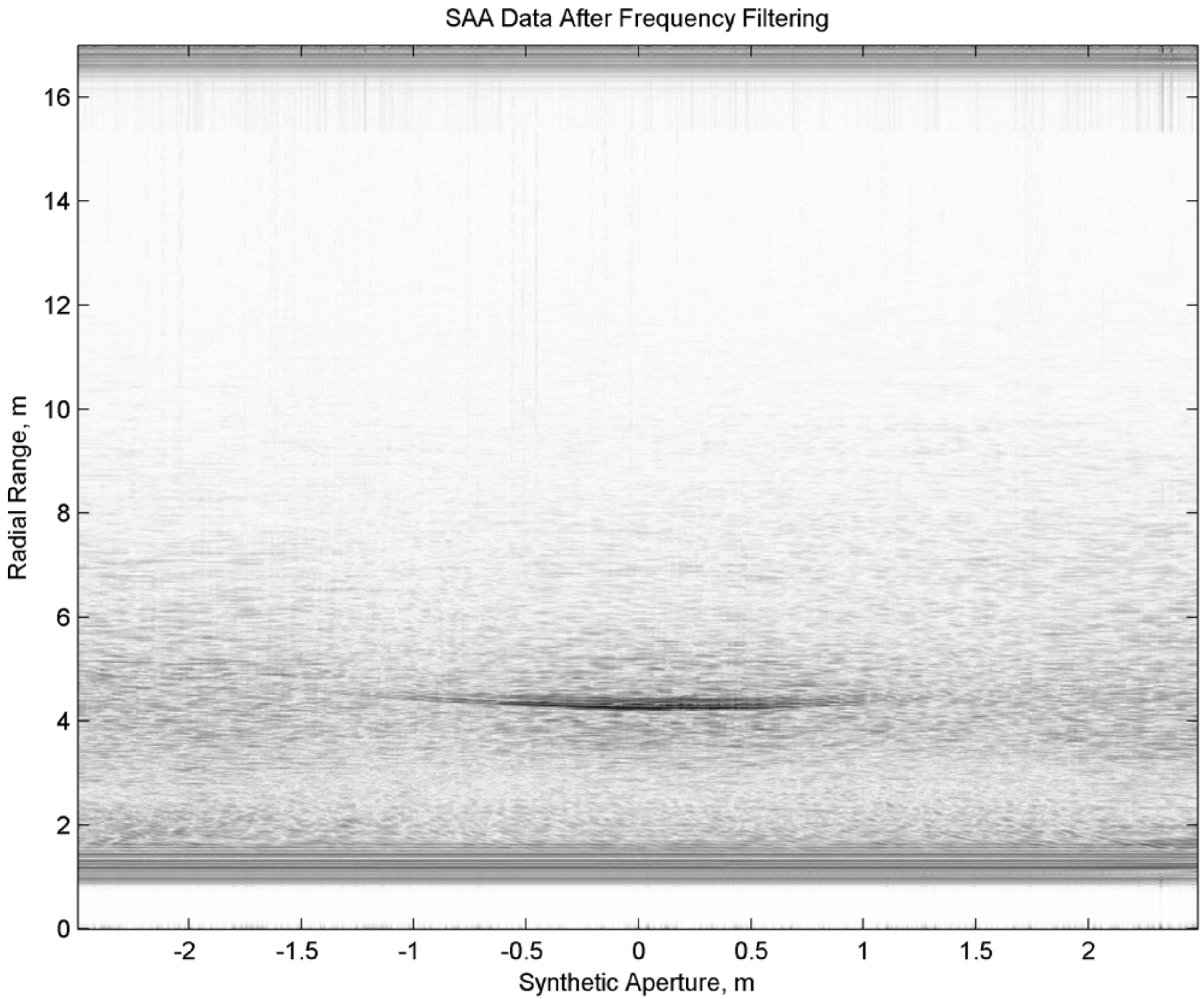
Environmental Noise

Before adaptive filtering

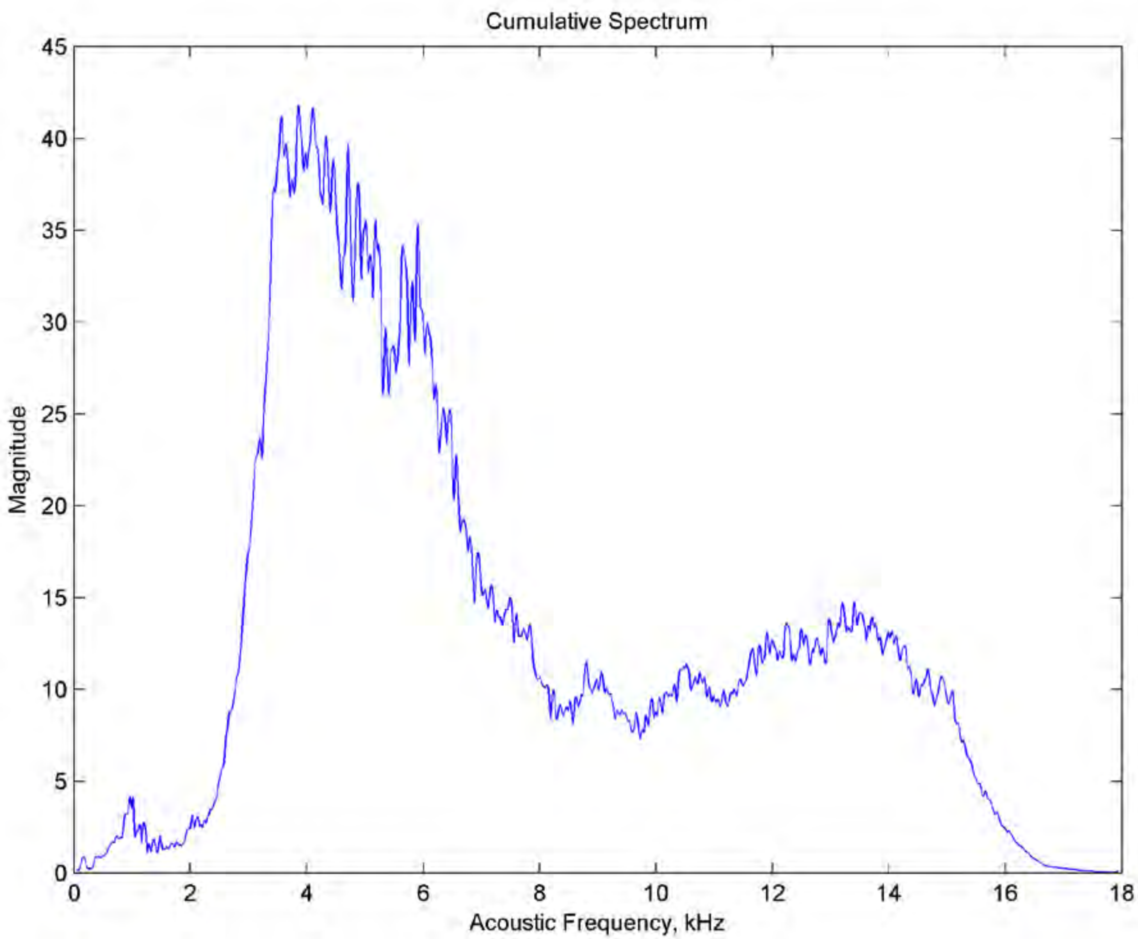


Environmental Noise

After adaptive filtering



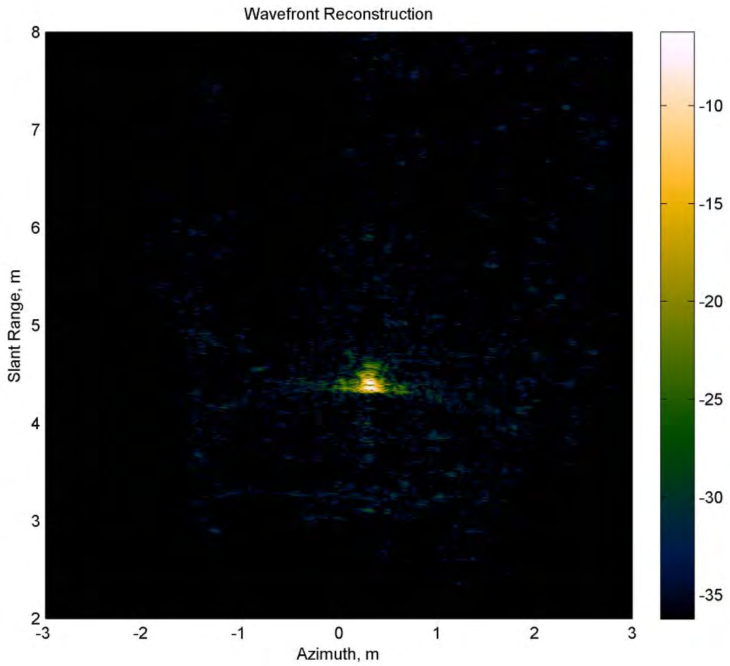
Insonification Transfer Function



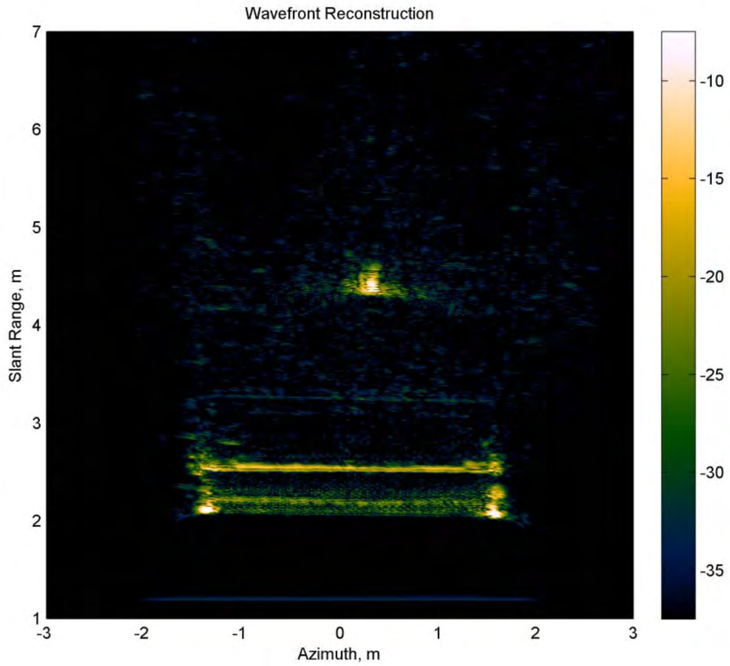
Cumulative spectrum indicates usable bandwidth between 2 and 16 kHz

