ENGINEERING

An Ultrawideband (UWB) Switched-Antenna-Array Radar Imaging System

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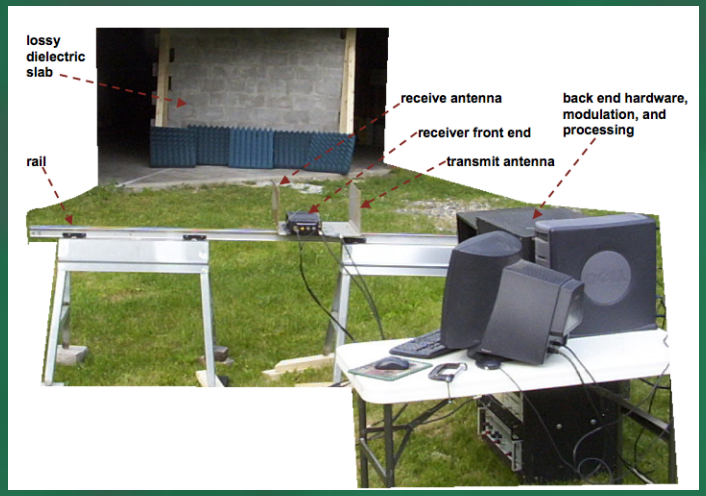
E N G I N E E R I N G

Thru-Slab S-Band Radar Imaging

- Rail SAR shown effective for thru-slab imaging
- 20 minute acquisition time does not support practical applications



G. L. Charvat, L. C. Kempel, E. J. Rothwell, C. Coleman, and E. L. Mokole, ``A through-dielectric radar imaging system," IEEE Transactions on Antennas and Propagation, vol. 58, Issue 8, pp. 2594-2603, August, 2010.

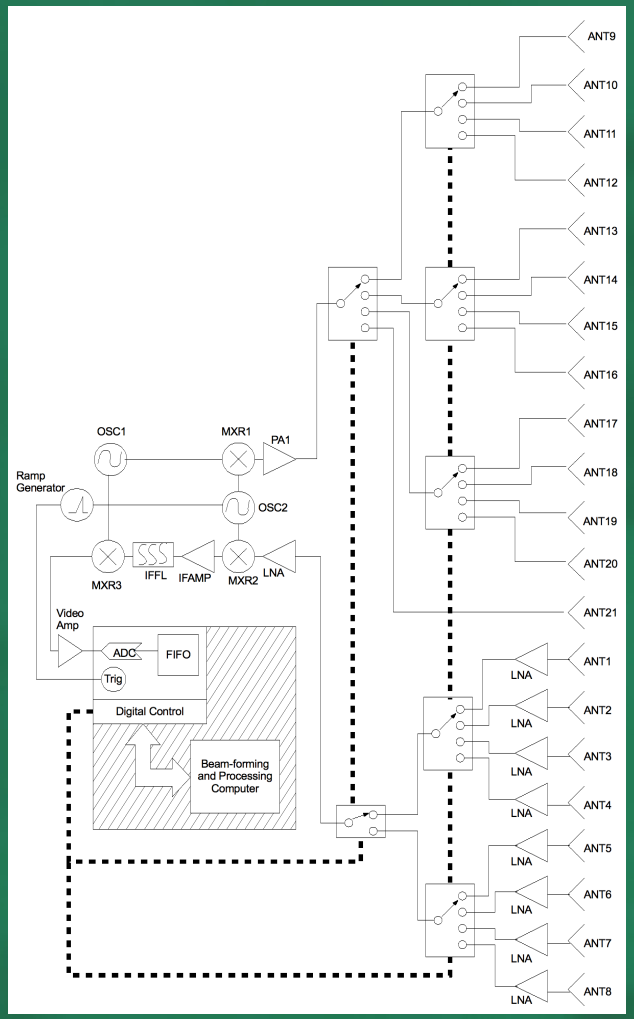
- *Phased array reduces acquisition time from 20 min to < 2 seconds*
- Proves thru-slab concept

