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Propagation Model for FINDER Radar

Presented by

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Clarksville, Tenn., May 6, 2003-- A home near Clarksville Tennessee is destroyed when hit by a tornado. Photo by Mark Wolfe/FEMA News Photo

Introduction

FINDER – Finding Individuals in Disaster and Emergency Response

Motivation - Finding persons still alive in piles of rubble, following an earthquake, a severe storm, or other disaster is a difficult problem (photo on beginning slide)

Team - This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology -

- Manager (PI) – James Lux
- Hardware design – Salman Haque, Richard Ohanian
- Software design - Hirad Ghaemi, Mike McKee
- Antenna design - Luis Amaro
- EM simulation – Vaughn Cable

Sponsor – Funding provided by the Department of Homeland Security, Science and Technology Directorate

Topics

Radar Approach
Lab Experiments Prototype
Field Testing Rubble Models
FDTD Results

Radar Configuration

CW Radar -

- Selected CW radar - simplest (e.g., police radar)
- ~3 GHz gives sufficient transparency of rubble

Processing -

- Consistent (periodic) motion of heart & lungs causes detectable phase shifts
- Can "see" multiple heartbeats

Antennas -

- Single transmit & multiple receive antennas allow 1st order spatial discrimination
- Both H & V polarizations are useful

Portability -

- Single package (suitcase)
- 12 hour battery pack

The Radar

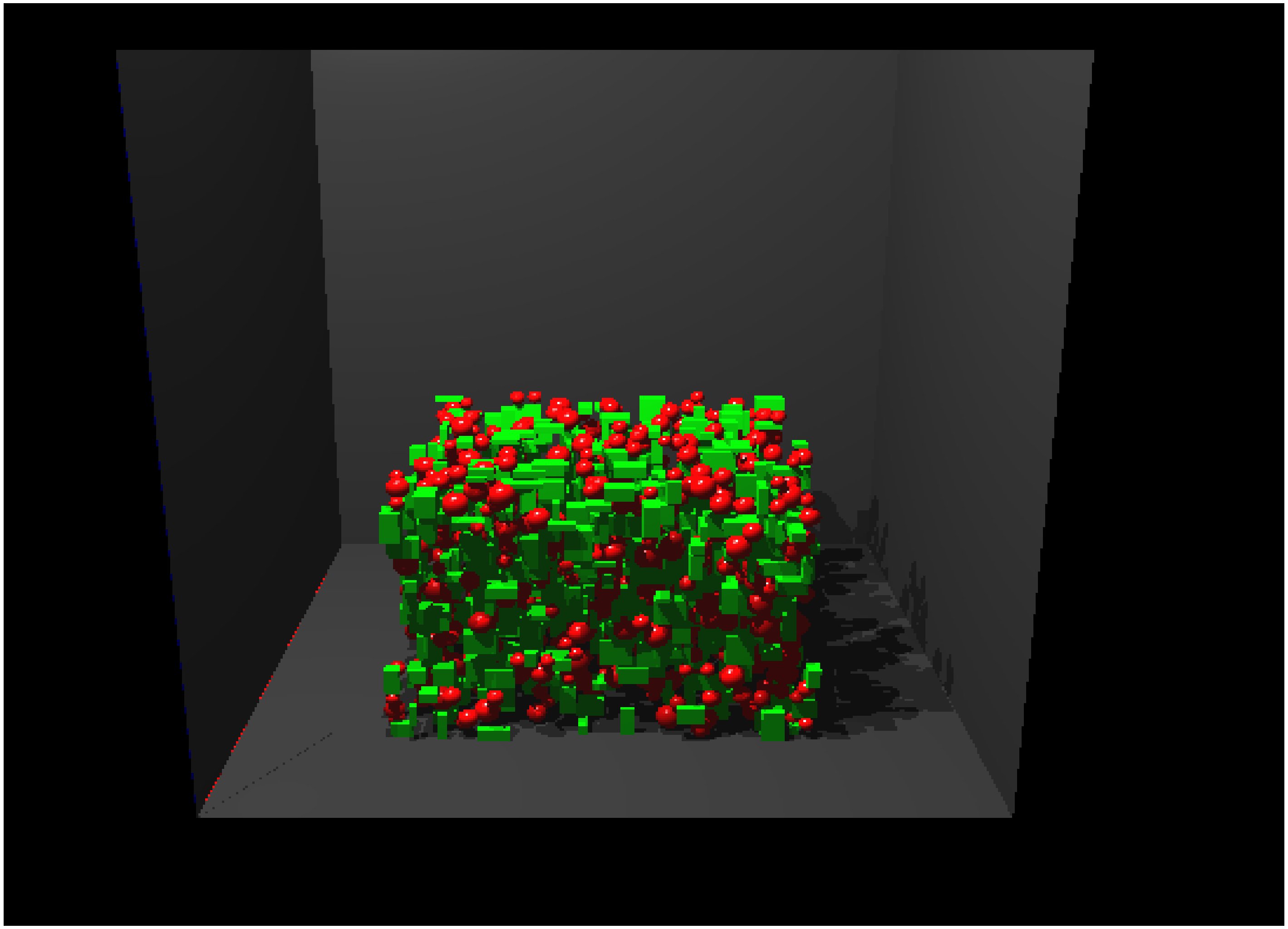
At the Virginia Task Force 1
Training Site in Lorton, VA

