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AN UNBALANCED SINUOUS ANTENNA FOR ULTRA-WIDEBAND POLARIMETRIC GROUND-PENETRATING RADAR

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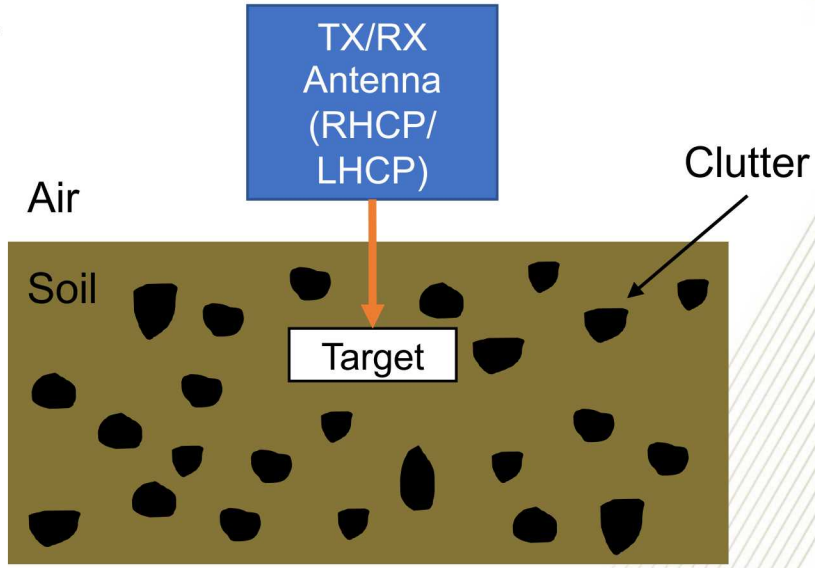
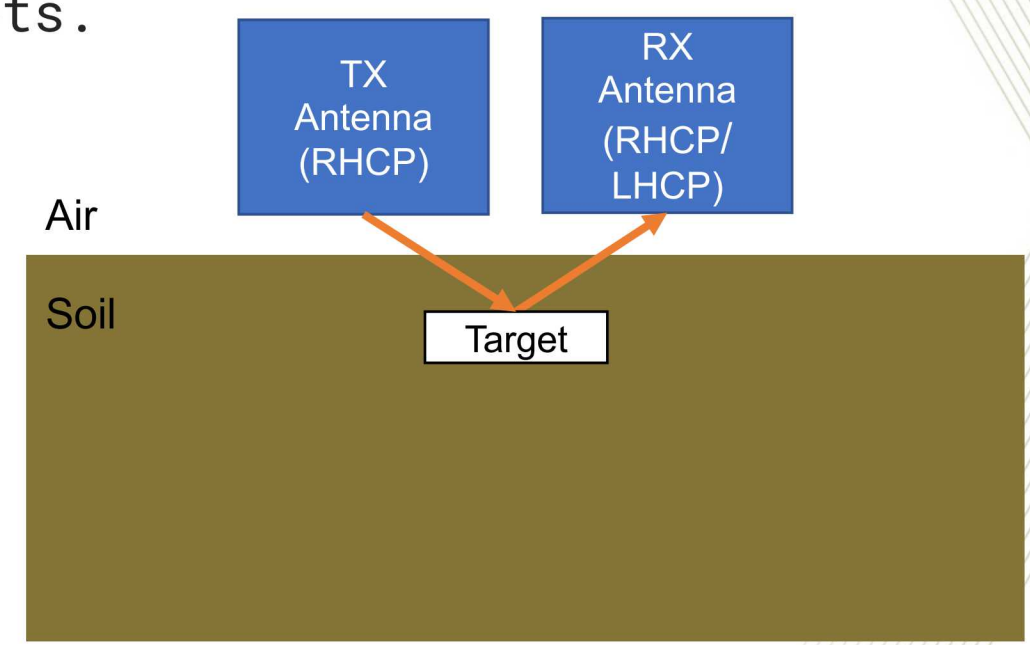
Goal

- Improve the ability to detect and classify near-surface buried targets.
  - Infer target attributes from the received signal.
    - Wide-band processing
    - Polarization
  - Classify targets to discern objects of interest.
    - Discriminate between targets and clutter.
- Develop a practical way to add polarimetric capability to the sensor.
- Desire compact system size.
- Improve system sensitivity.



GPR Antennas

- Most GPR systems are bi-static having separate transmit and receive antennas
  - Better isolation between TX and RX channels.
  - Simpler system design.
  - Extreme angles for near-surface targets.
  - Increased system size and weight.
- Extreme angles degrade:
  - Polarization purity,
  - Pattern uniformity.
- The lack of radiation overlap reduces the sensitivity for close-in targets.
- A monostatic system is desired.



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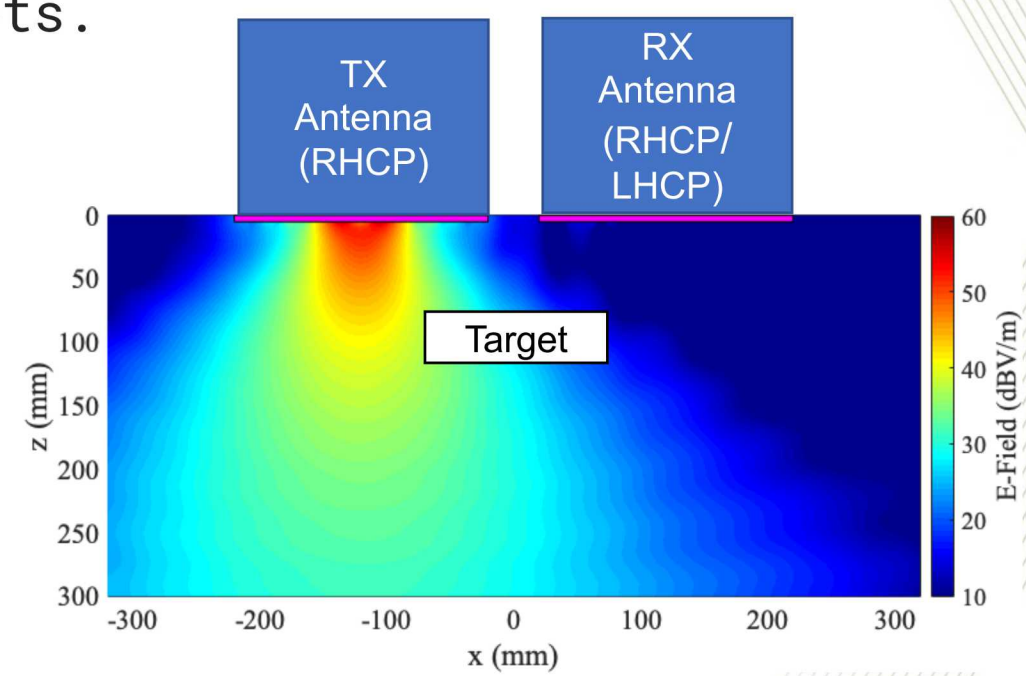