Concave Capped Cylinder (CCC)

Unobscured target

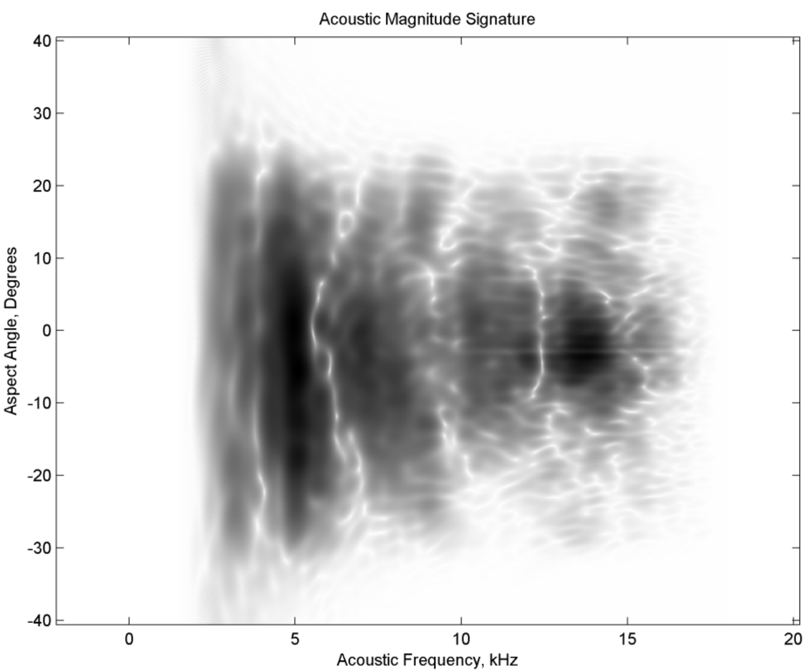


Obscured by chain-link fence

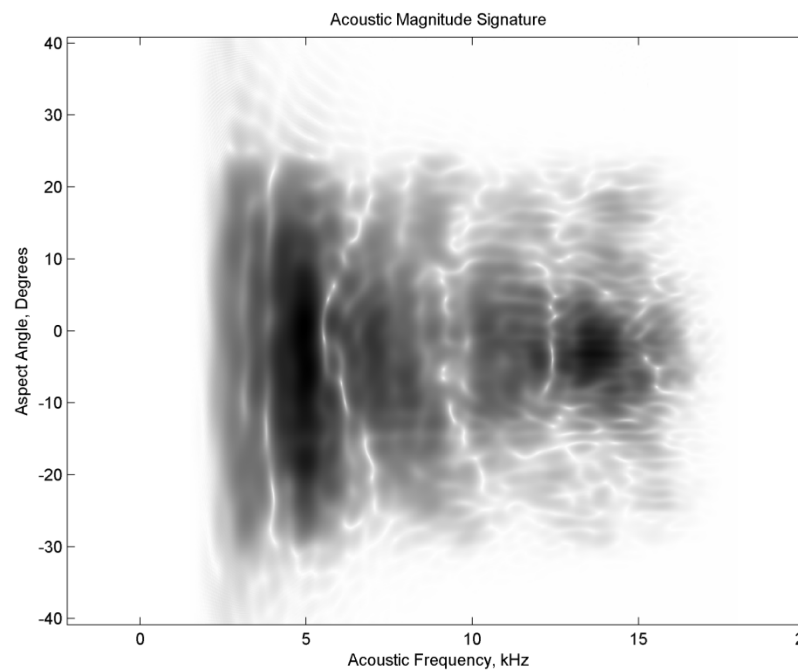


Concave Capped Cylinder (CCC)

Unobscured target

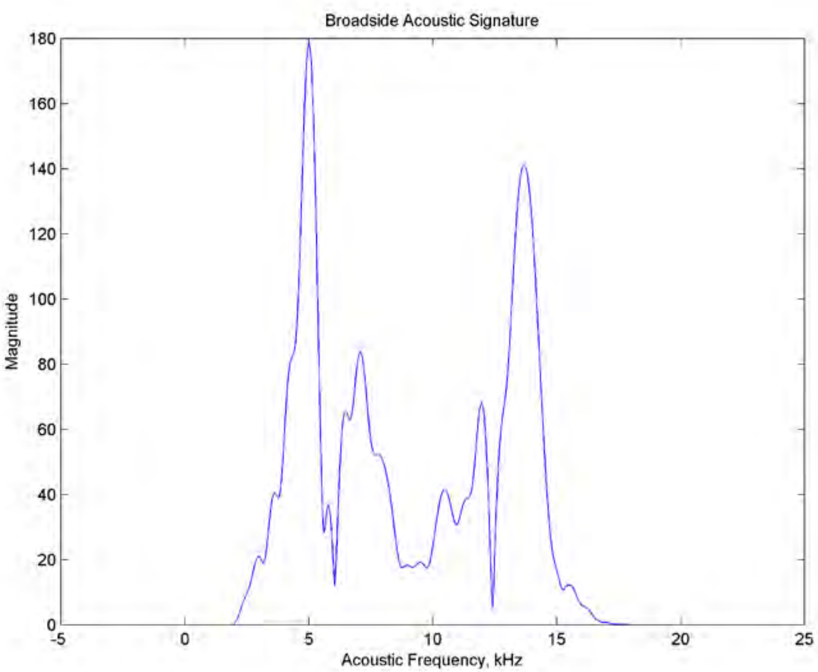


Obscured by chain-link fence

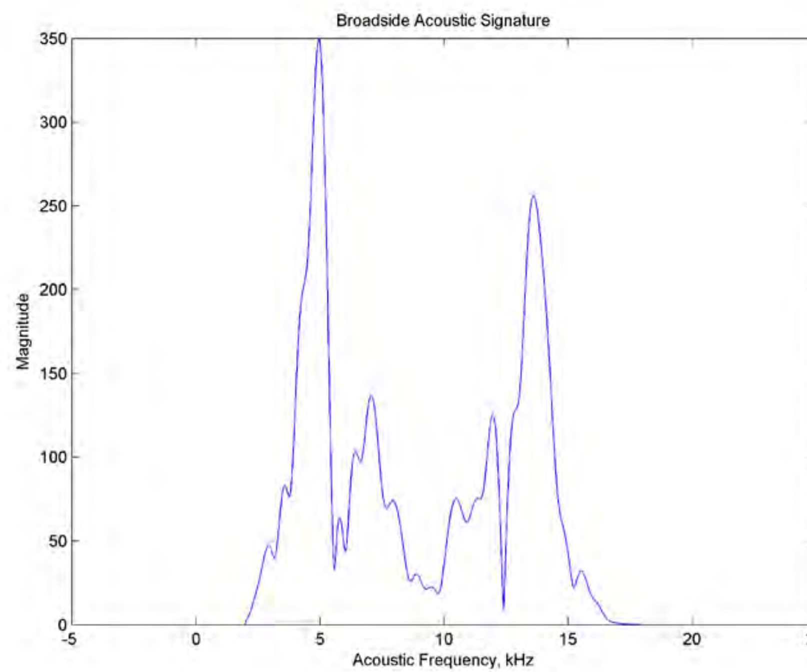


Concave Capped Cylinder (CCC)