Rubble Models

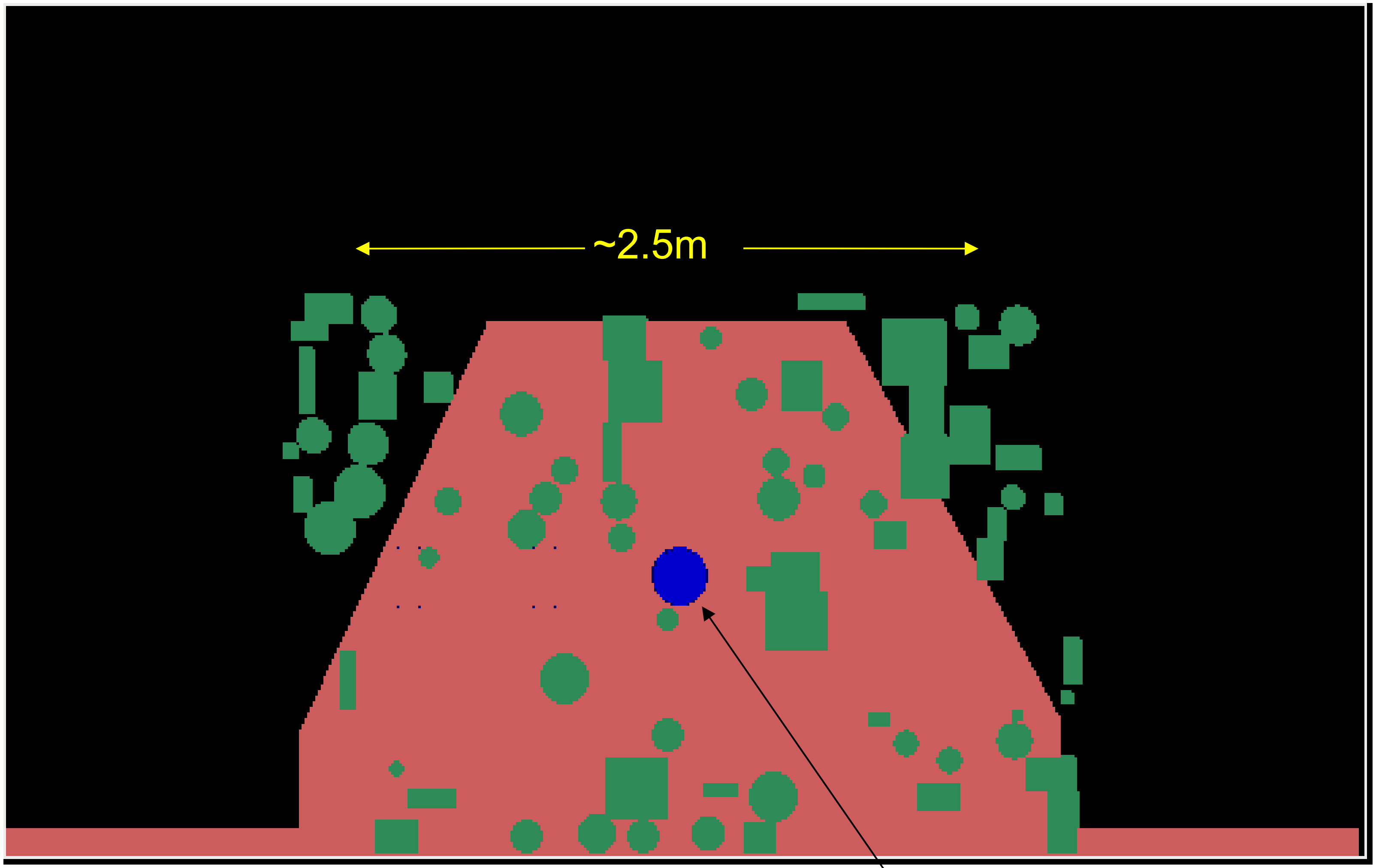
Prototype Field Tests

- Outside on real rubble
- Typical range of detection was ~25' in rubble & 100' in free space
- Rebar does not matter – just scatters more
- 4”x4” metal mesh does not matter (λ = 5-10cm)
- Spurious target processing is yet to be implemented
  - Targets behind or next to the radar, with the propagation reflecting off the rubble