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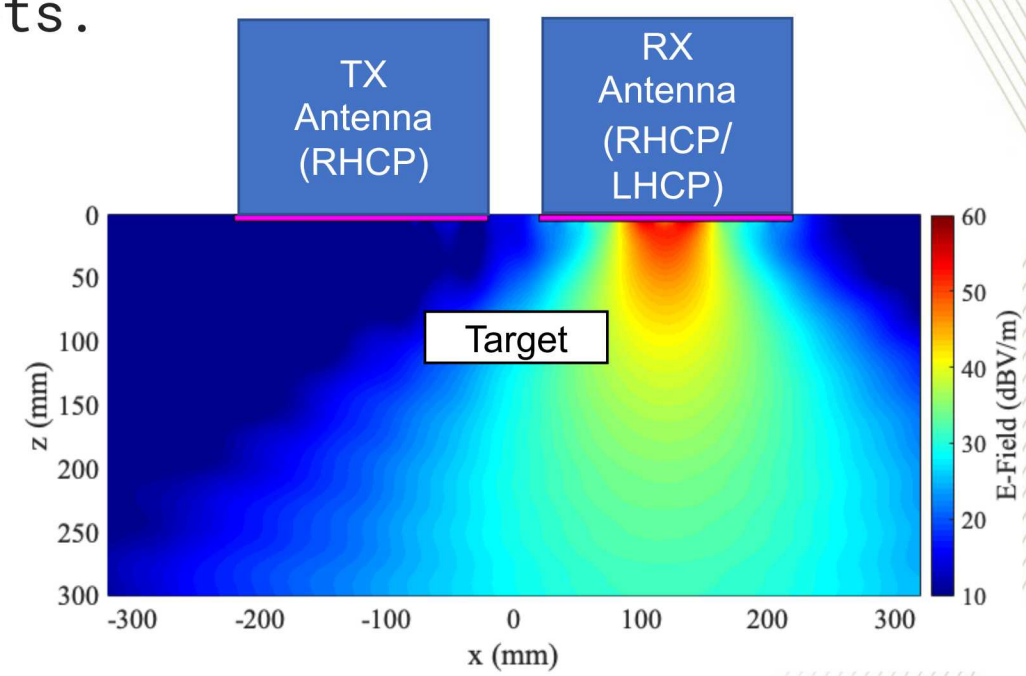

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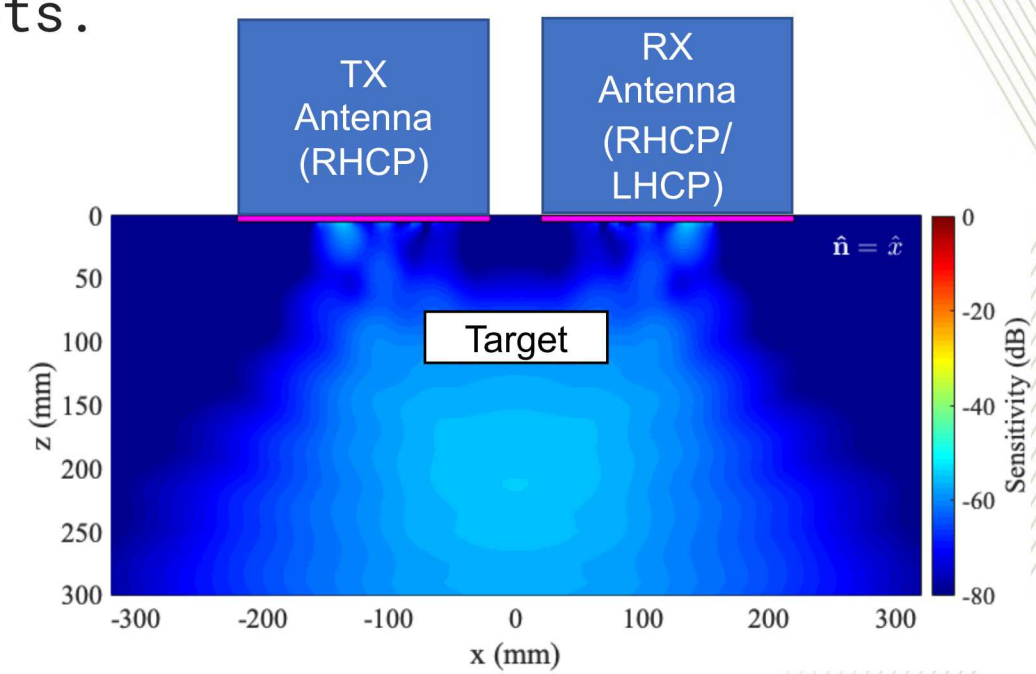