Unobscured target



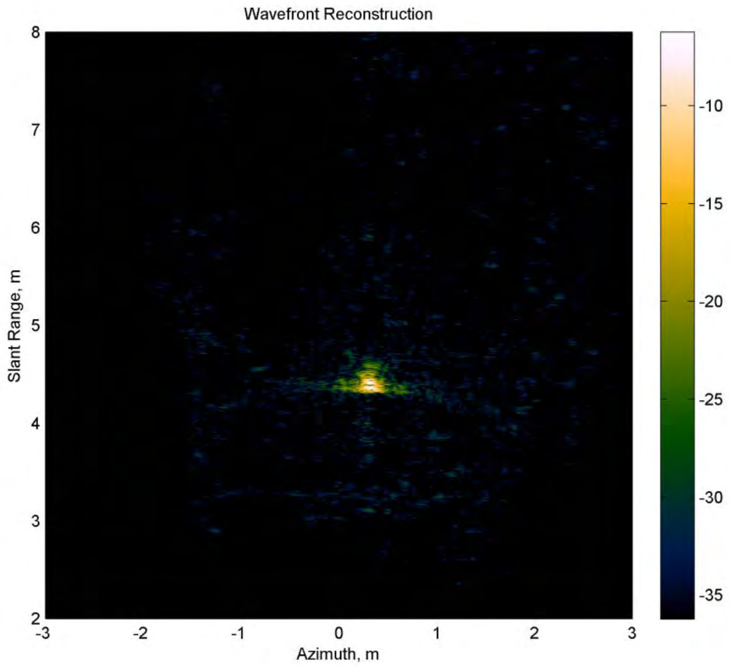
Obscured by chain-link fence



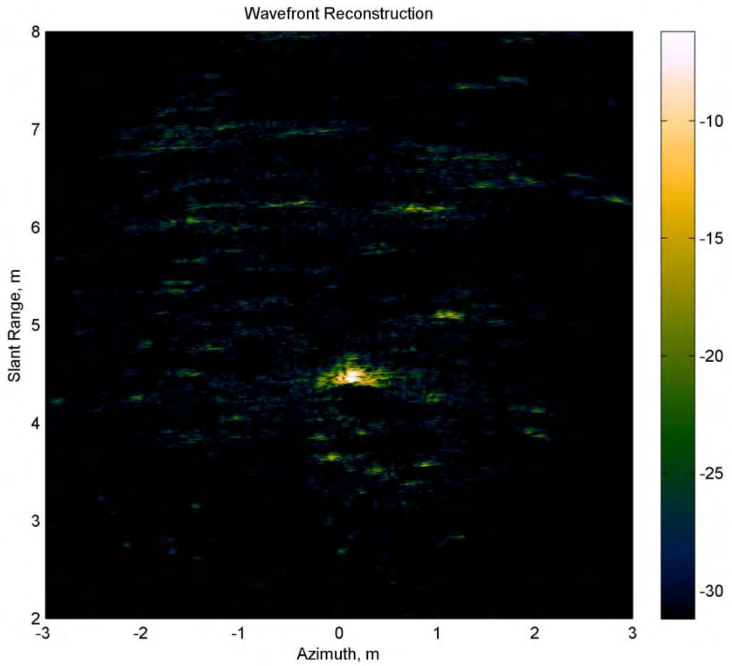
Chain-link fence has minimal effect on signature

Concave Capped Cylinder (CCC)

Target on dirt

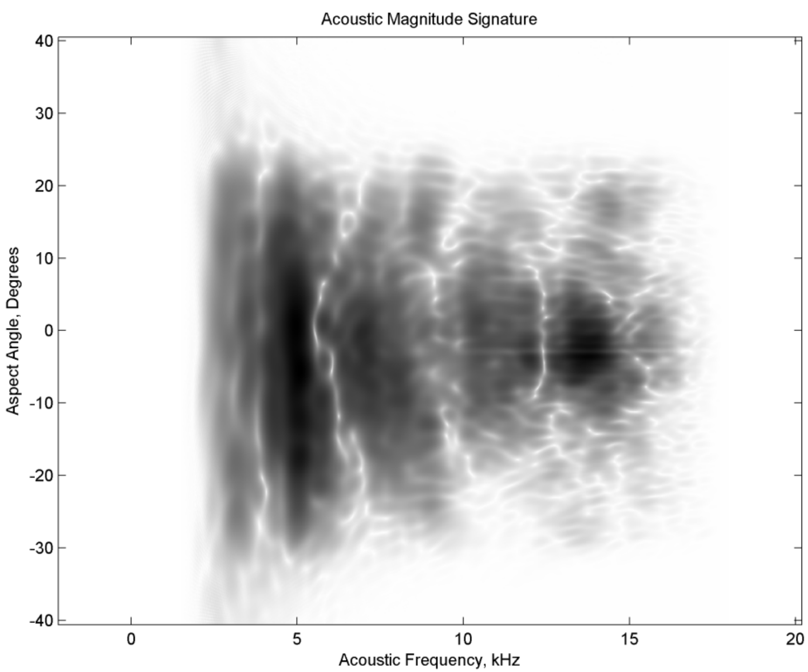


Target on grass

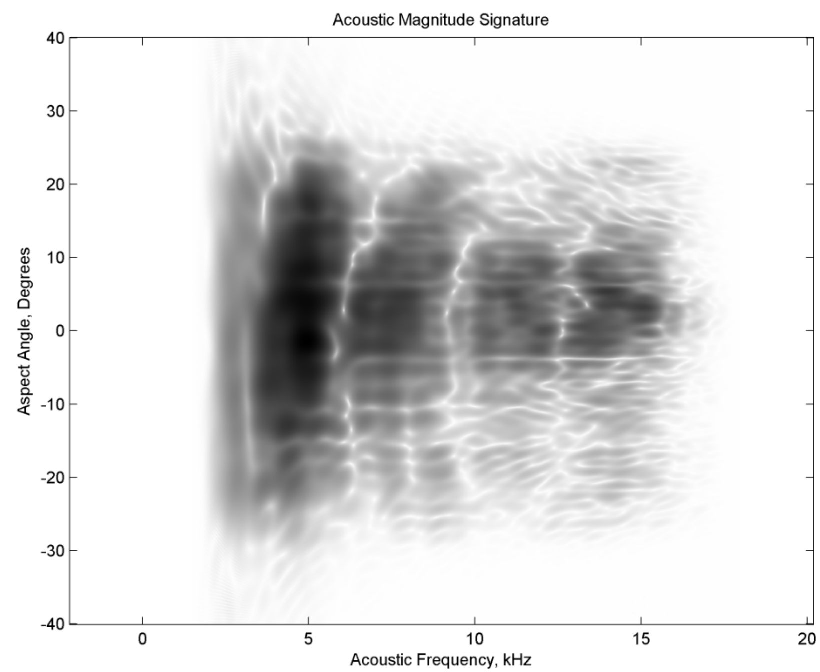


Concave Capped Cylinder (CCC)