Rubble Numerical Model

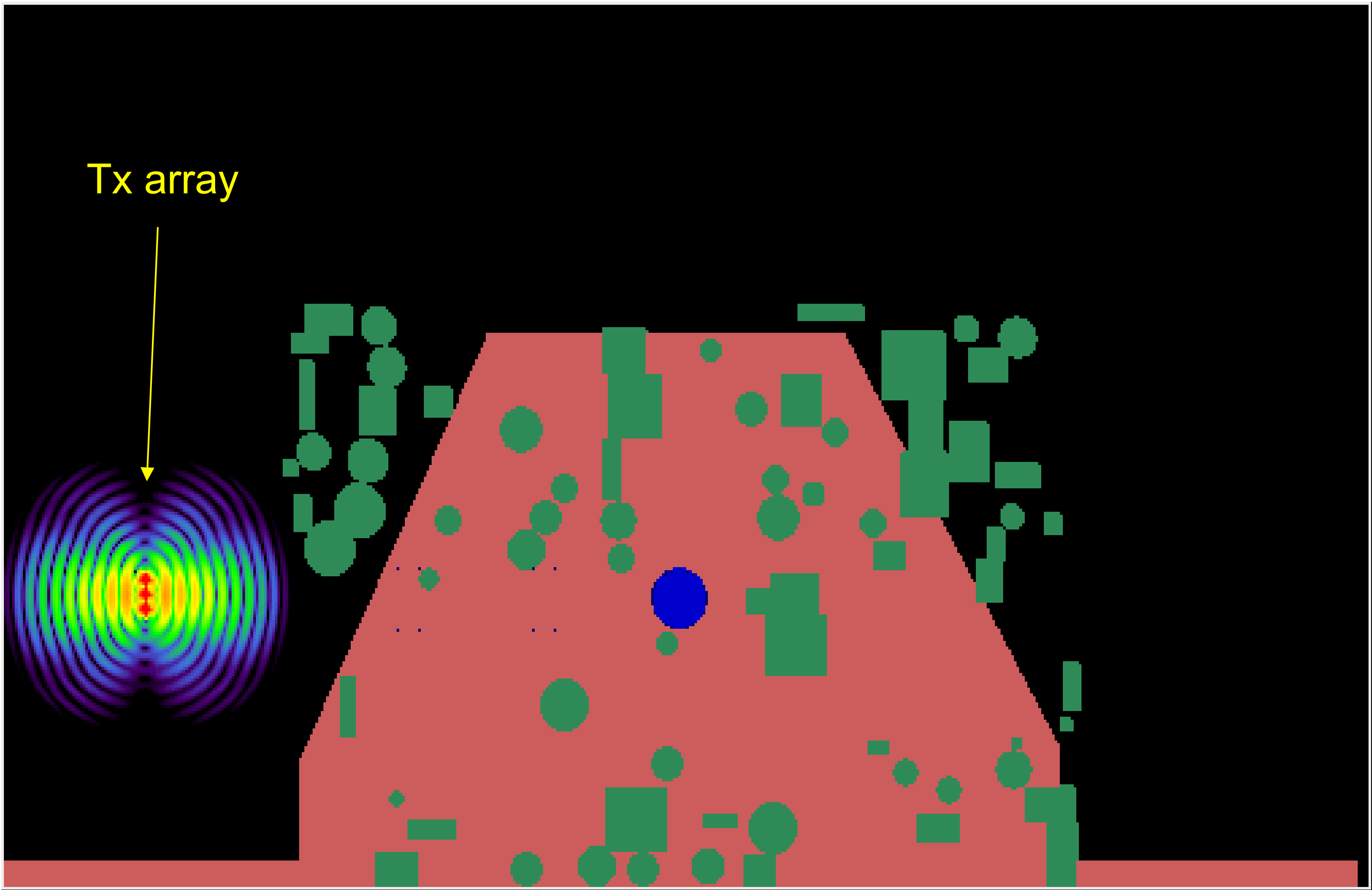


3D FDTD
500x500x300 cell Model