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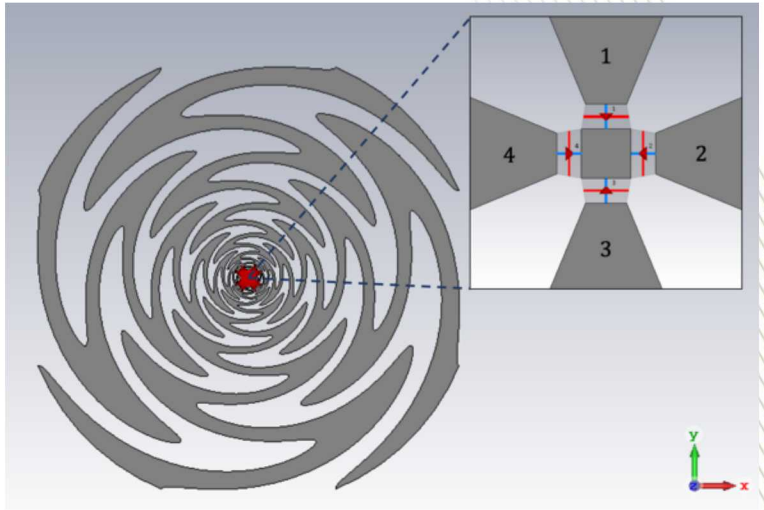
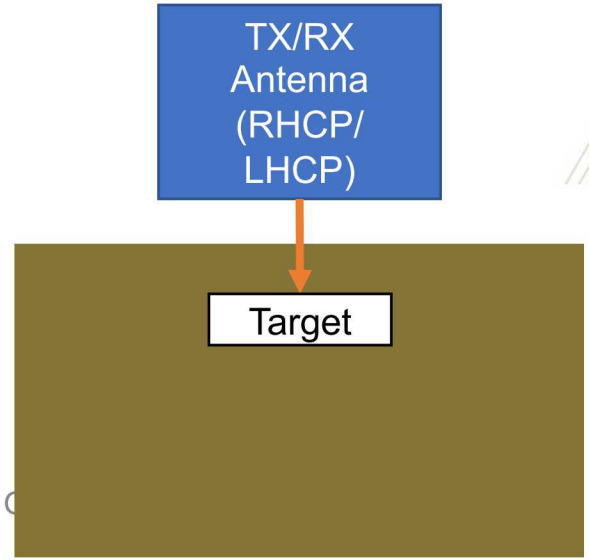
Monostatic Polarimetric Concept

- Independent operation of each sinuous antenna arm resulting in a Quasi-monostatic system.
- Separate transmit and receive channels:
  - $\begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix} = \begin{bmatrix} S_{31} & S_{32} \\ S_{41} & S_{42} \end{bmatrix}$
- Monostatic operation is desired.
  - Better angles give:
    - Good polarization,
    - Better pattern uniformity.
  - The system may be more difficult to design.
  - Reduced isolation between TX and RX.





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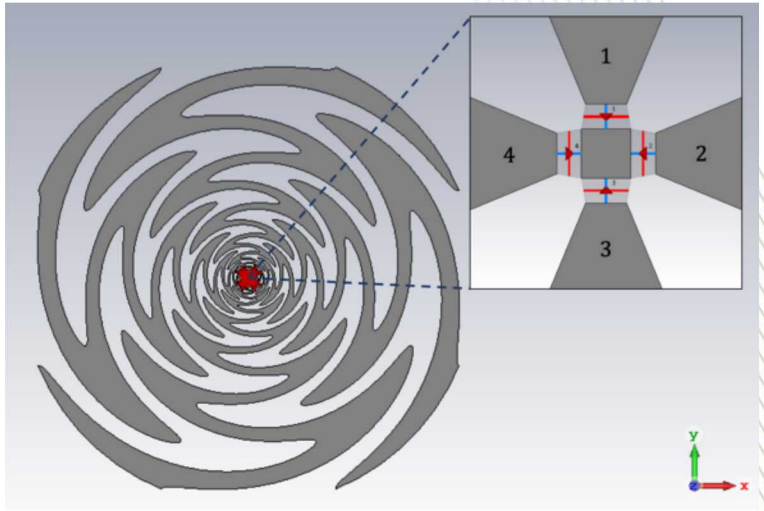
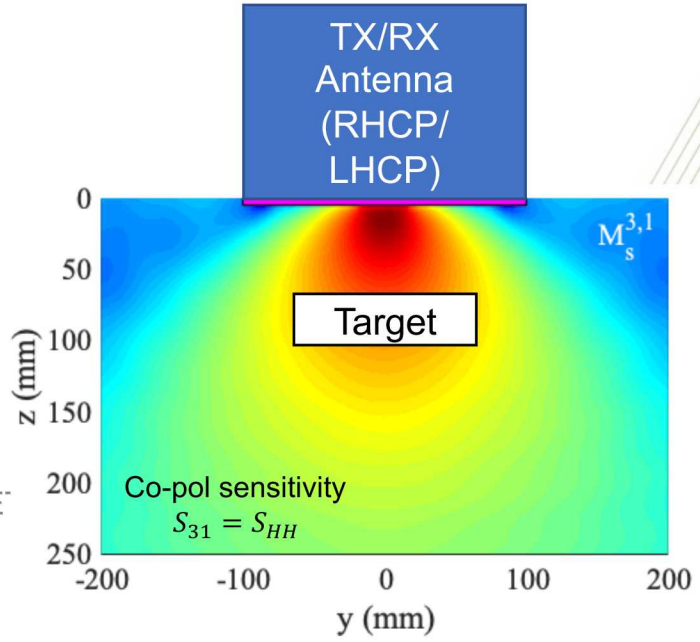
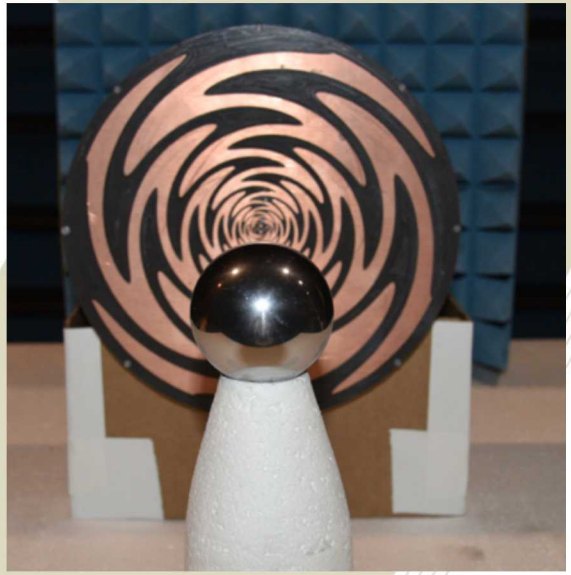
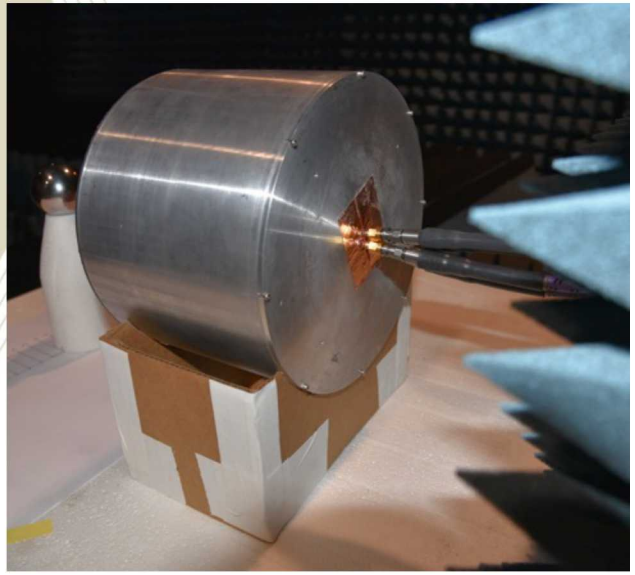