Outline

- Radar Architecture
- Array
- Simulated Performance
- Implementation
- Measured vs. Simulated Results
- Point Target Imagery
- Measured Near Real-Time Imagery
  - free-space
  - thru-slab
- Summary

Radar Architecture

- FMCW, LFM chirp 1.926-4.096 GHz in 2.5-10 ms, 1 mw peak TX, PRF = 20 Hz (approx.)
- Range gate by band-limiting IF using crystal filters
  - Filters out air-wall boundary
  - Apply full dynamic range of digitizer
- TX/RX to fan-out switch matrices
    - One RX and TX element at any time



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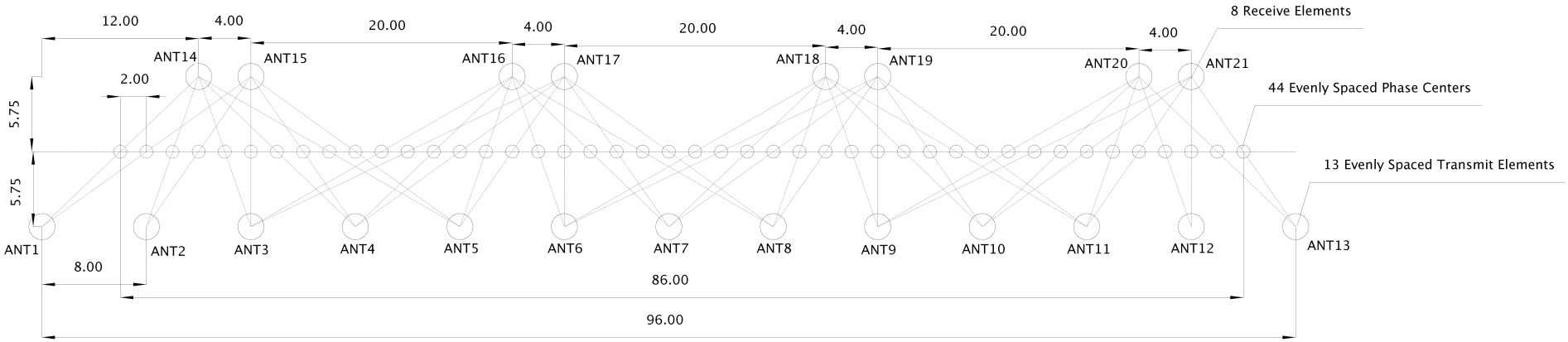
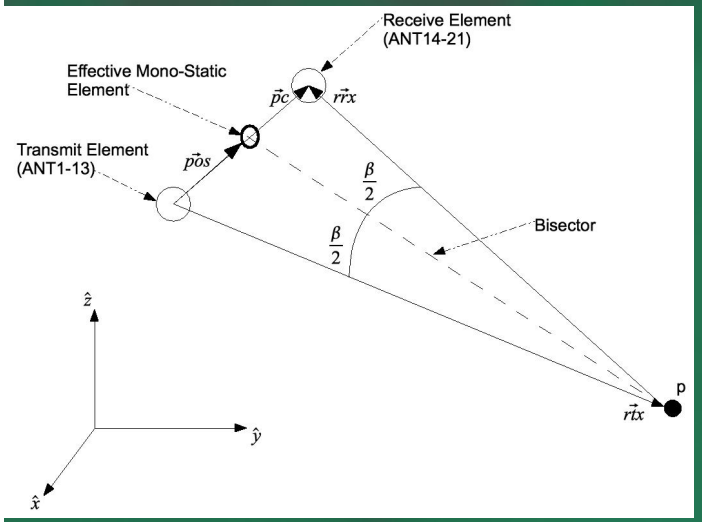
Array





- Subset of bistatic TX/RX element combinations acquired
  - 44 used, shown here
- Phase centers of bi-static combinations effectively forms a 8.5’ long linear array with λ/2 element spacing at 3 GHz