Lossy Dielectrics

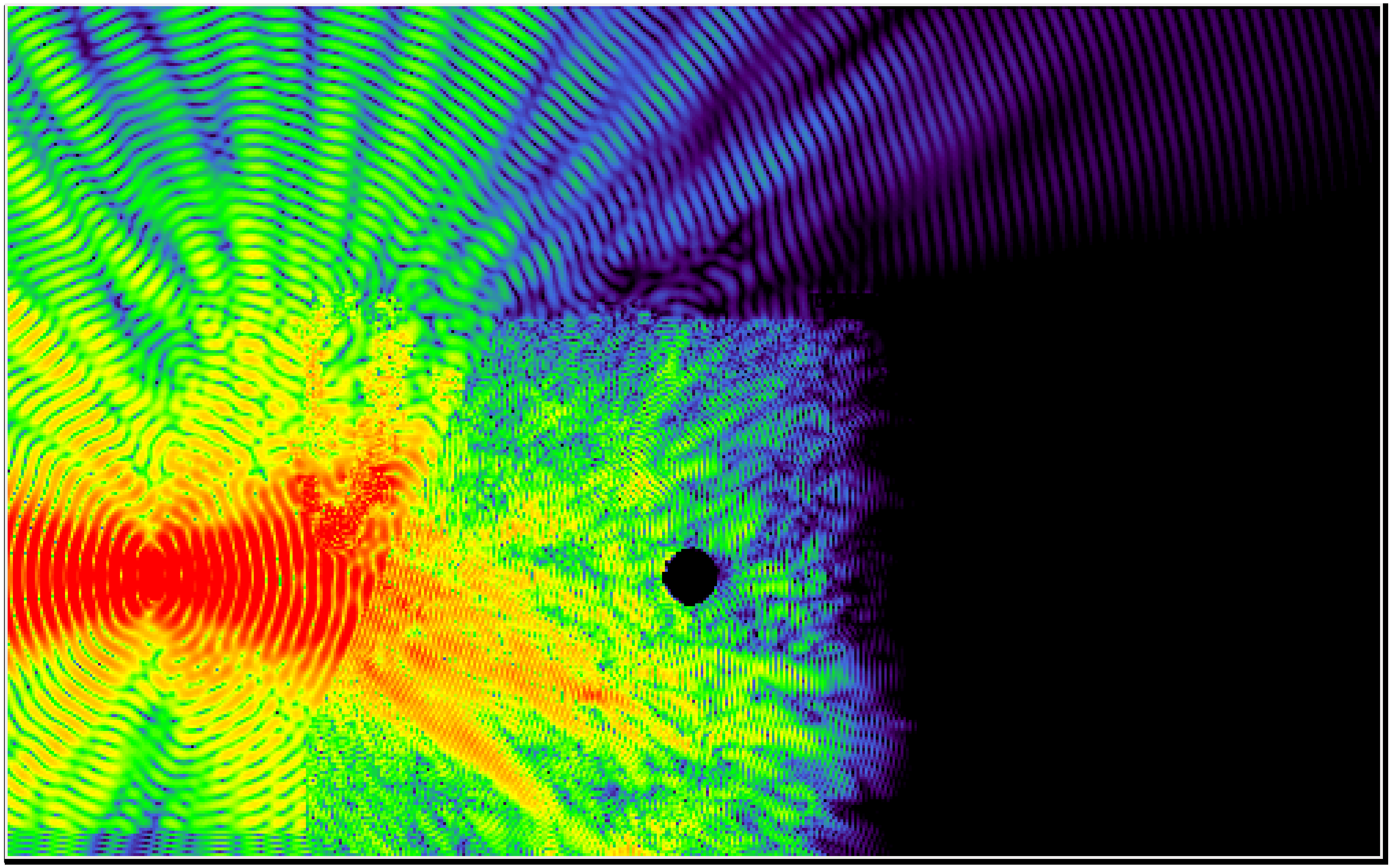


20 cm sphere (saltwater)

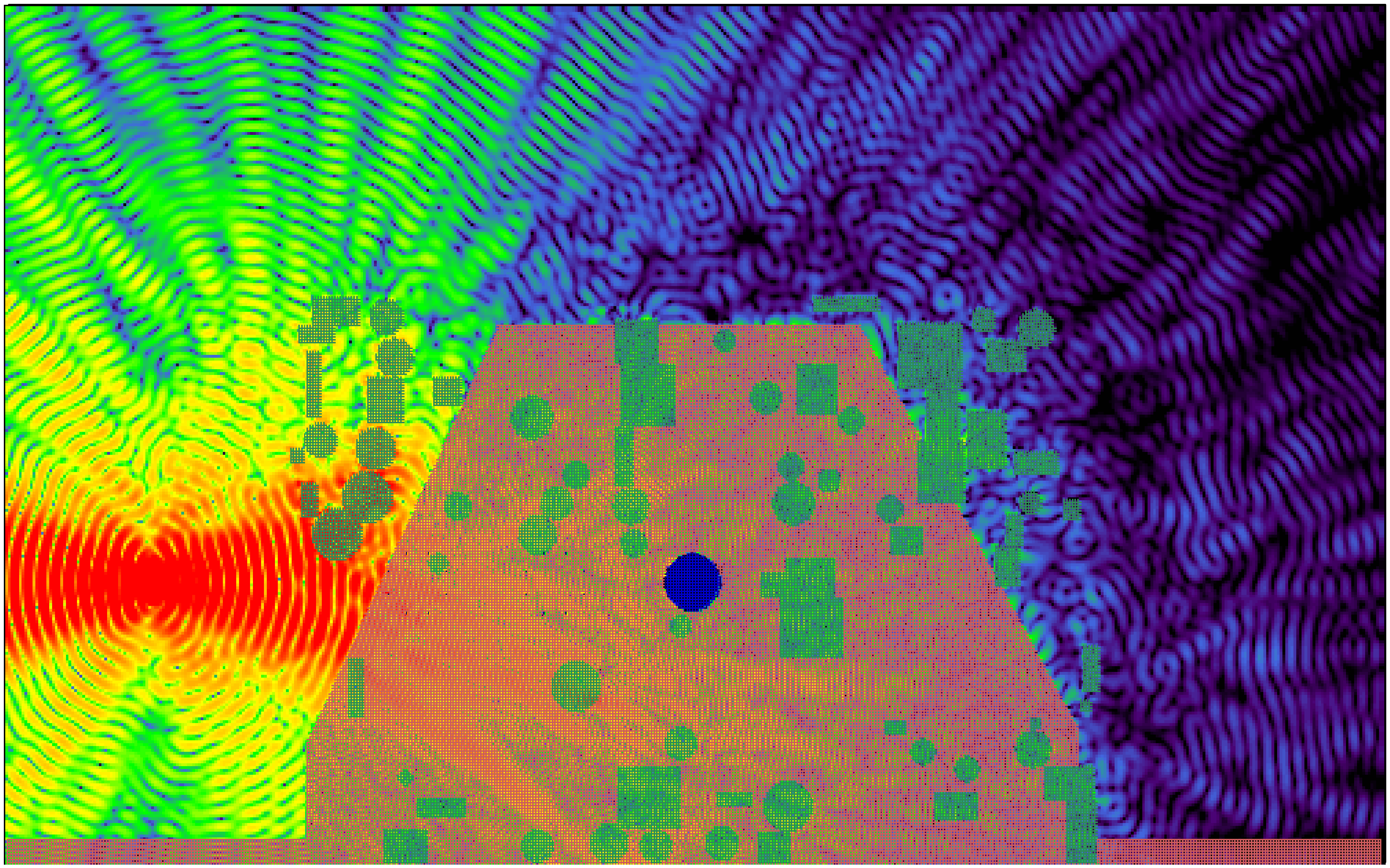
3D FDTD Excitation
3x3 broadside V-pol array at 3 GHz
Timestep 100 with 19.3 psec/step