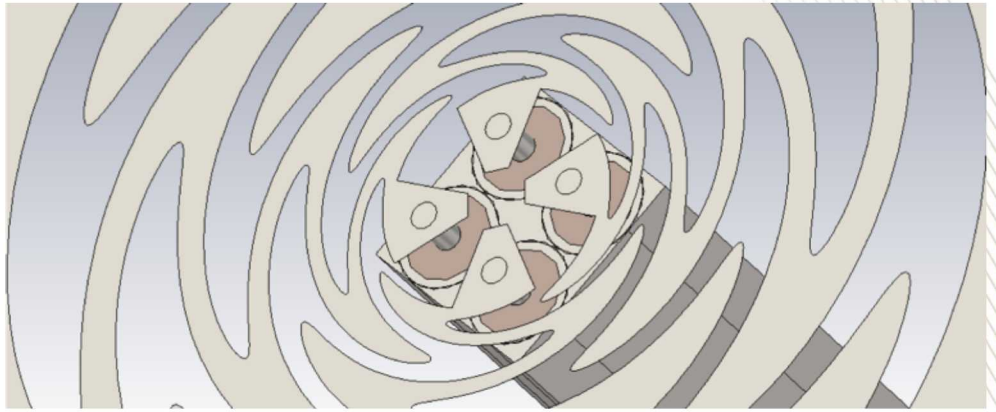
Prototype Antenna

- Milled from 0.062” RT/duroid 5880 material ($\varepsilon_r = 2.2$).
- Backed with an absorber (AN-79) loaded cavity.

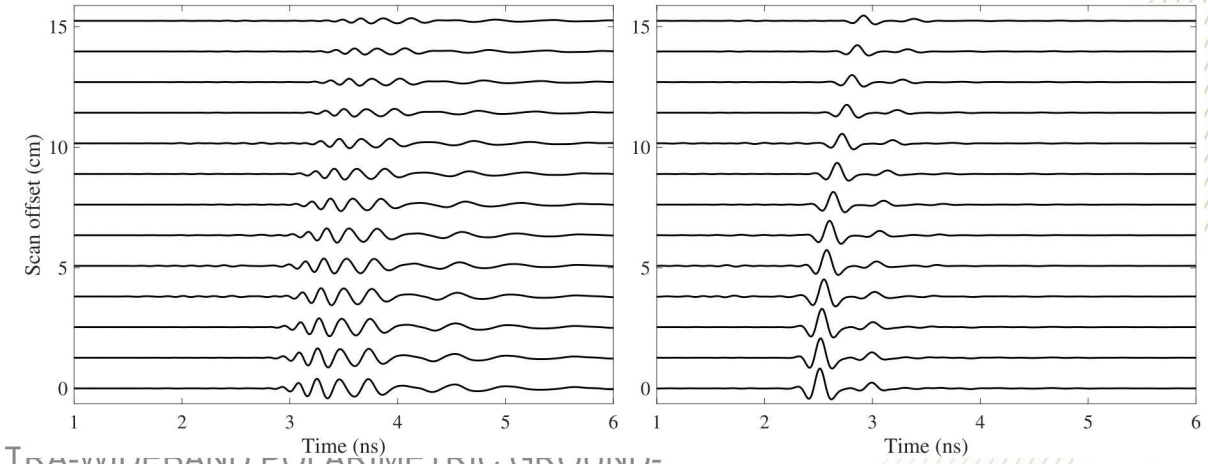




- Driven by four 50 Ω cables.

