Target & Propagation Models for the FINDER Radar

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***Abstract*— Finding persons still alive in piles of rubble following an earthquake, a severe storm, or other disaster is a difficult problem. JPL is currently developing a victim detection radar called FINDER (Finding Individuals in Emergency and Response). The subject of this paper is directed toward development of propagation & target models needed for simulation & testing of such a system. These models are both physical (real rubble piles) and numerical. Early results from the numerical modeling phase show spatial and temporal spreading characteristics when signals are passed through a randomly mixed rubble pile.**

I. Introduction

Finding persons still alive in piles of rubble following an earthquake, a severe storm, or other disaster is an ongoing problem. JPL is currently investigating various implementations for finding victims, including the FINDER (Finding Individuals in Emergency and Response), a 3 GHz CW FM radar for detection of heartbeat and lung action. Development of appropriate propagation & target models for simulation & testing of such systems is also part of the project. These models are both real (physical rubble piles) and numerical. Early numerical results show that with and without simulated victims present distinct differences are not always present, a somewhat unexpected characteristic for backscatter signals from and propagation through randomly mixed rubble pile.

II. Victim Models

A physical model of the simulated victim has been created for laboratory & field tests. The exterior of the model is an adult size neoprene wet suit "stuffed" with vacuum packed vinyl bags holding a mixture of shredded polyethylene and salt water with ε_r (relative epsilon) of ~50 and σ (sigma) of ~1S/m. Two air filled bladders simulate the lungs and hear, with solenoid valves controlling the inflation and deflation in a realistic pattern. This anthropomorphic phantom has RF properties that mimic those of a human, particularly with respect to the small scale movements of the chest wall.

The initial victim model for the numerical simulation is a ~20 cm diameter sphere representing the chest-lung object with the same ε_r of ~50.0 and σ of ~1.0 S/m.

III. Rubble Models

Figure 1 shows an example of the true complexity and randomness of the rubble we are attempting to simulate. The important requirement on our physical model is that reflection and propagation characteristics be constant with time for every configuration.

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

Figure 1. Real rubble pile from a tornado disaster

A rubble model was created for numerical simulations with FDTD by dropping random, non-overlapping blocks and spheres into a virtual box. The box can then be "flooded" with simulated sand, dirt or mud. Figure 2 shows a 500x500x300 cell box partly filled with the spheres and blocks (200-300 cells deep).

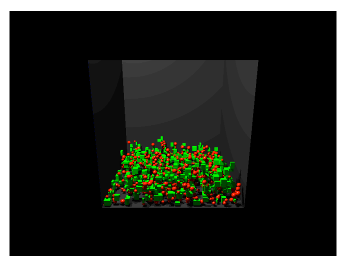

Figure 2. Complex rubble pile for numerical simulations

IV. FDTD Numerical Simulations

The above discretized models, including the random pile with ε_r=7.0 σ=0.005 S/m and spherical chest-lung model with ε_r=50.0 σ=1.0 S/m, form the 3D cubic mesh processed by FDTD. The following data are based on 6.4 ps timesteps and 3.33 mm cell size and FDTD excitation was supplied by a 3 GHz ~1 ns modulated Gaussian pulse.

A. Beam Spreading

Figure 3 shows a series of images of the FDTD pulse at 3 different stages as it passes through the pile. The source field in this case is radiated by a 3x3 array of vertical dipoles. Just for reference in these images, the rubble pile is superimposed in the 1st and 3rd stages. Note, the 2nd image shows the pulse inside the pile as well as reflected pulse from the face.

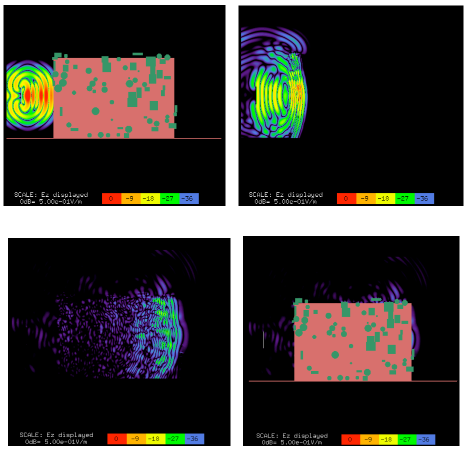

Figure 3. Pulse passing through pile; elapsed time (left-to-right) 25.6 ps, 57.6 ps, and 173 ps (both with and without pile).

These results illustrate the fragmentation and spreading that occurs to the original radar beam due the "random" medium. This effect may end up setting a limit on how narrow the beam can be and, hence, this investigation will analyze not just a single beam with range resolution (like a traditional radar), but multiple beams (targets where the beams cross).

B. Pulse Spreading

While Figure 3 (2nd image) shows the pulse as "compressed" inside the pile, due of course to the slower phase velocity inside the pile (~1/2 free space velocity), the random, discrete, debris in the pile introduces significant multiple scattering within the pile. This produces multipath that, in effect, stretches the pulse as it passes through the pile. Figure 4 shows the E_z (vertical pol) field vs time (ns) for the pulse after passing through 16.7 cm of the pile (green) and the pulse after passing through 100 cm of the pile (red). Note, the first portion of each case is the pulse of interest, whereas, the second portion (pulse) in each case is the array groundplane reflection. This qualitative comparison shows the red

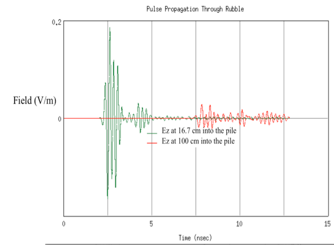

Figure 4. Pulse is stretched by multiple scattering.

pulse being stretched by a factor of ~1.3.

C. Chest-Lung Response

An example of a pulse arriving at the target (spherical chest-lung object) and the reflection emerging from the pile are illustrated in Figure 5.

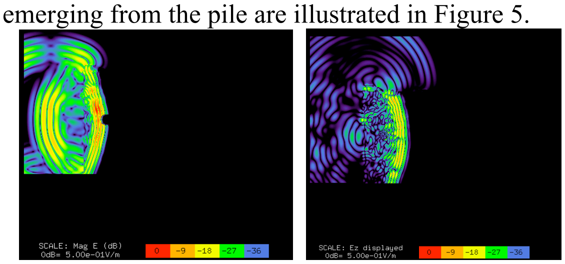

Figure 5. Pulse arriving and eventual reflection emerging from pile.

Figure 6 shows the chest-lung reflection arriving back at the radar.

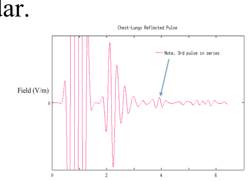

Figure 6. Reflected pulse from chest-lung object arriving at radar.

D. Comments on Simulations

Both spreading factors limit the accuracy with which we can locate the victim with a single antenna. For example, if a very narrow pencil beam is used, the beam spreads rapidly and doesn't provide good location information, so some other technique must be used, possibly a multiple beam configuration.

The random nature of the medium, on the other hand, stretches the pulse and reduces resolution available for a given pulsewidth. Here, narrowing the pulse further by signal processing (e.g., chirp) may be the answer. Our latest results will be presented in July.

ACKNOWLEDGEMENT

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