Ray-Based Model for Material Characterization Using Mm-Wave Scanner

Northeastern University

ALERT
AWARENESS AND LOCALIZATION OF EXPLOSIVES-RELATED THREATS

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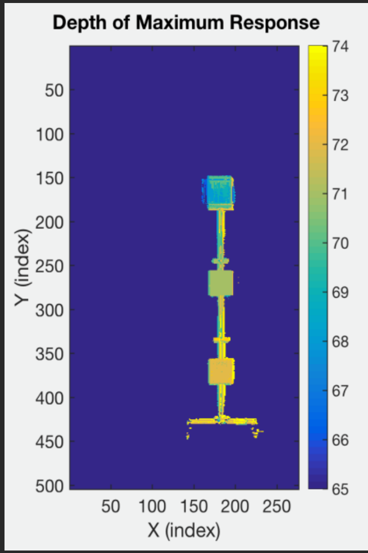
Elevator Speech

- **Problem Area:** AIT Passenger screening
- **Problem:** Detecting and characterizing concealed non-metalic threats on the body with high accuracy to reduce false alarms
- **Solution:** Develop an inverse model to determine dielectric constant and thickness of foreign objects as a feature to rule out non-explosives
- **Why it matters:** Potential to determine the nature of concealed foreign objects with fewer false alarms; using existing hardware

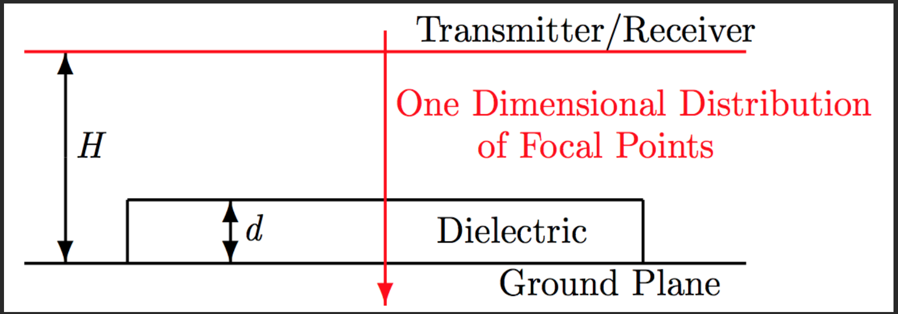
The Setup

Smiths eqo scanner

Image of 3 metal target plates on stand, the top plate has a dielectric threat material attached.



Top view of threat material on plate.