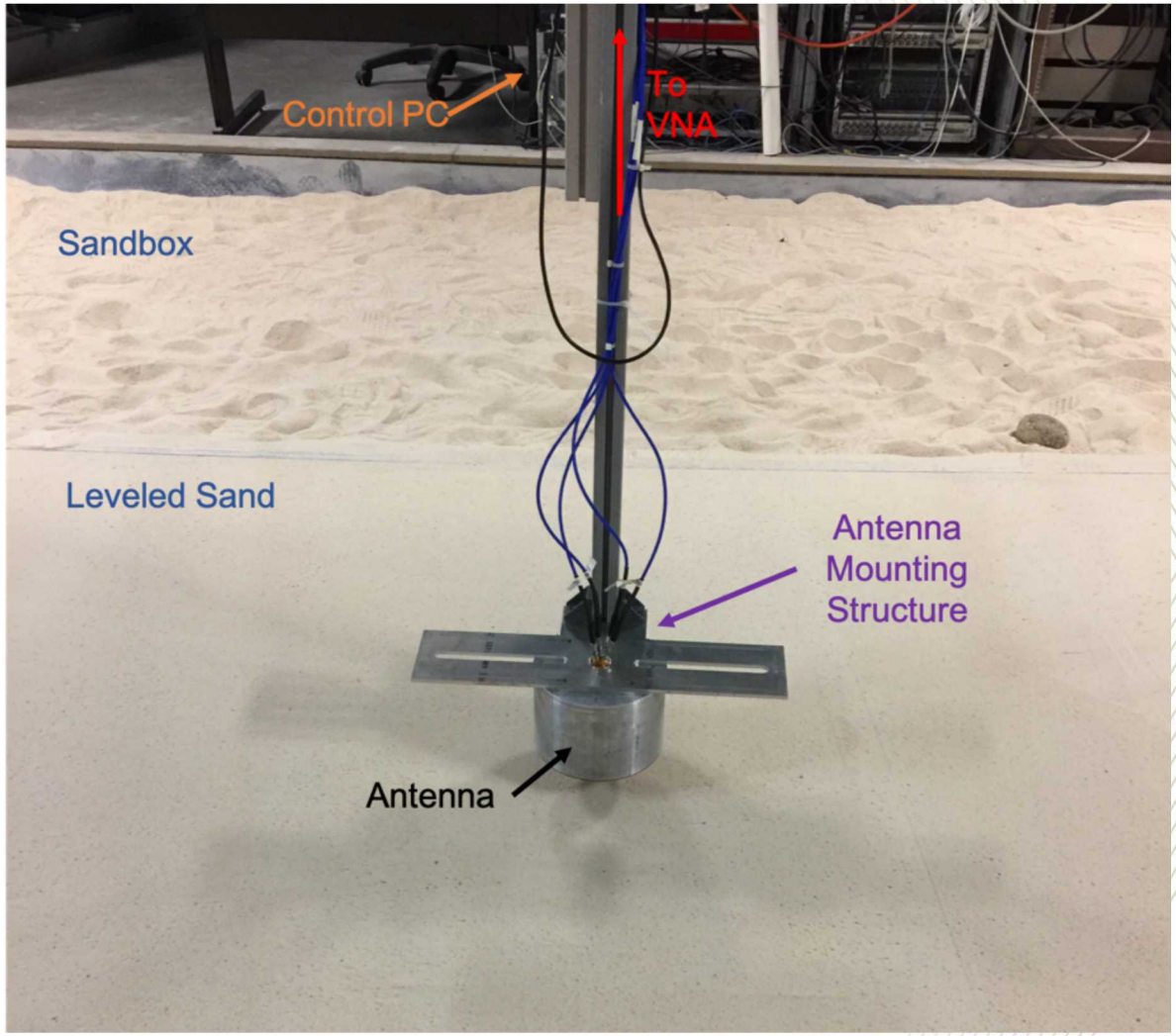


- Dispersion model fit to sphere measured in the air.