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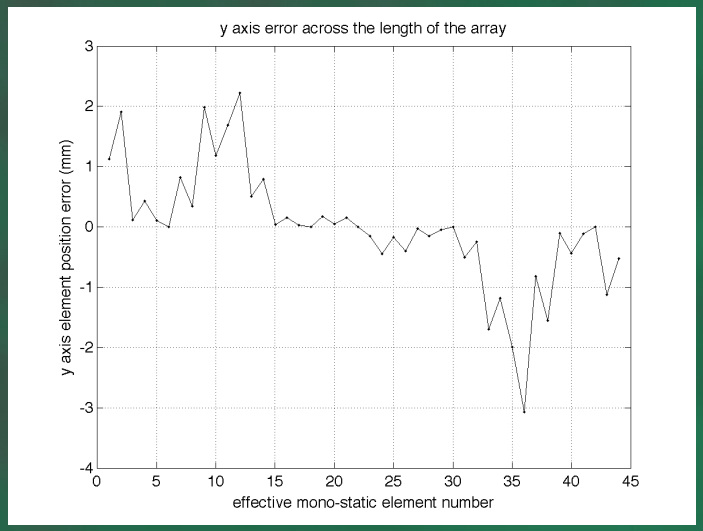
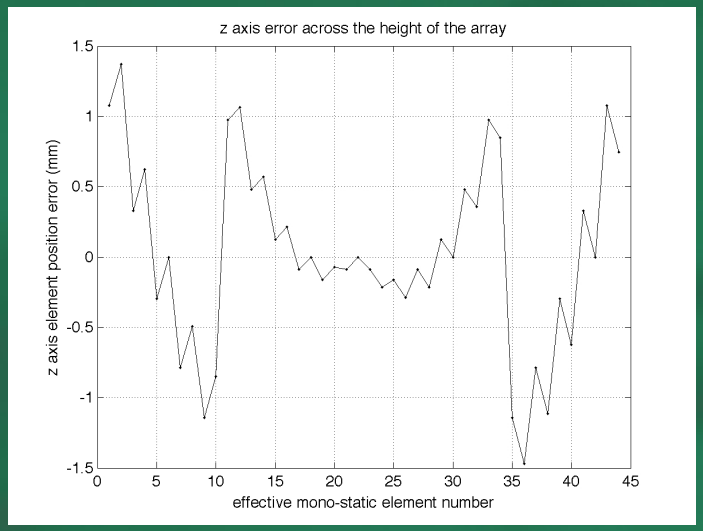
Element Position Errors