Target on dirt



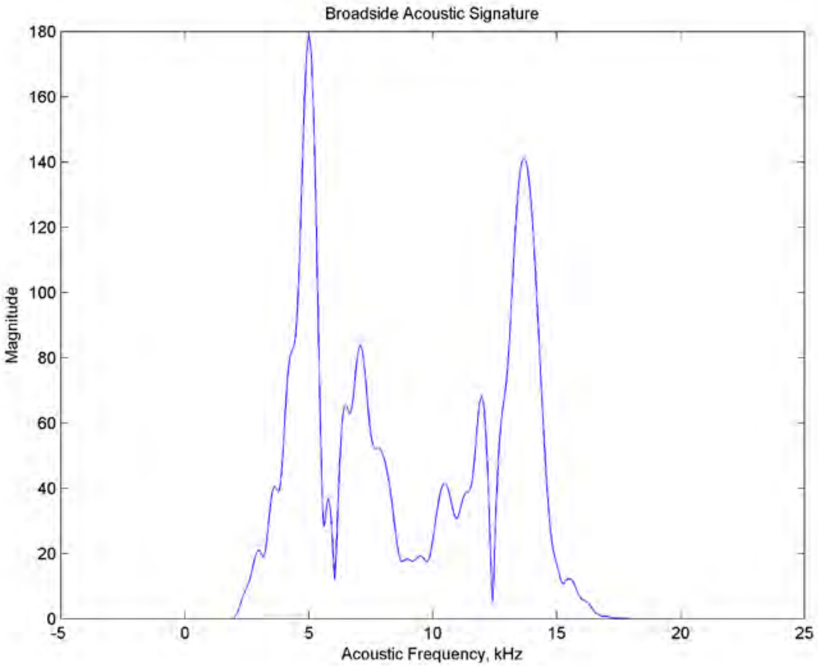
Target on grass



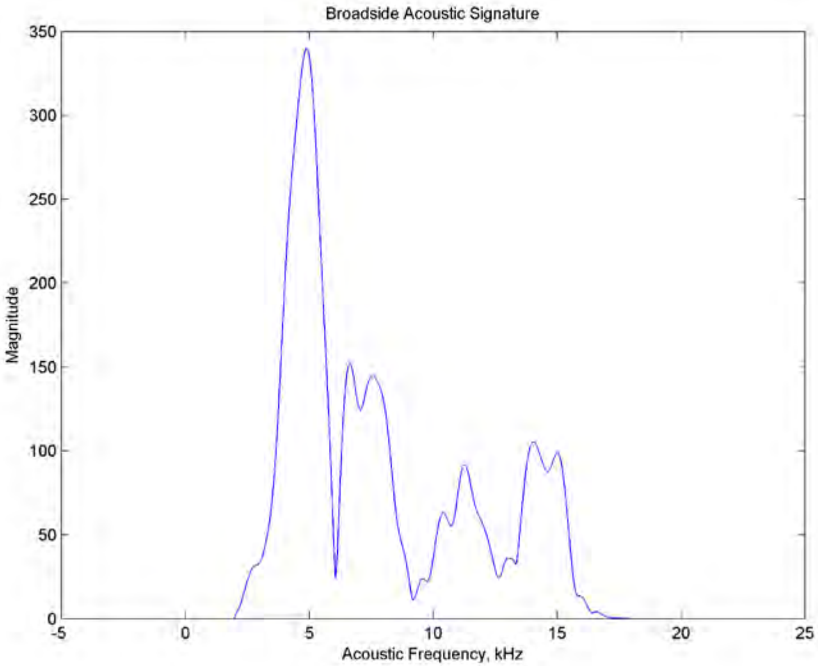
Different surfaces exhibit similar acoustic signature…

Concave Capped Cylinder (CCC)

Target on dirt

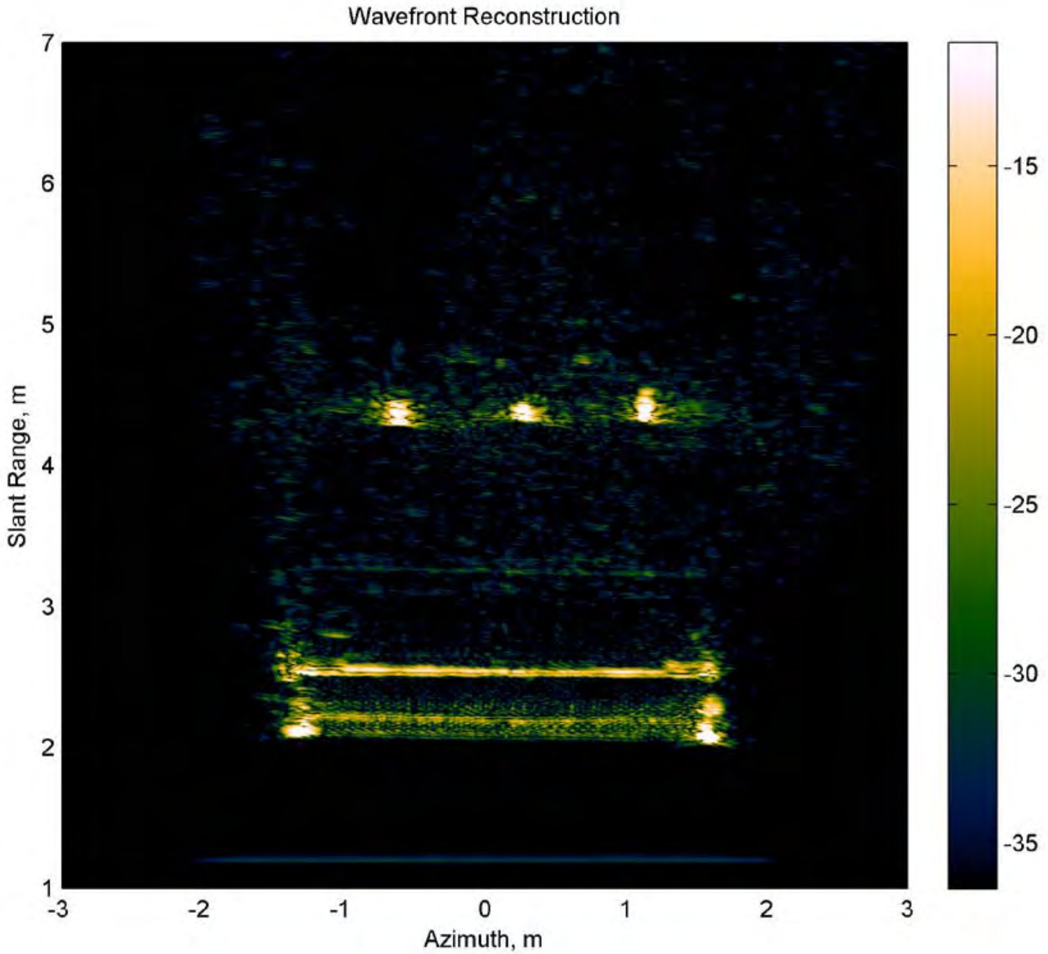


Target on grass



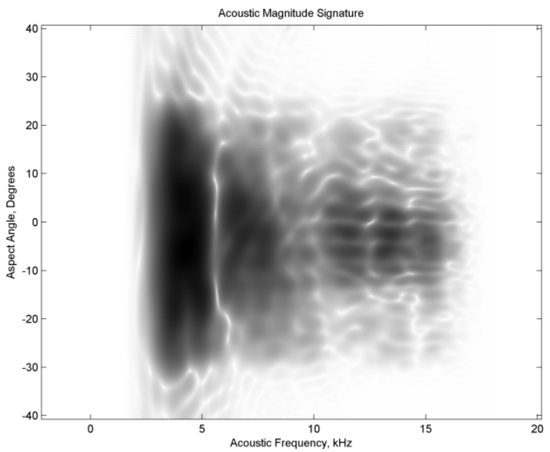
… however, grass introduces high frequency attenuation