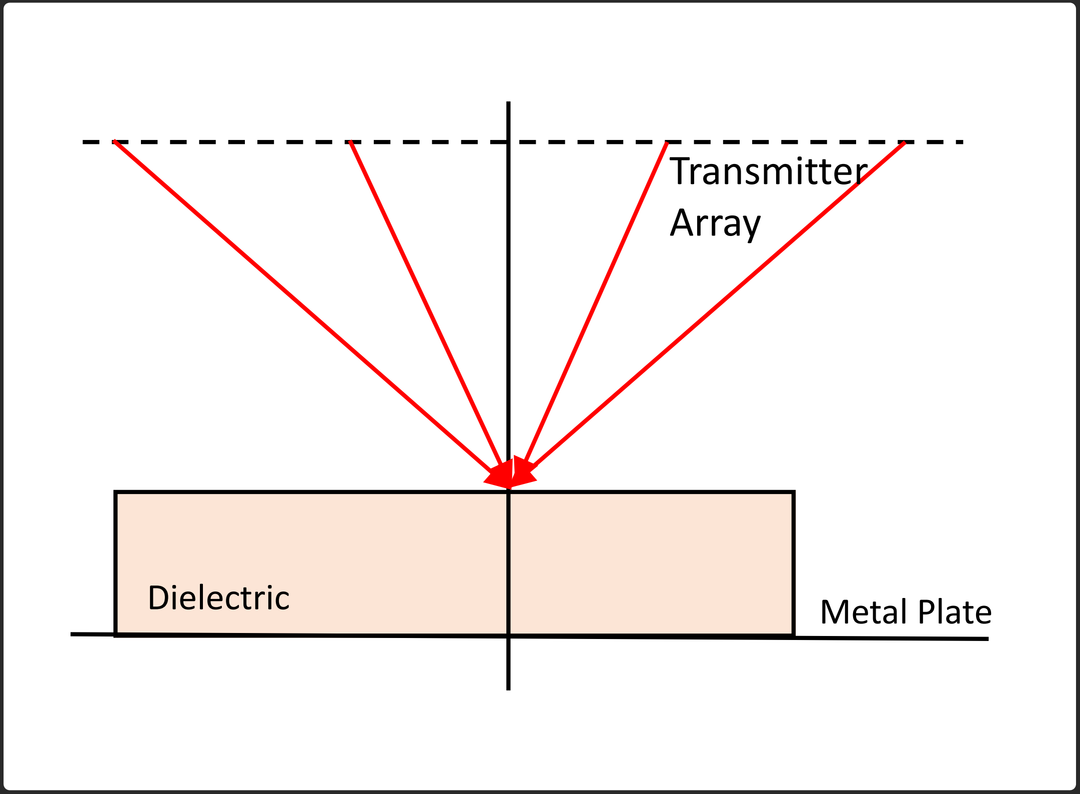


The authors are grateful to Christoph Weiskopf and Claudius Volz of Smiths Detection, Inc. for providing measured data from the eqo system. This work is supported by the U.S. Department of Homeland Security, Science and Technology Directorate, Office of University Programs, under Grant Award 2013-ST-061-ED0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