y-axis error



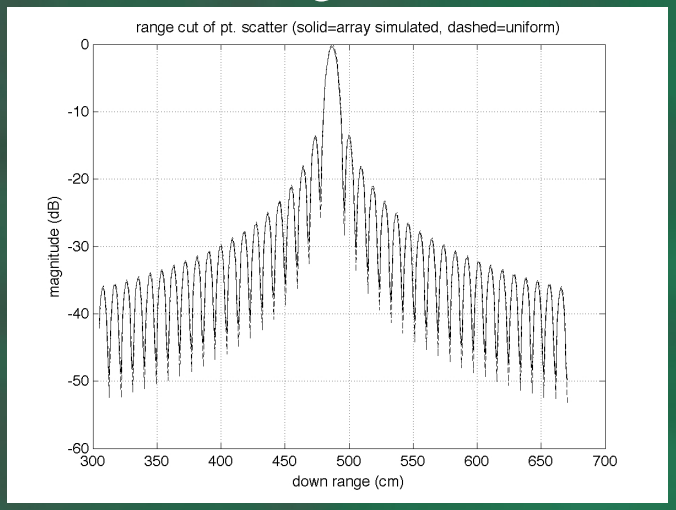
z-axis error



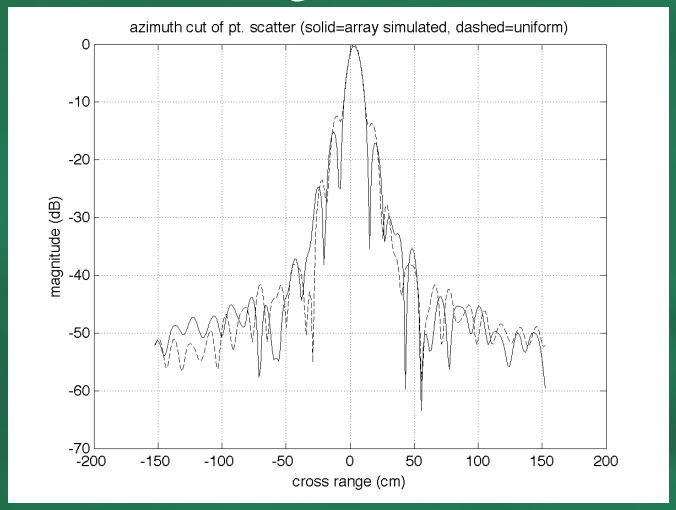
- Simulated point target at: (x,y,z) = (484.2, 113.3, 14.6) cm
- y phase center error from ideal = 3 mm max
- z phase center error from ideal = 1.5 mm max
- $\lambda/2$ = 5 cm => acceptable phase center errors from ideal

Simulated Sidelobe Performance

down-range sidelobes



cross-range sidelobes



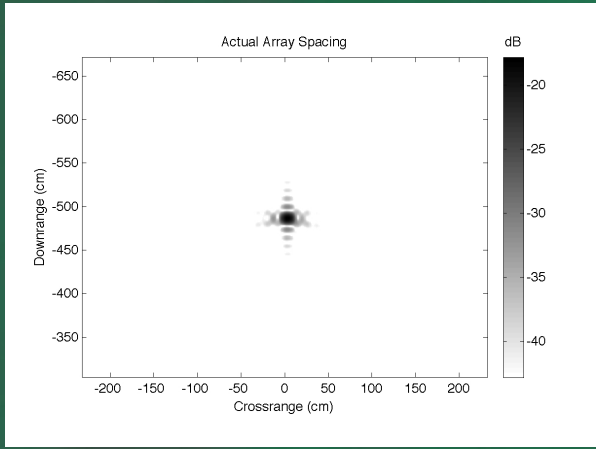
- Simulated point target at: (x,y,z) = (484.2, 113.3, 14.6) cm
- Imaged using RMA SAR algorithm
  - Near-field beamforming, accounts for wavefront curvature
- 0.5 dB reduction in signal
- Range sidelobes nearly identical
- Close-in cross-range sidelobes reduced by 2 dB
  - slight element randomization

Implementation

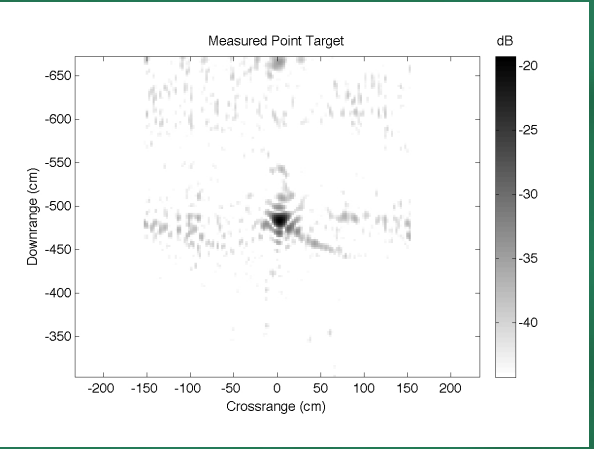
- LFM, 1.926-4.069 GHz in 2.5-10 ms (adjustable)
- 1 mw peak TX power, 20 Hz PRF (software limited)
- 0.5 Hz imaging rate
- 8.75 ns, 17.5 ns, or 35 ns range gate