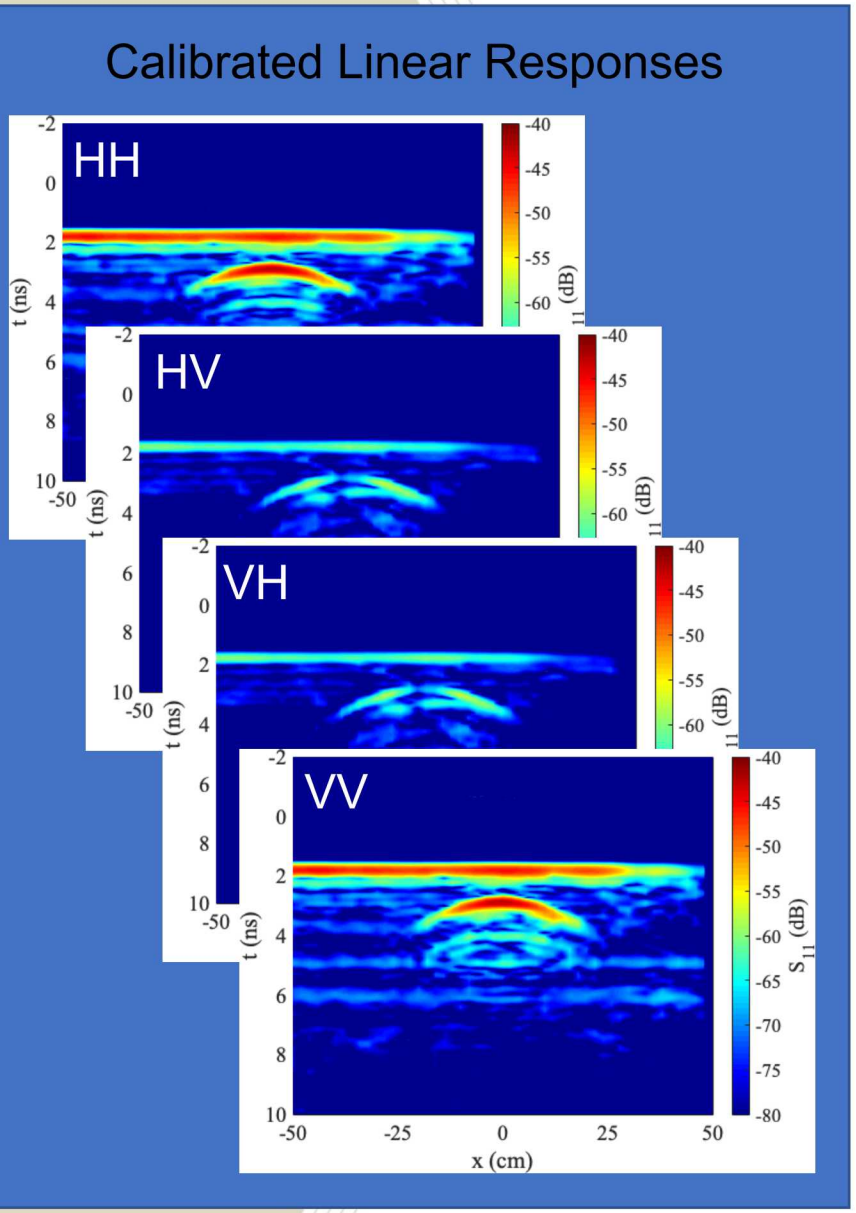


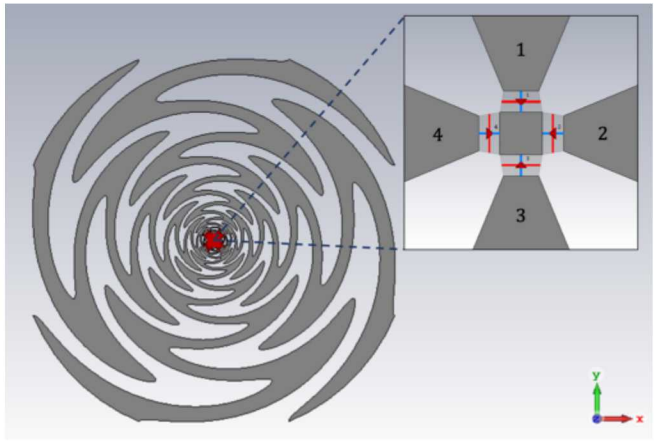
GPR Measurements

- Antenna prototype was integrated into a GPR testbed.
- Measured dual linear polarization and synthesized circular polarization (CP).
- A “stop-and-stare” measurement technique was used.
- Collected frequency domain data (10 MHz – 8 GHz).
- Performed a background subtraction to increase sensitivity.



Processing Chain (7.62 cm Sphere Example)





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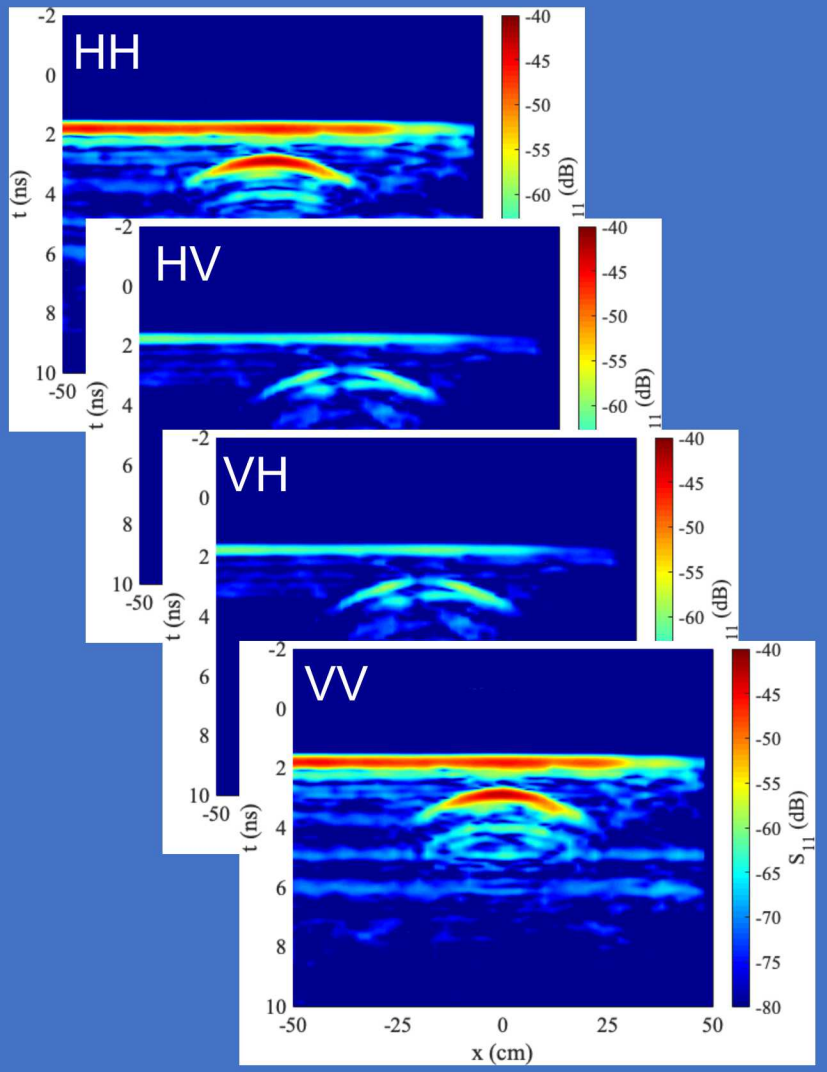
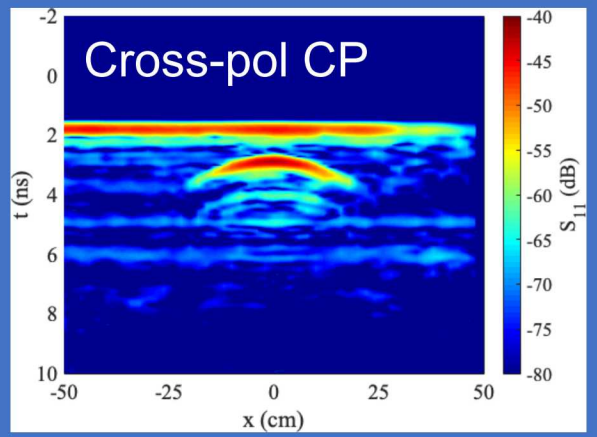
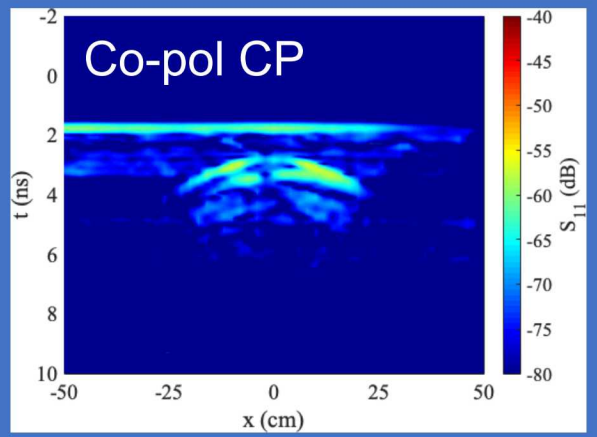
Processing Chain (7.62 cm Sphere Example)