Target Elevation

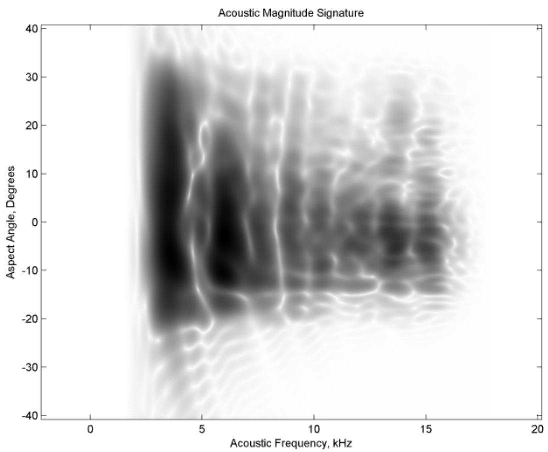


Elevation Comparison

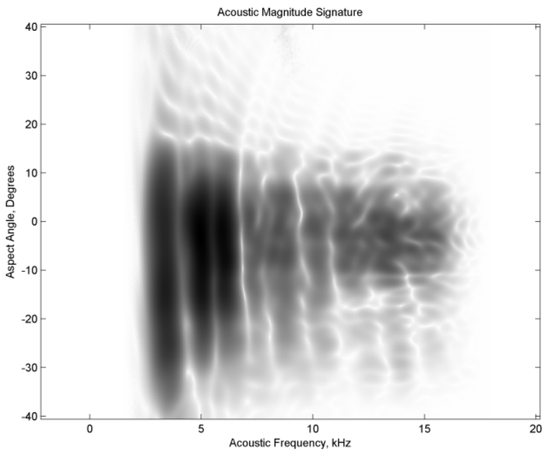
bowling ball on surface



bowling ball elevated 1 inch

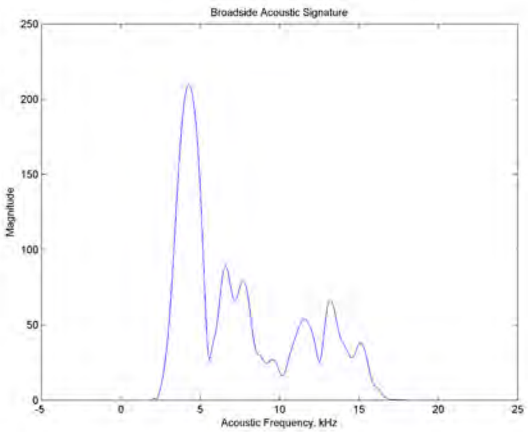


bowling ball elevated 2 inches

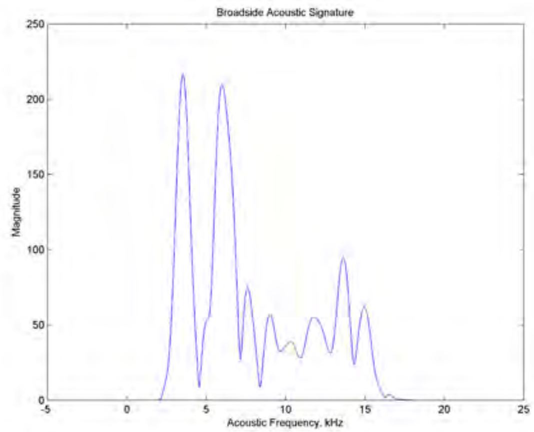


Elevation Comparison

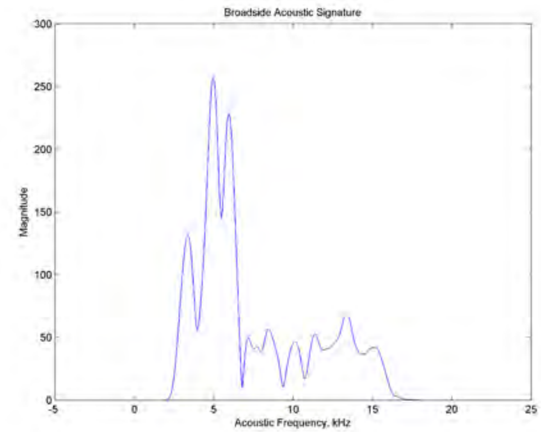
bowling ball on surface



bowling ball elevated 1 inch



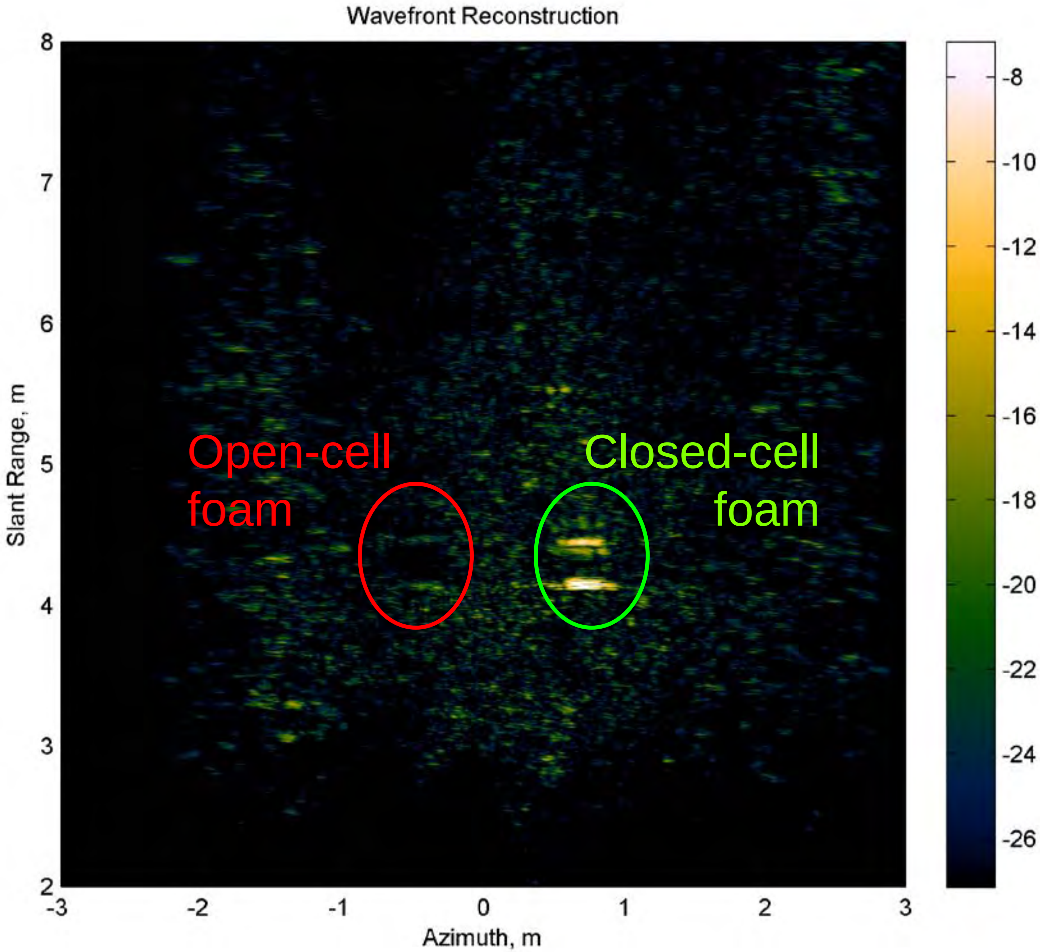
bowling ball elevated 2 inches



Signature is sensitive to target elevation due to multi-path effects

