Electromagnetic Strategies for Locatable Plastic Pipe

U.S. Department of Transportation
Pipeline and Hazardous Materials
Safety Administration

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Main Objective

Plastic utilities pipes are difficult to locate with traditional detection systems. This research seeks to study two approaches for intrinsically detectable plastic pipe. The first approach is to impregnate the plastic with microencapsulated magnetic materials.. The second approach is to develop multilayer pipe that has an intrinsic response to RFID, which would allow the pipe to carry data about its contents and surrounding pipes.

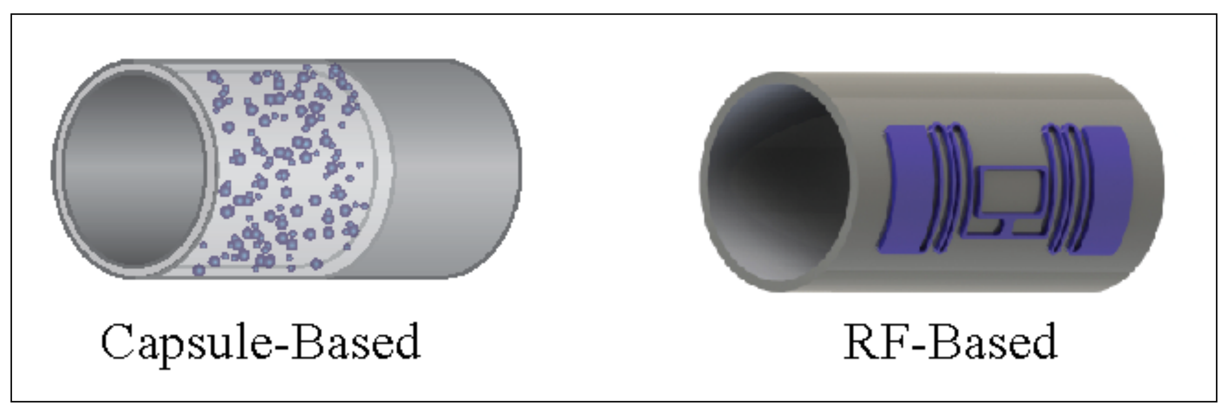

Figure 1: Schematics of the capsule-based approach (left) and RF-based approach (right).

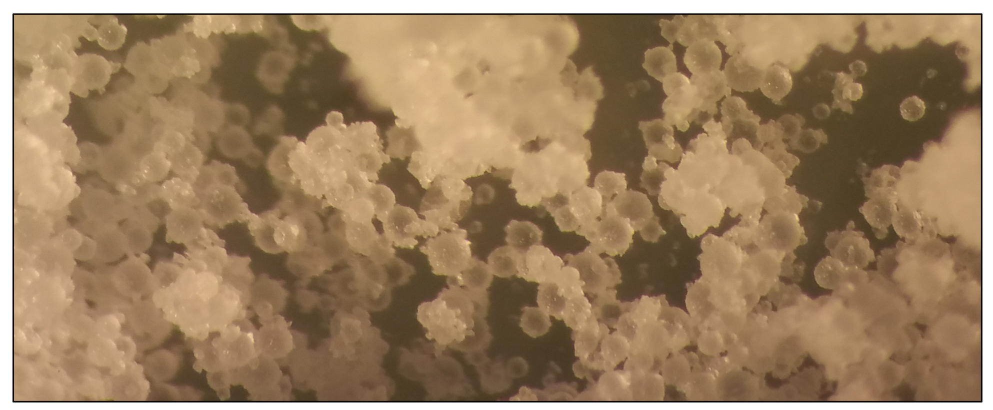

Figure 2: Microcapsules with an approximate diameter of 100 µm.

Project Approach and Scope

Samples of polyethylene compounded with metal flake or magnetic microcapsules will be tested for material properties and electromagnetic properties. Pipes will also be developed with various radiofrequency identification tags on the surface of the pipes. To test the viability of both methods, a physical simulation will be conducted using polyurethane foam doped with titanium dioxide and graphite to simulate various ground conditions.