Calibrated Linear Responses



Synthesized CP Responses





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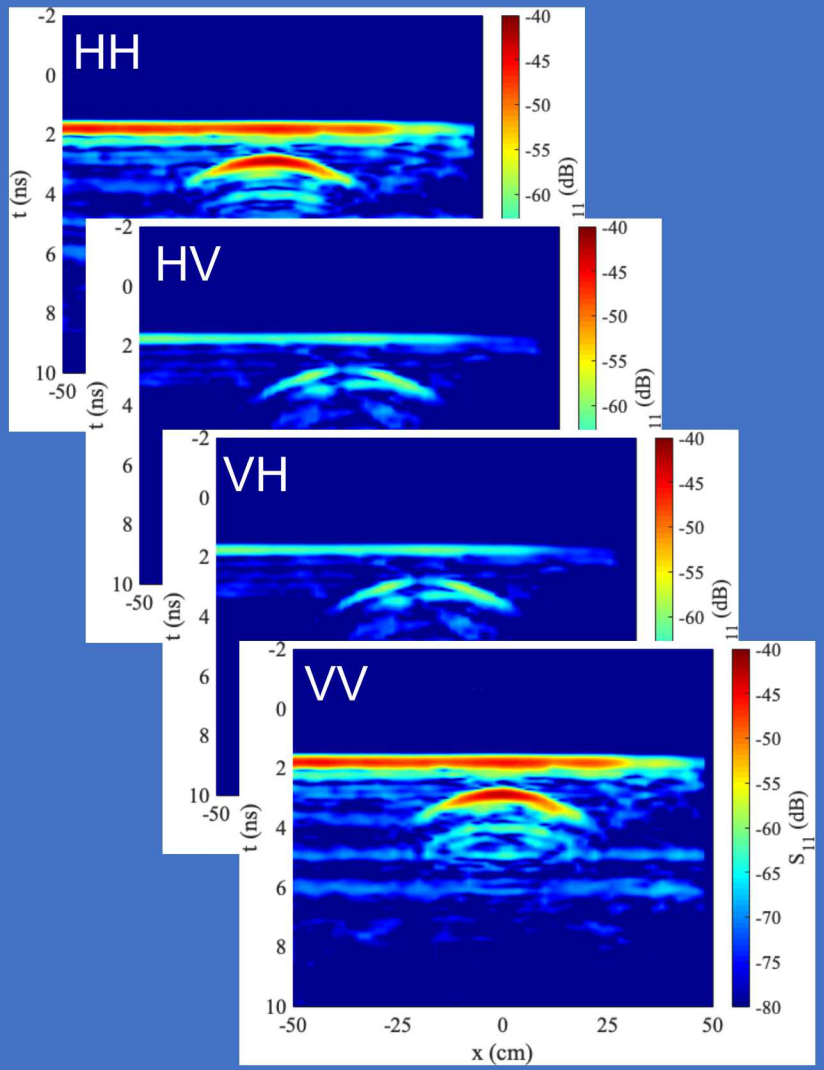

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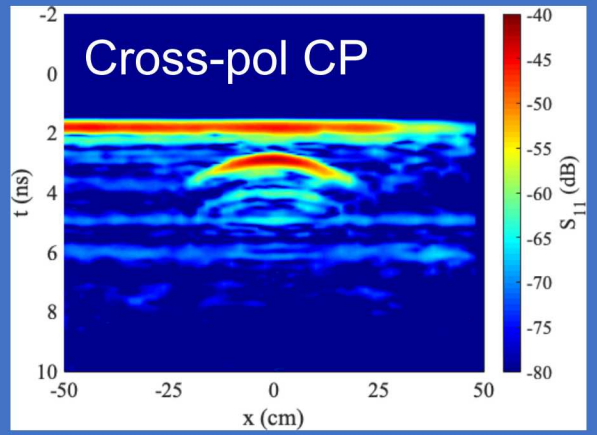
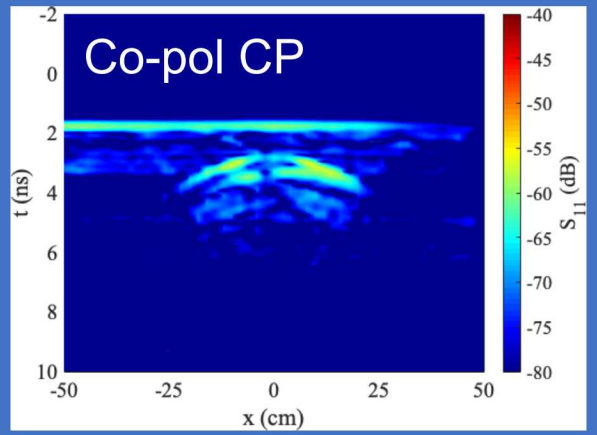
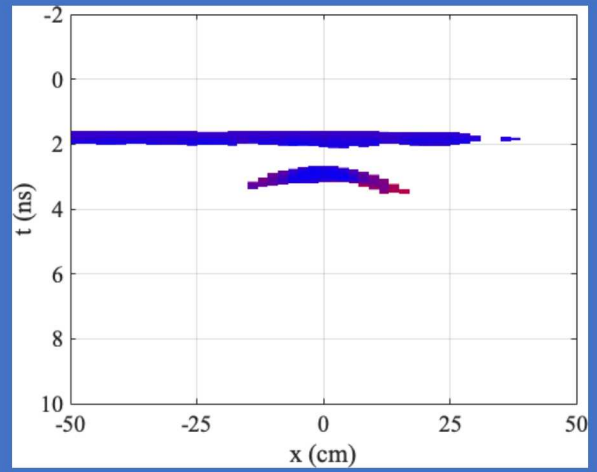