Simulated vs. Measured

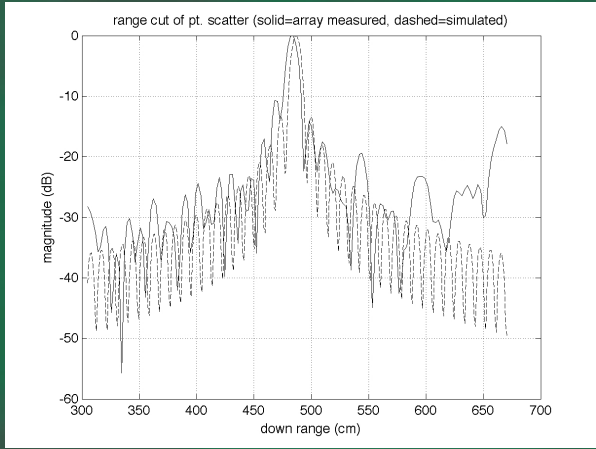
simulated



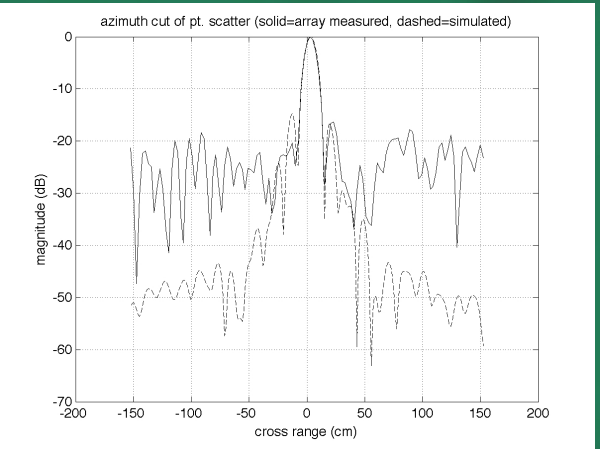
measured



down-range sidelobes



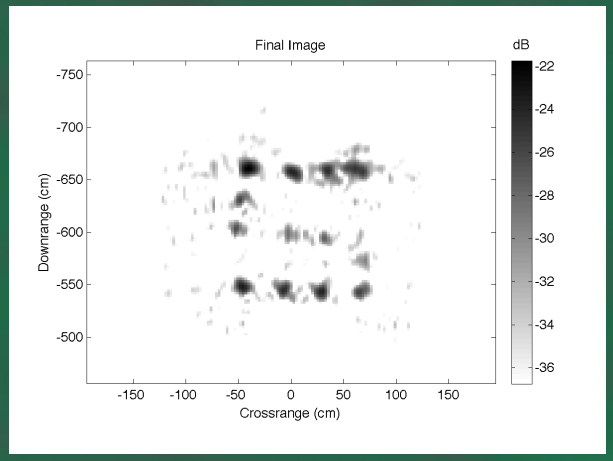
cross-range sidelobes



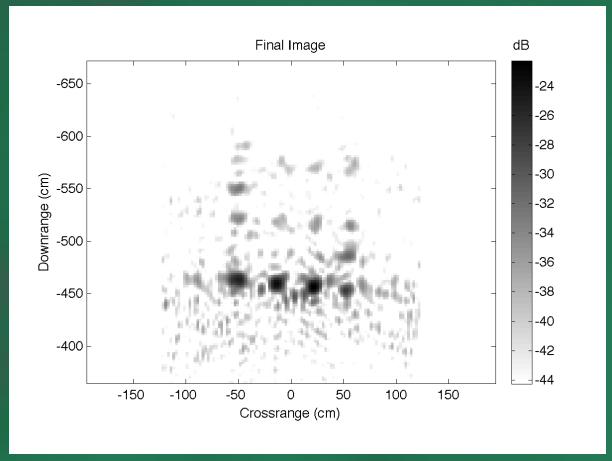
elevated far-out cross-range sidelobes likely due to switch/cable coupling