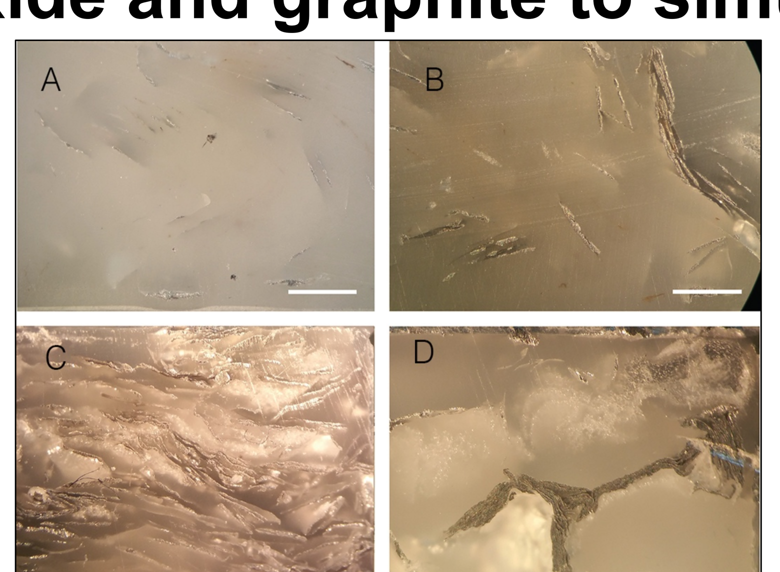

Figure 3: Cross sections of metal flake-polymer mixtures at A) 1.25 wt%, B) 2.5 wt%, C) 10 wt% of flake mixed in melt, D) 10 wt% of flake mixed in compression.

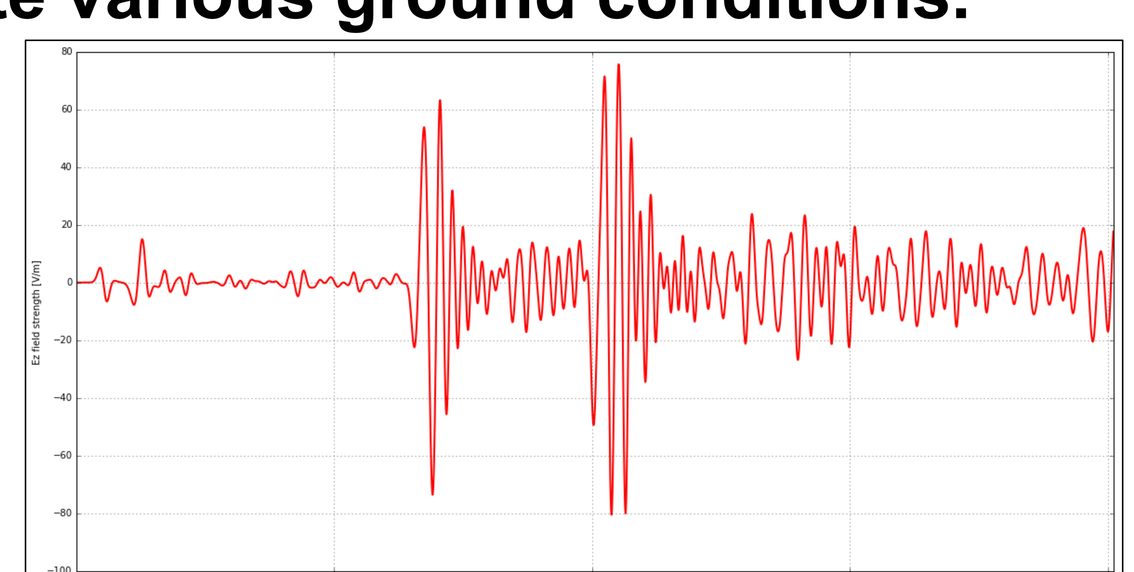

Figure 4: Simulation of A-scan. This indicates what a single frame of the GPR will see varying with Voltage and time.

Expected Results and Results to Date

Material property tests will provide data on how the compounding of magnetic materials affects the behavior of the polyethylene. The magnetic field of the materials will also be tested. A Finite-Difference Time-Domain (FDTD) software from gprMax simulates how Ground Penetrating Radar (GPR) interacts with soil conditions and pipes in order to properly understand conditions quickly before tuning an accurate test bed. Electromagnetic Finite Element Analysis through HFSS verifies FDTD simulations and RFID antenna shapes. Simulations investigating other RF approaches are ongoing.

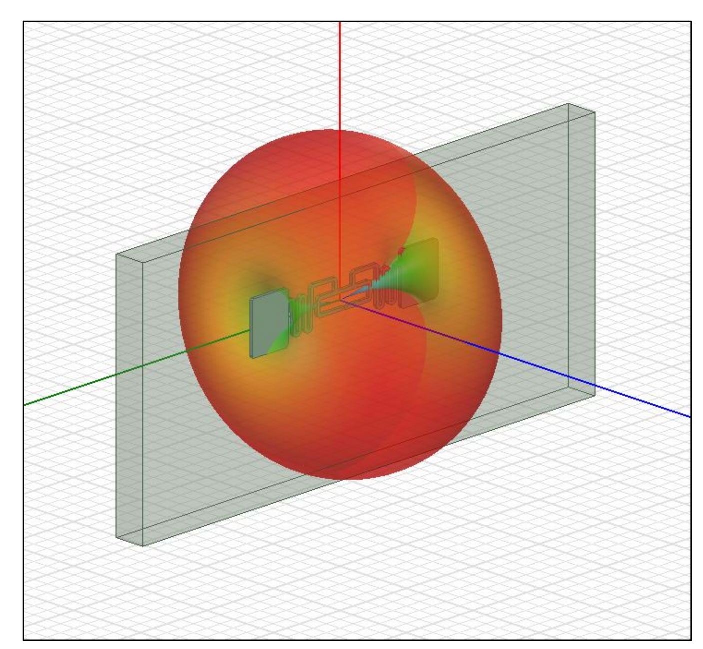

Figure 5: HFSS antenna directivity simulation of RFID tag.