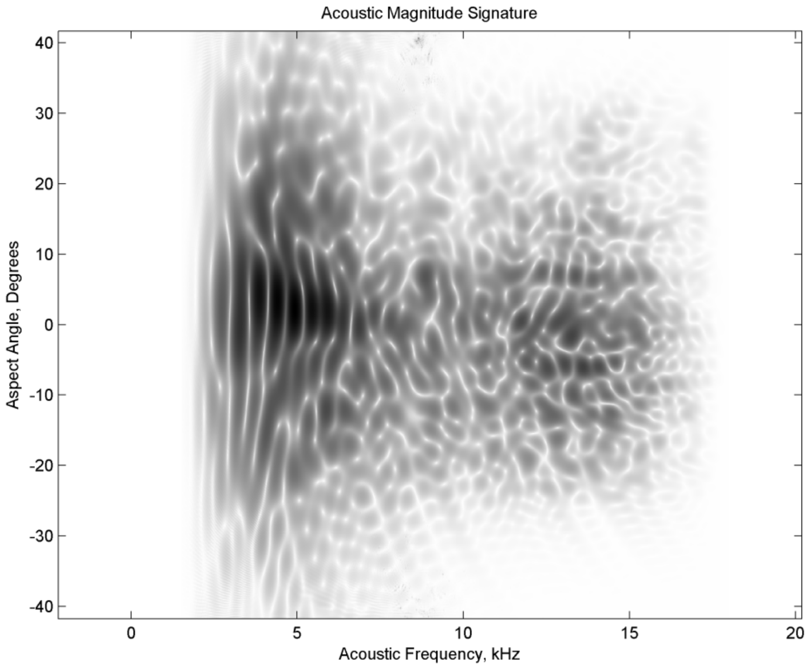
Target Materials

Reconstruction of foam panels on dirt

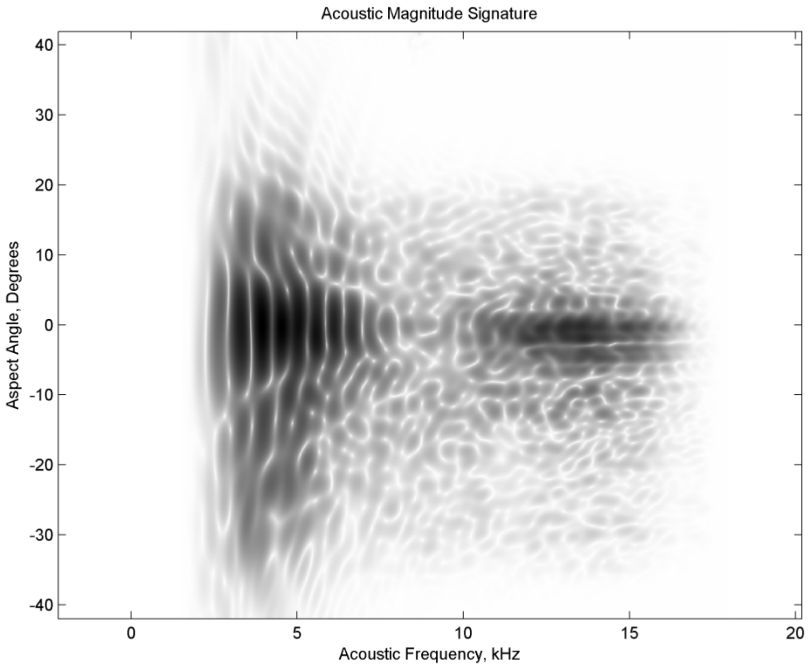


Target Materials

Open-cell foam panel

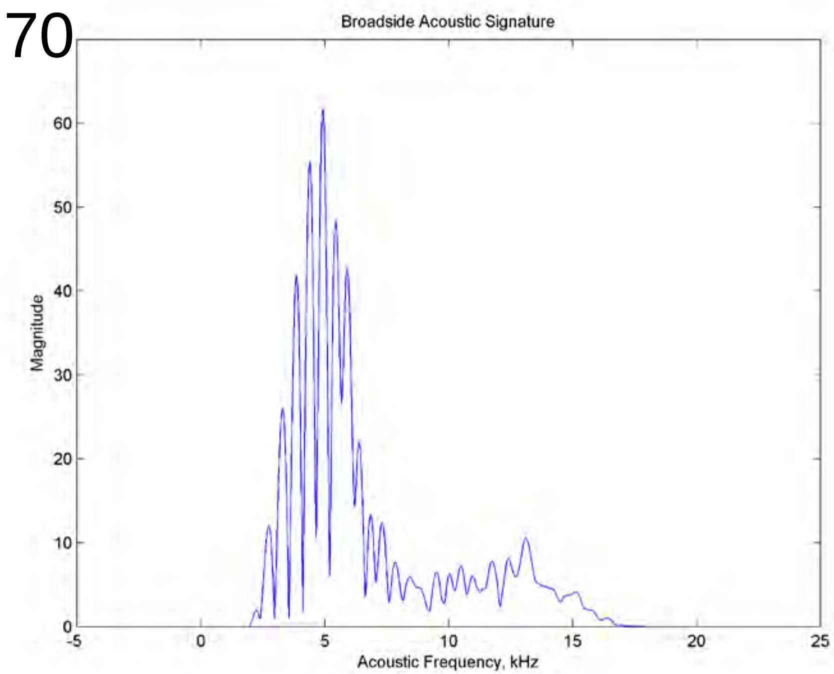


Closed-cell Styrofoam panel

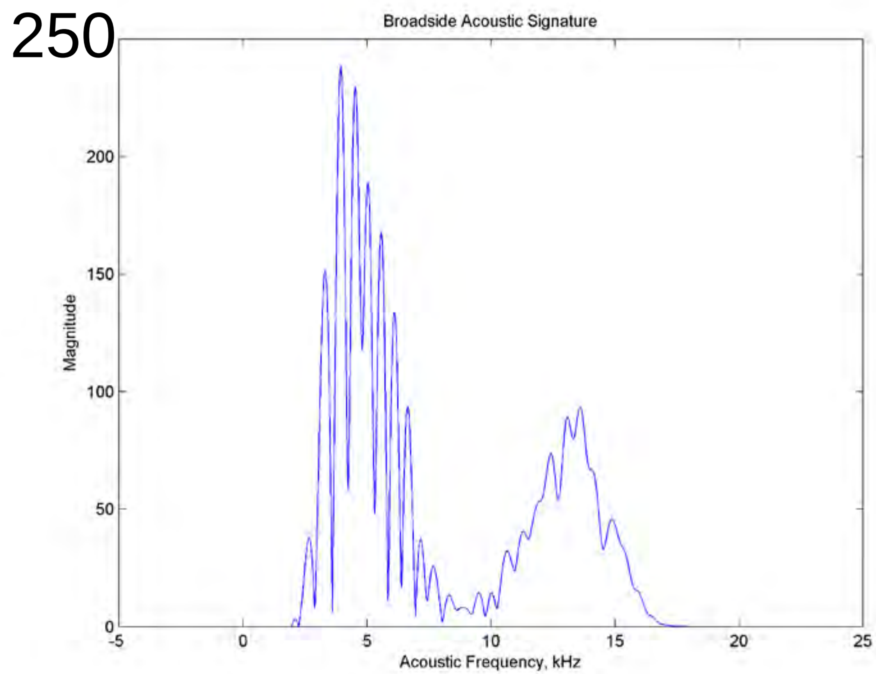


Target Materials

Open-cell foam panel



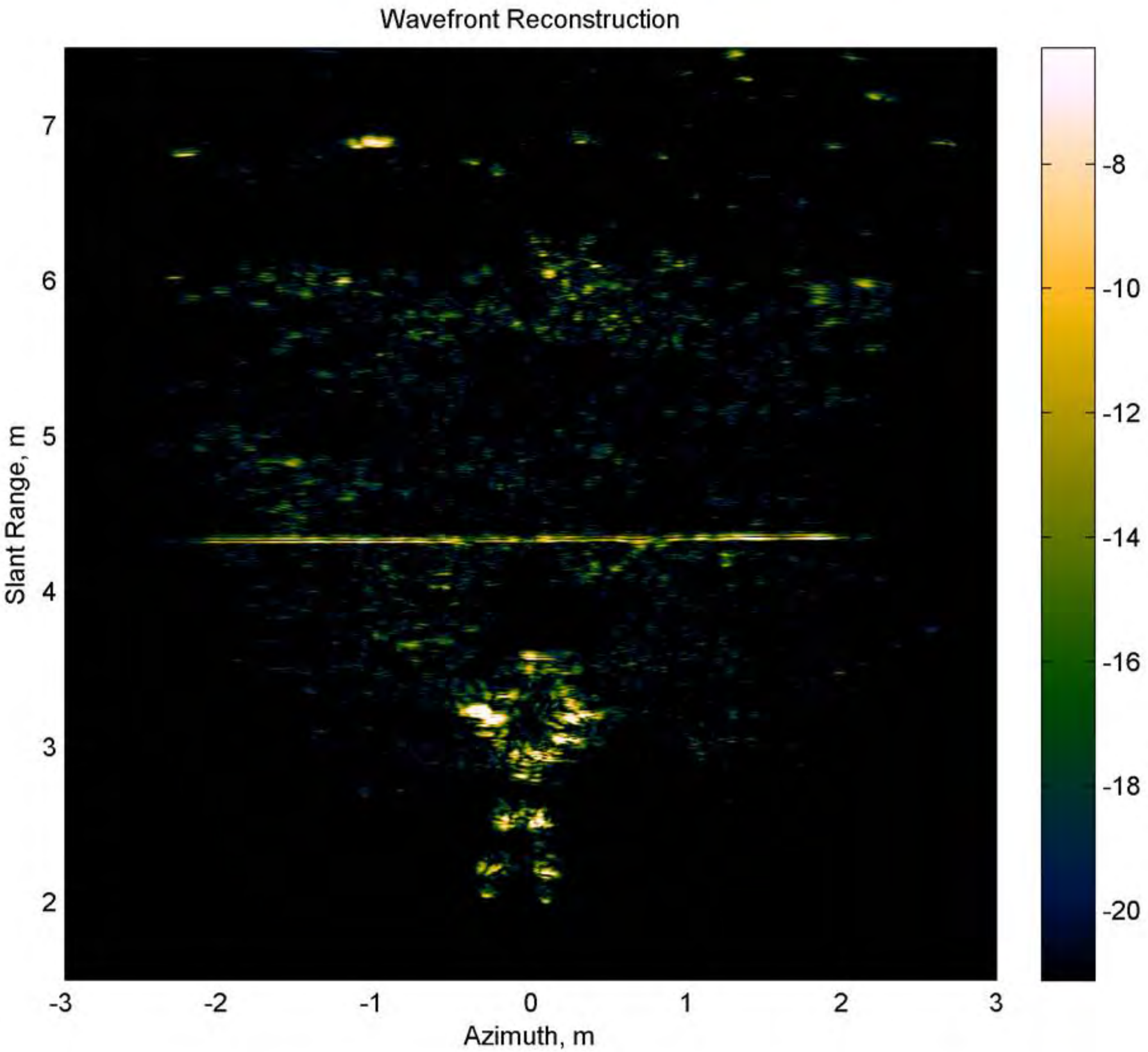
Closed-cell Styrofoam panel



Amplitude is dramatically effected by material

Human Target

Reconstruction of a human supine on dirt (SAA_143038,).