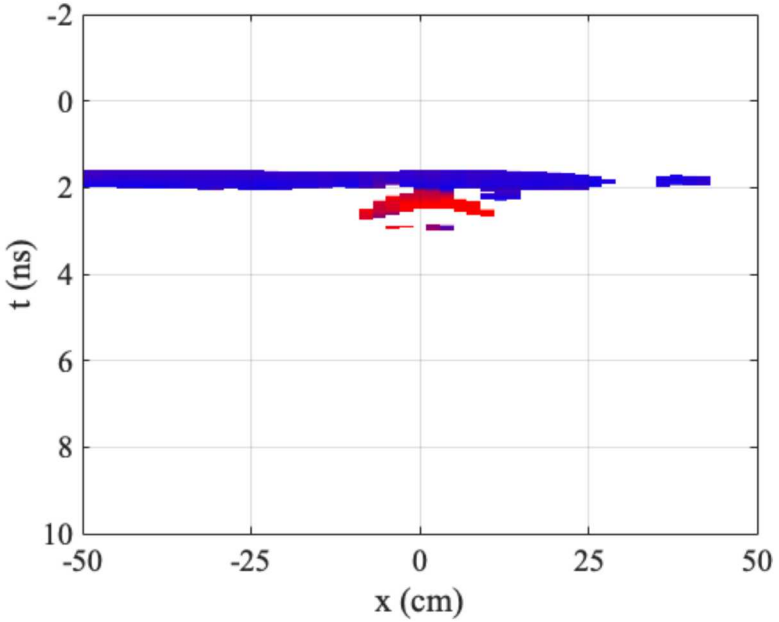
False Colormap

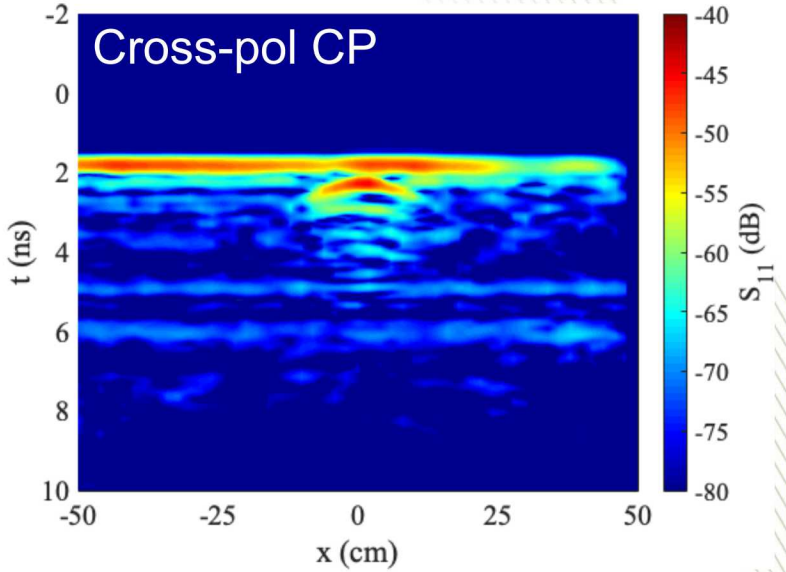
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \frac{|S_{RL}|}{|S_{LL}|} \\ 0 \\ \frac{|S_{RL}|-|S_{LL}|}{|S_{RL}|} \end{bmatrix}.$$

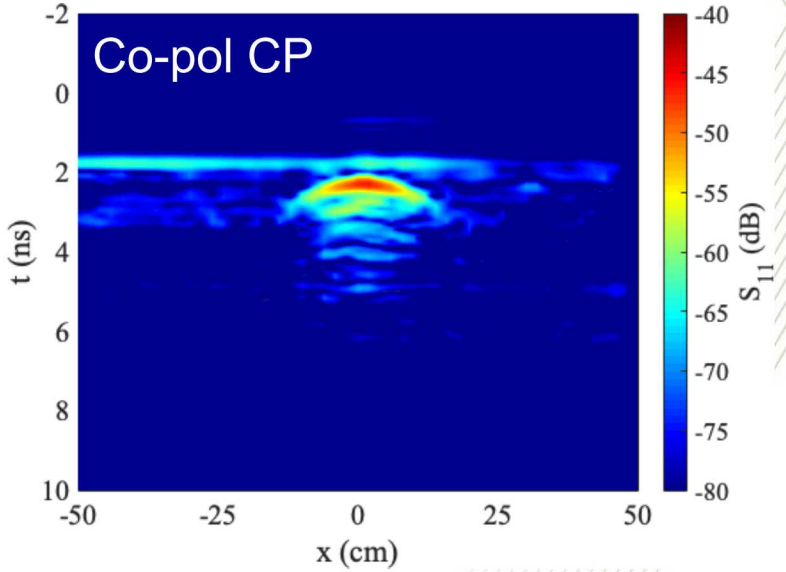


Buried 10 cm Wire

- Depth 5 cm
- Antenna Height 5 cm
- Rotation 0°







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Summary

- Proposed a novel operation of the sinuous antenna for quasi-monostatic GPR with polarimetric capabilities.
  - Improved sensitivity for near-surface targets when compared to the conventional two antenna bi-static setup.
  - Fabricated a prototype antenna.
  - Experimentally integrated the prototype into a GPR testbed for measurements.
  - Successfully utilized the system to discriminate between symmetric and asymmetric targets.