FDTD Run
Timestep 1200
Dielectrics hidden



FDTD Run
Timestep 5000 (~SS)
Dielectrics visible

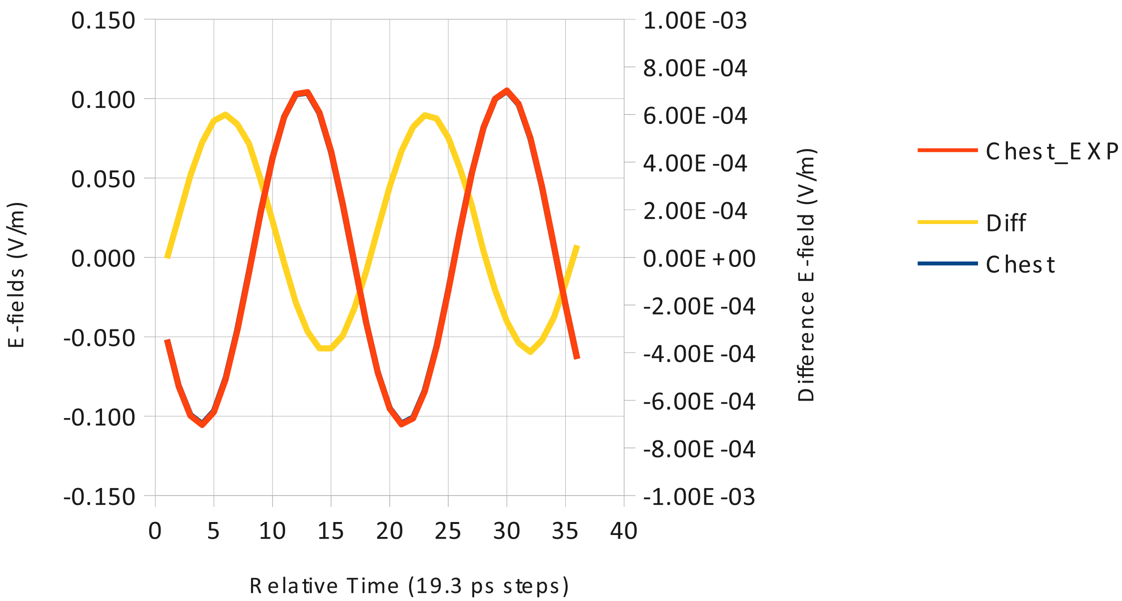


Simulated Measurement of Phase

Difference Between Received CW Radar Signals

CW Radar Received E-fields

E_{chest}, E_{chest_EXP}, & Difference field



$E_{chest}=0.1\sin(\omega t)$
$E_{chest\_EXP}=0.1\sin(\omega t-\Psi)$
Ψ=phase shift induced by expansion (EXP) of chest model