Conclusions

Robust Data Acquisition: data was successfully collected outdoors under uncontrolled ambient conditions

Data is robust to environmental acoustic noise (wind, vehicular traffic, gunfire and explosions)

Acoustic measurements are not influenced by EMI

Geometric characterization: targets and target configurations have distinct and repeatable signatures

Signatures are not sensitive to ground surface type but are sensitive to target elevation

Signatures can be obtained despite the presence of obscurants (e.g., chain-link fence)

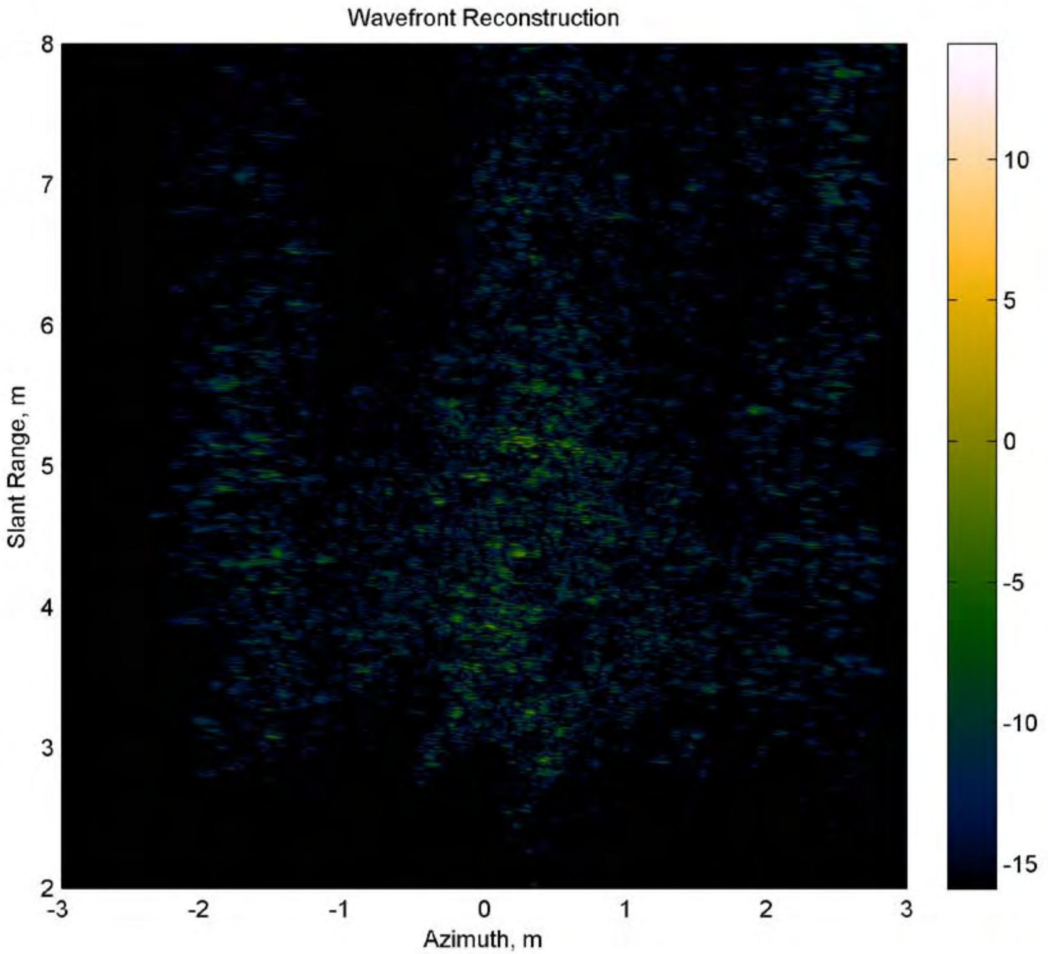
Material characterization: comparison of samples of different materials (with identical geometry) show differences in signature and amplitude

Distinguish different bulk properties (stiffness, density) and surface characteristics (roughness, porosity, surface impedance)

Backup Slides

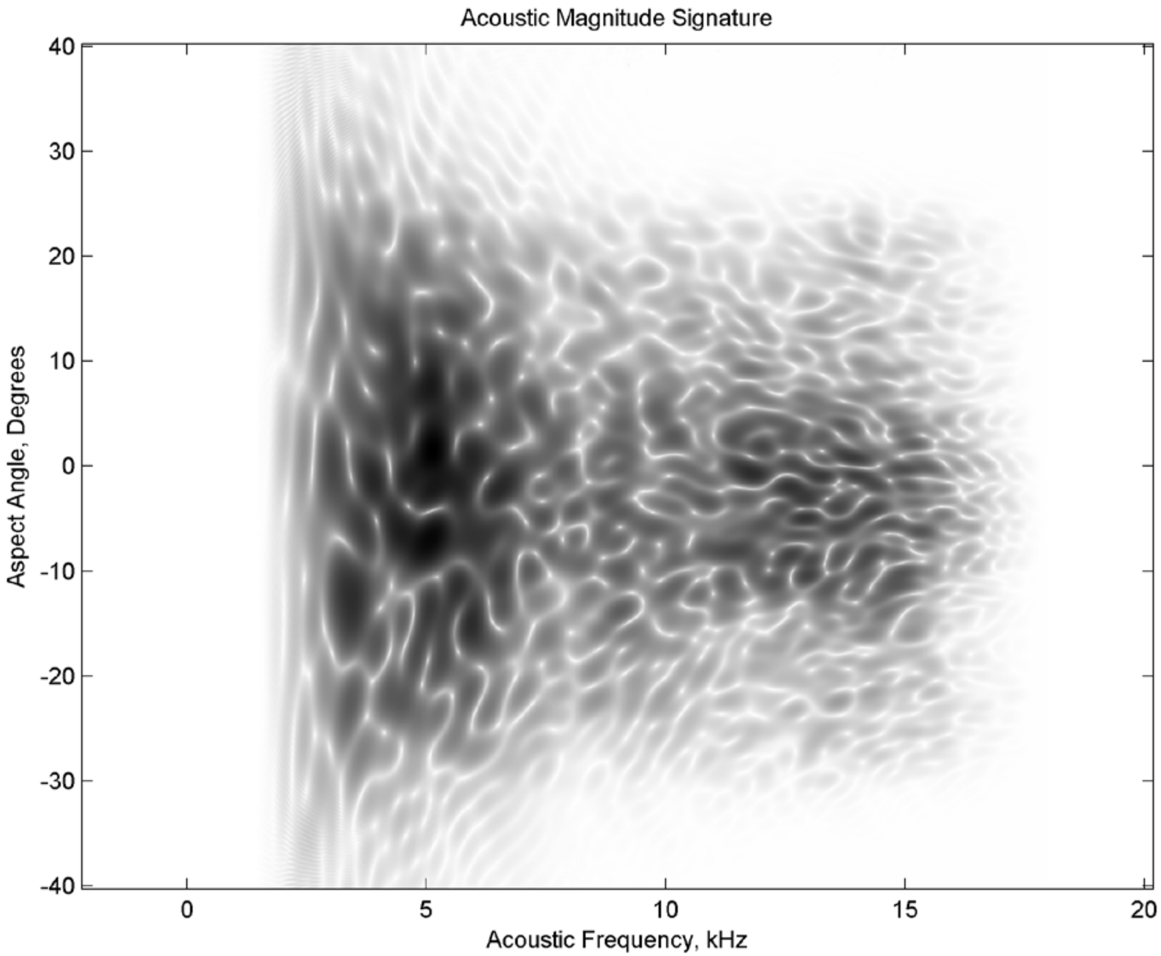
Surface Environment: Dirt

Reconstruction of lightly textured soil on a dirt lane (SAA_100616).