Point Target Imagery

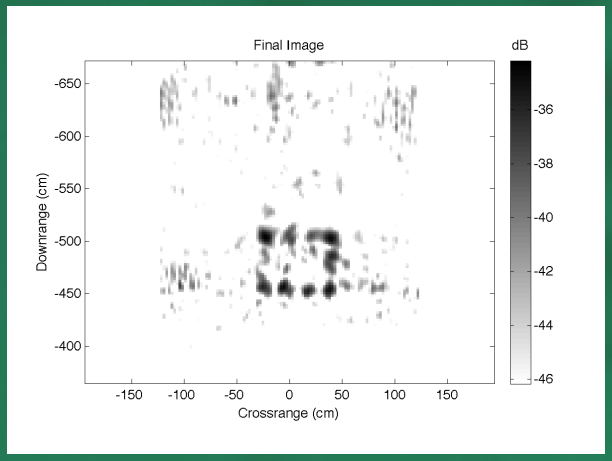
6” carriage bolts



2” nails



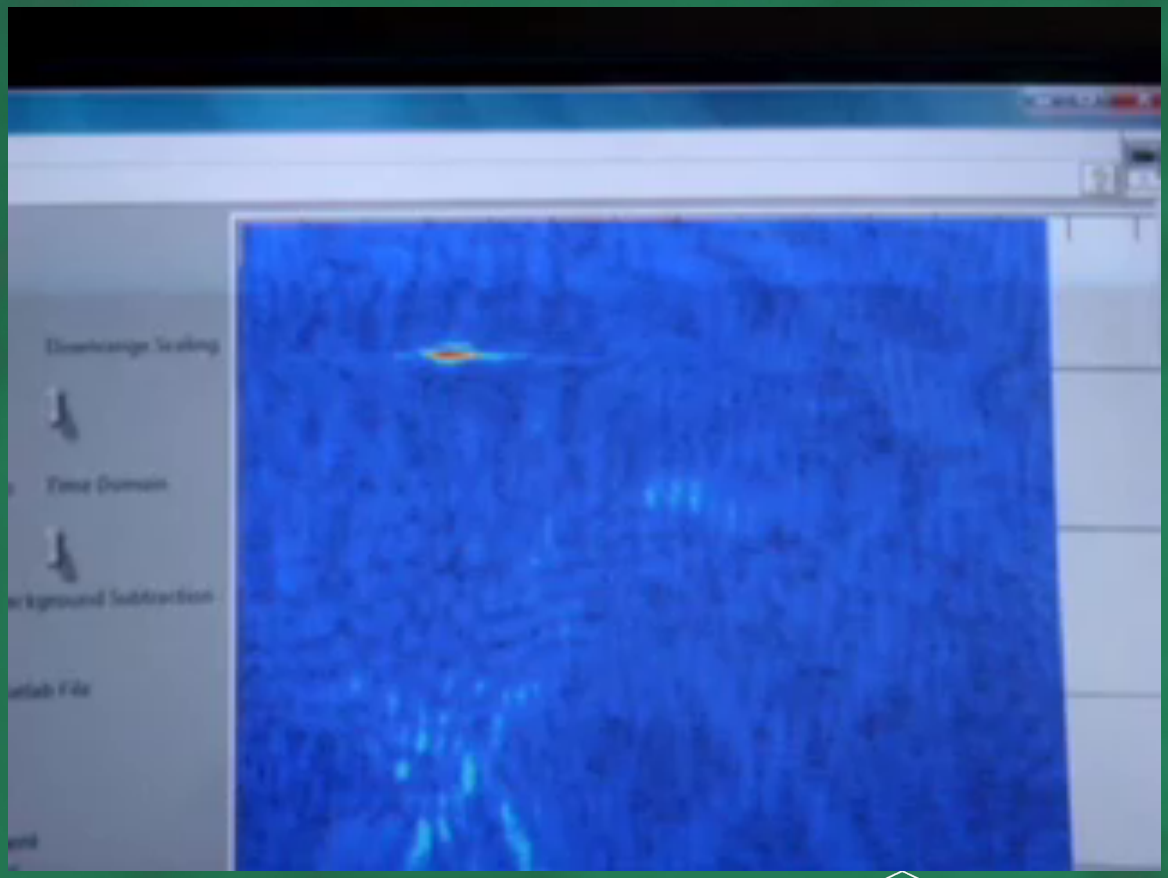
1.25” nails



- Target scenes consisting of point targets
- Location of each point target shown
  - top row of 1.25” nails fading into noise