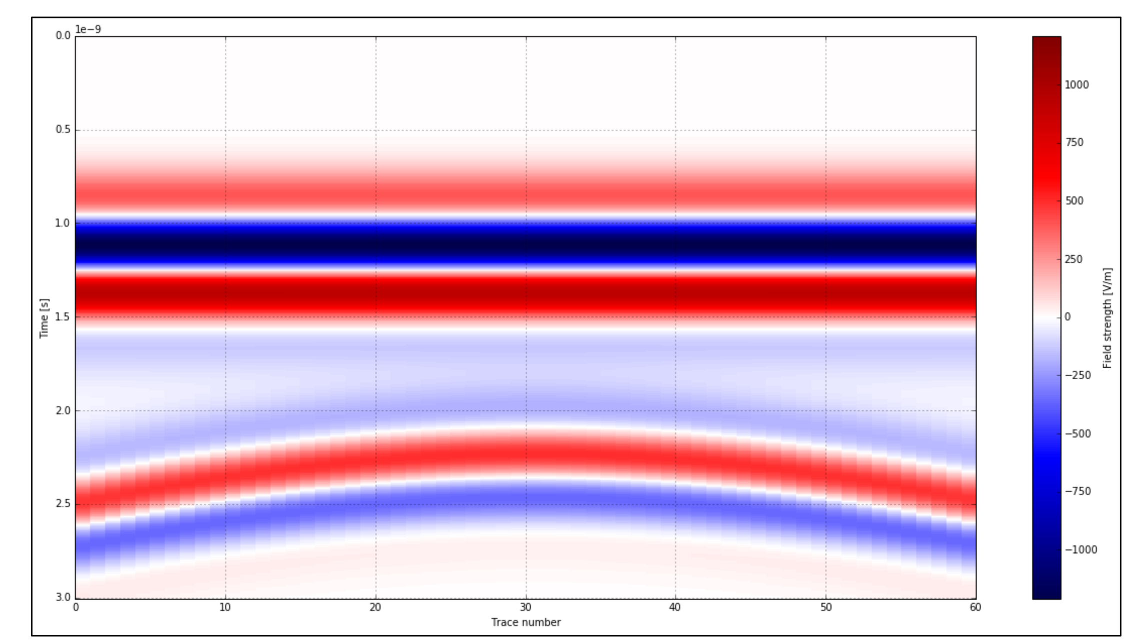

Figure 6: Simulation of B-scan with basic pipe. This indicates what the GPR will see with the gprMax simulation software.

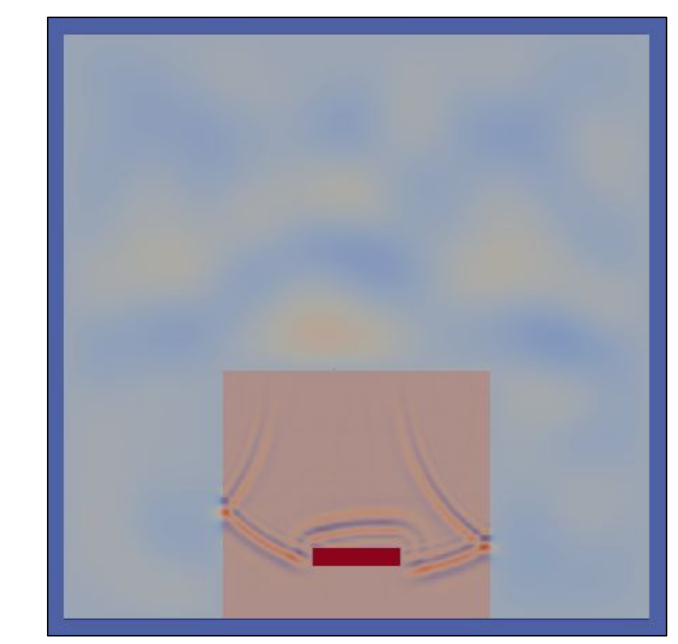

Figure 7: Simulated cross-section of ground with radar pulse bouncing off of plate in a simulated environment.

Acknowledgments

This project is funded by DOT/PHMSA's Competitive Academic Agreement Program.
Other assistance for this project has been provided by Matt Crall and Douglas Jussaume, The University of Tulsa.

References

Warren, C., Giannopoulos, A., & Giannakis I. (2016). gprMax: Open source software to simulate electromagnetic wave propagation for Ground Penetrating Radar, Computer Physics Communications (http://dx.doi.org/10.1016/j.cpc.2016.08.020)

Public Project Page

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