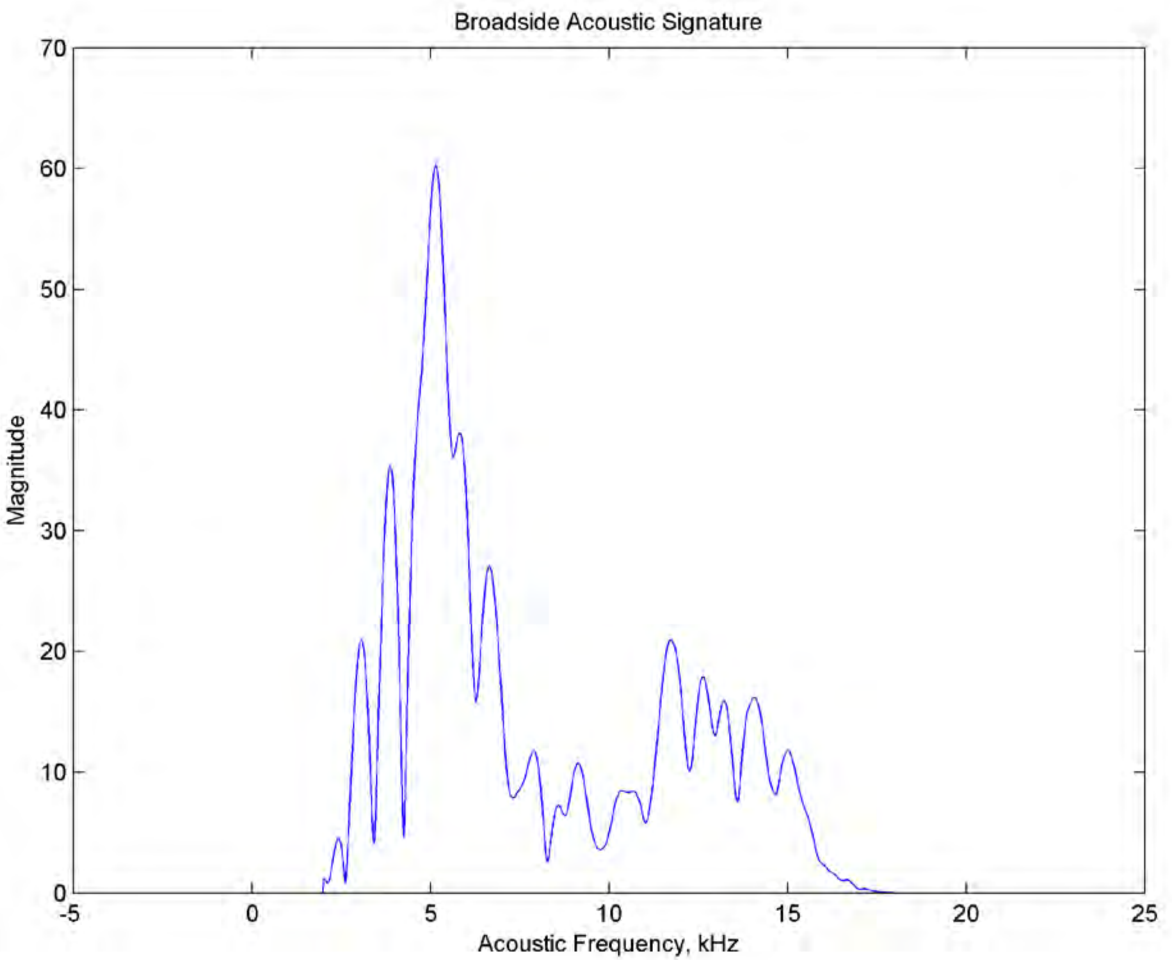
Surface Environment: Dirt

2D signature of lightly textured soil on a dirt lane (SAA_100616).



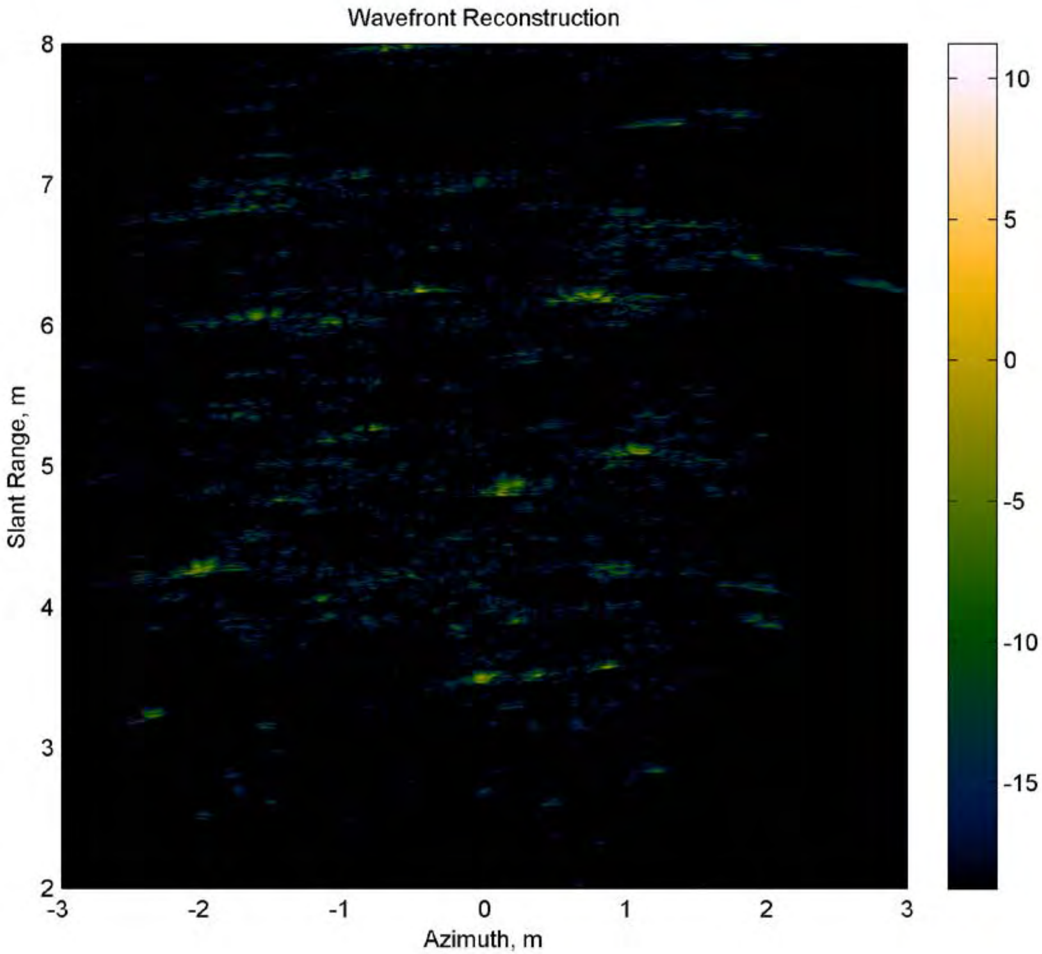
Surface Environment: Dirt

Dirt area 1D broadside signature lightly textured soil on a dirt lane (SAA_100616).



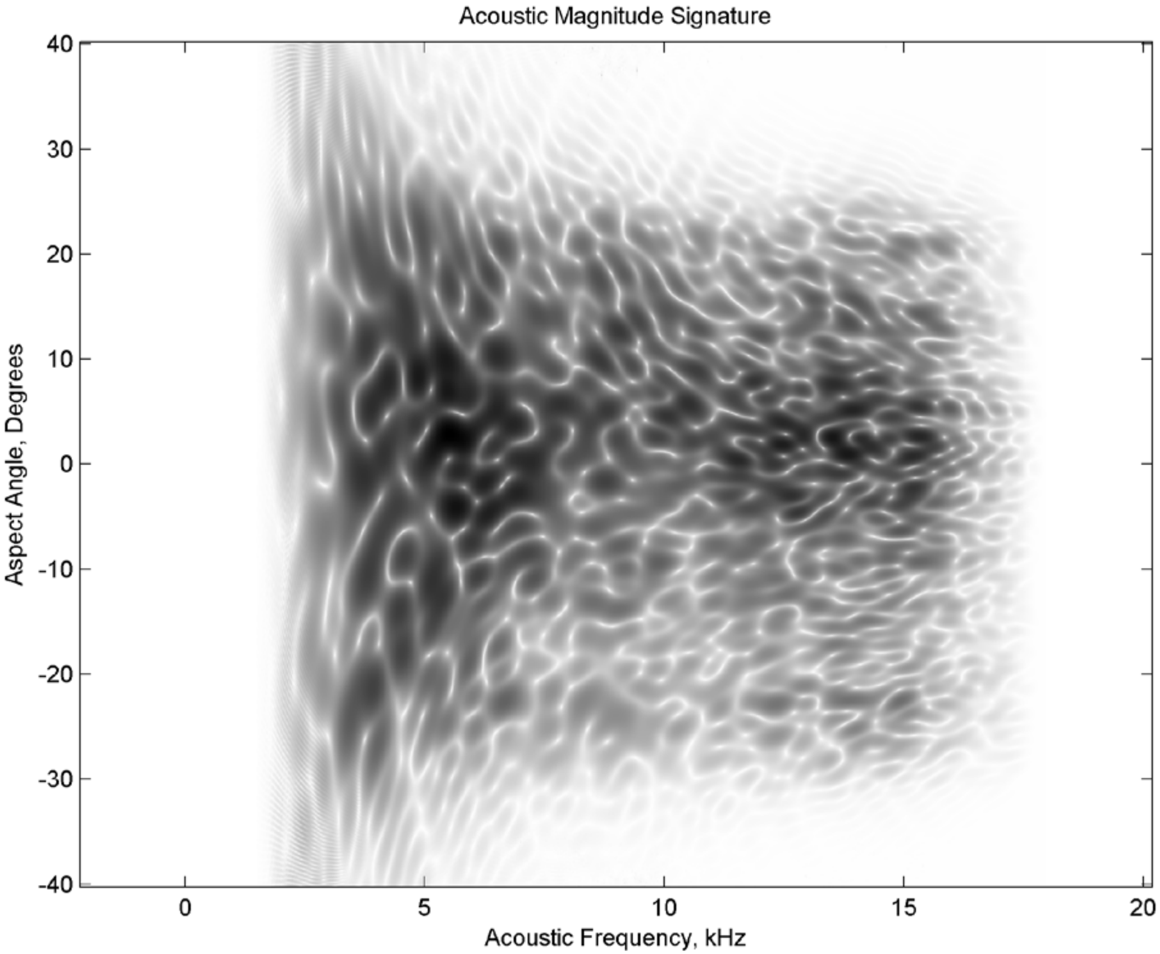
Surface Environment: Grass

Reconstruction of grass area (SAA_113821).



Surface Environment: Grass

Grass area 2D signature (SAA_113821).



Surface Environment: Grass

Grass area 1D broadside signature (SAA_113821).