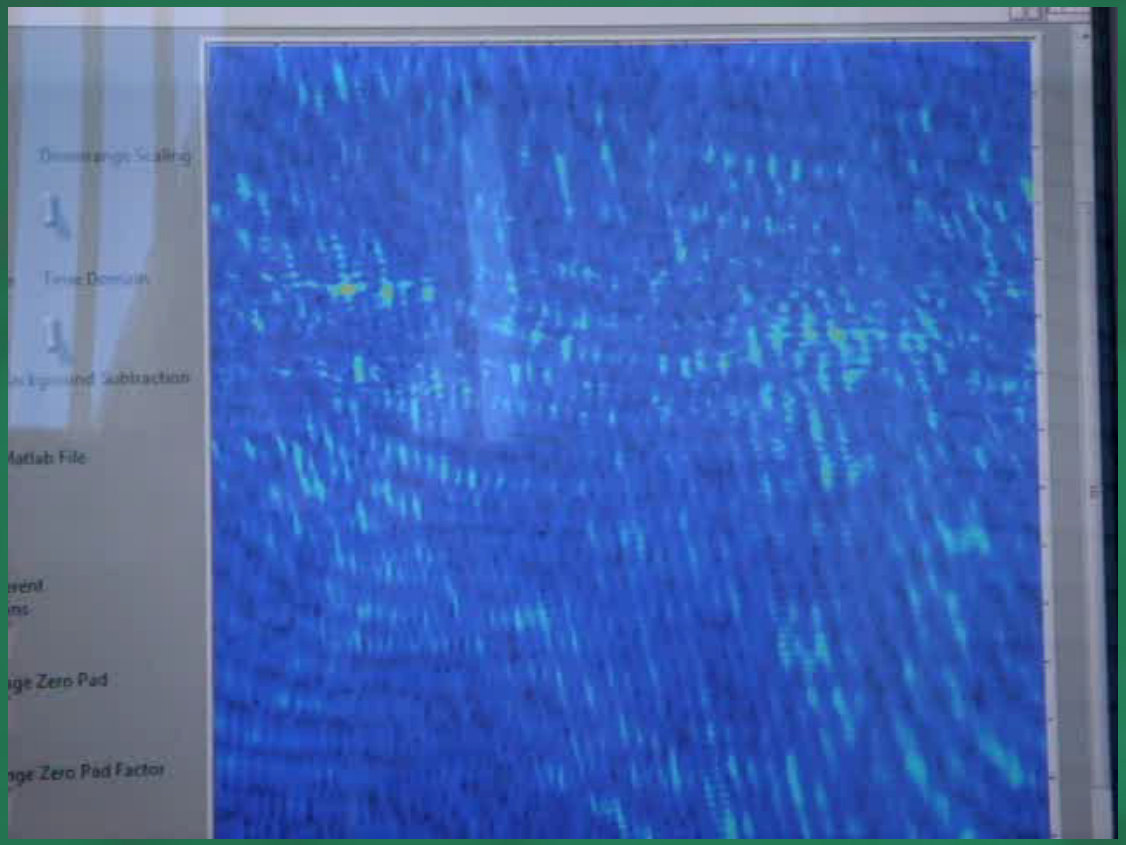
Near Real-Time Imagery (free-space)

- 12 oz soda can
- 0.5 Hz imaging rate
- Location clearly shown



Near Real-Time Imagery (thru-slab)

- 12 oz soda can thru a 10 cm thick solid concrete slab
- 0.5 Hz imaging rate
- Location clearly shown



Summary

- Near-field phased array as a method for reducing data acquisition time of thru-slab rail SAR
  - 20 min to < 2 seconds achieved
- Measurements agree with simulation
- Point target scenes imaged
- 0.5 Hz near real-time imagery shown
- *Future work: video frame-rate imaging*