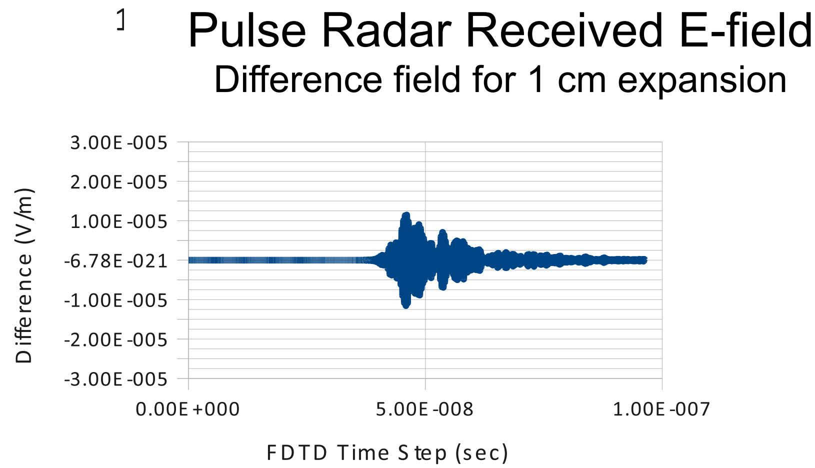
$Diff=\sin(\omega t)-\sin(\omega t-\Psi)\approx\Psi\cos(\omega t)$

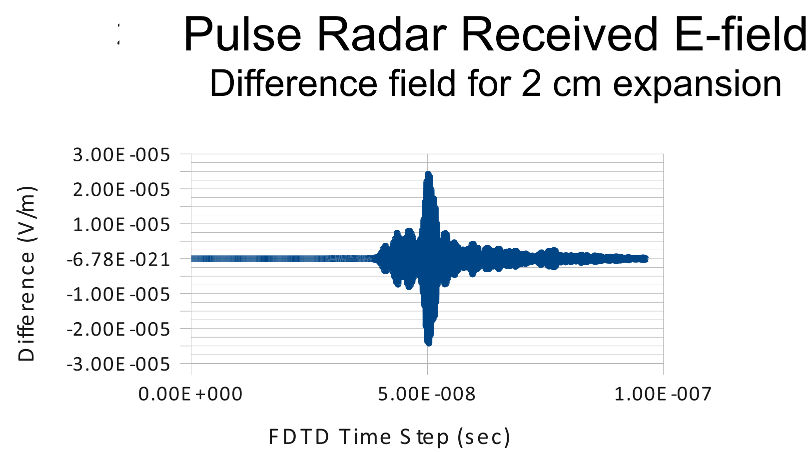
where phase shift Ψ is small, so Ψ modulates the amplitude of $\cos(\omega t)$.

In this case, the perceived phase shift is ~0.34 deg for a 2 cm expansion of 20 cm dia sphere.

Note, here, Ψ is too small to see on this time scale so E_{chest_EXP} hides E_{chest} .

Simulated Measurement of Phase
Difference Between Received Pulse Radar Signals





In this case, the received pulse is a sine wave "windowed" by a Gaussian pulse, so we again have

$$\text{Diff}=\{E_{chest}- E_{chest\_EXP}\}\approx\Psi\cos(\omega t)$$

where phase shift Ψ is small.

Here, we see the perceived phase (amplitude) has doubled for double the sphere expansion for a 20 cm (dia) sphere.

Conclusions

- First Prototype (Mark 1) completed and tested with real rubble.
- Target phase shifts modeled & verified with FDTD
- Design in progress for smaller RF modules
- Software improvements in progress
- More performance testing at outdoor sites