5 Distinct Scattering Phenomena Emerge

1A. Direct Scattering from front dielectric surface

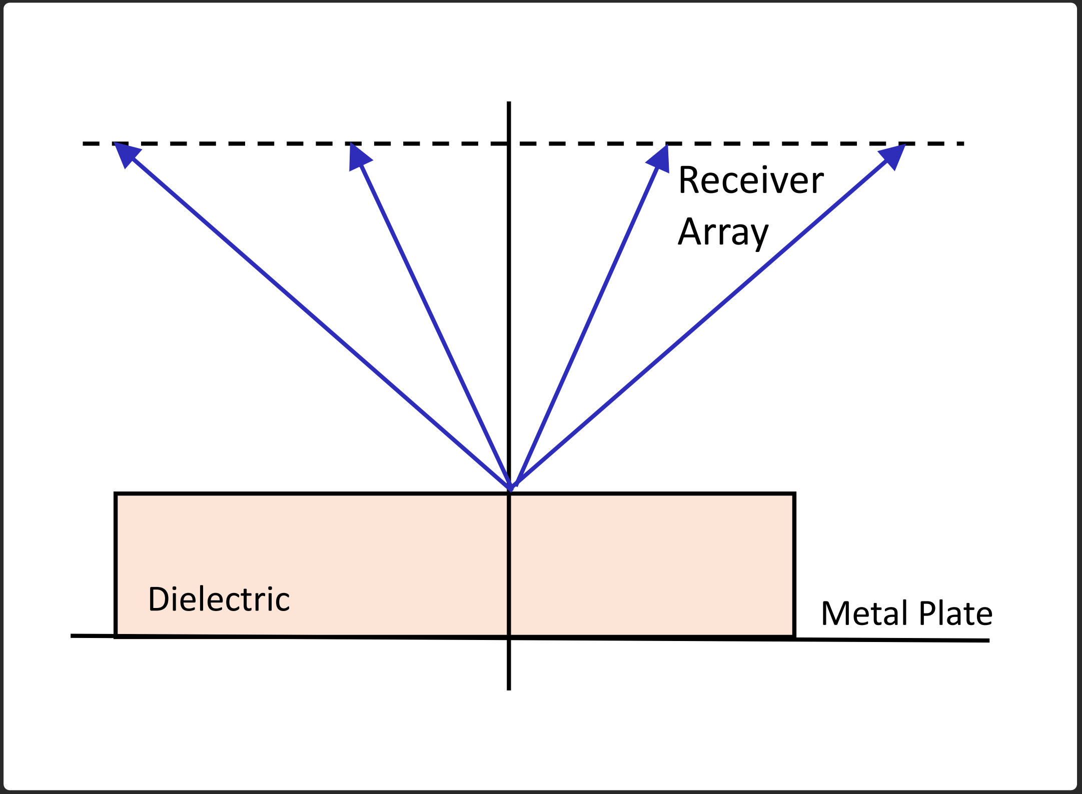
Focusing on transmission



5 Distinct Scattering Phenomena Emerge

1A. Direct Scattering from front dielectric surface

Focusing on reception

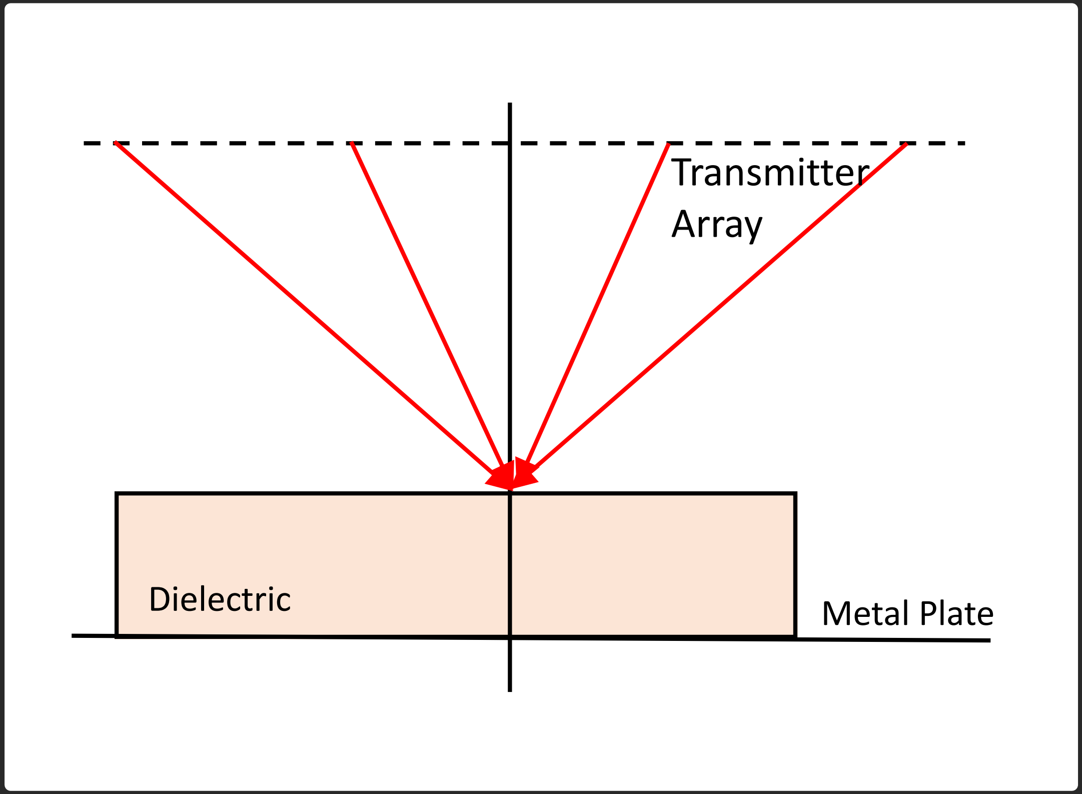


5 Distinct Scattering Phenomena Emerge

1A. Direct Scattering from front dielectric surface

1B. Focus at front surface, consider scattering through dielectric from front surface image

Focusing on transmission



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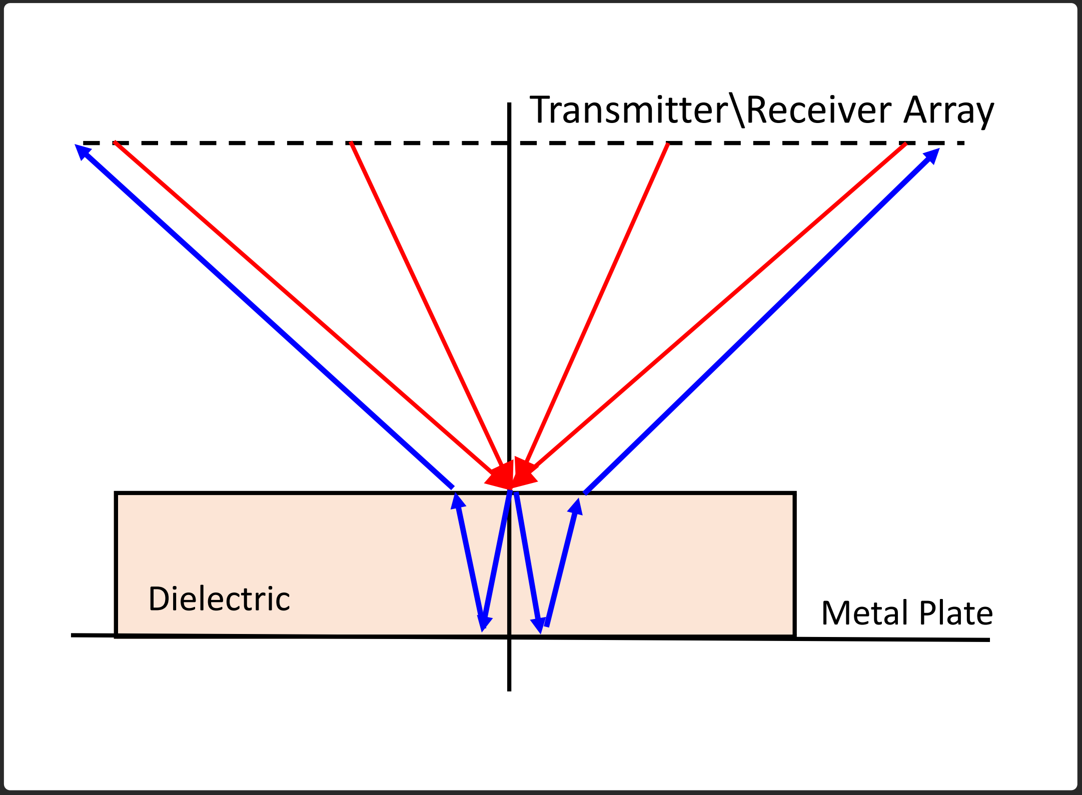
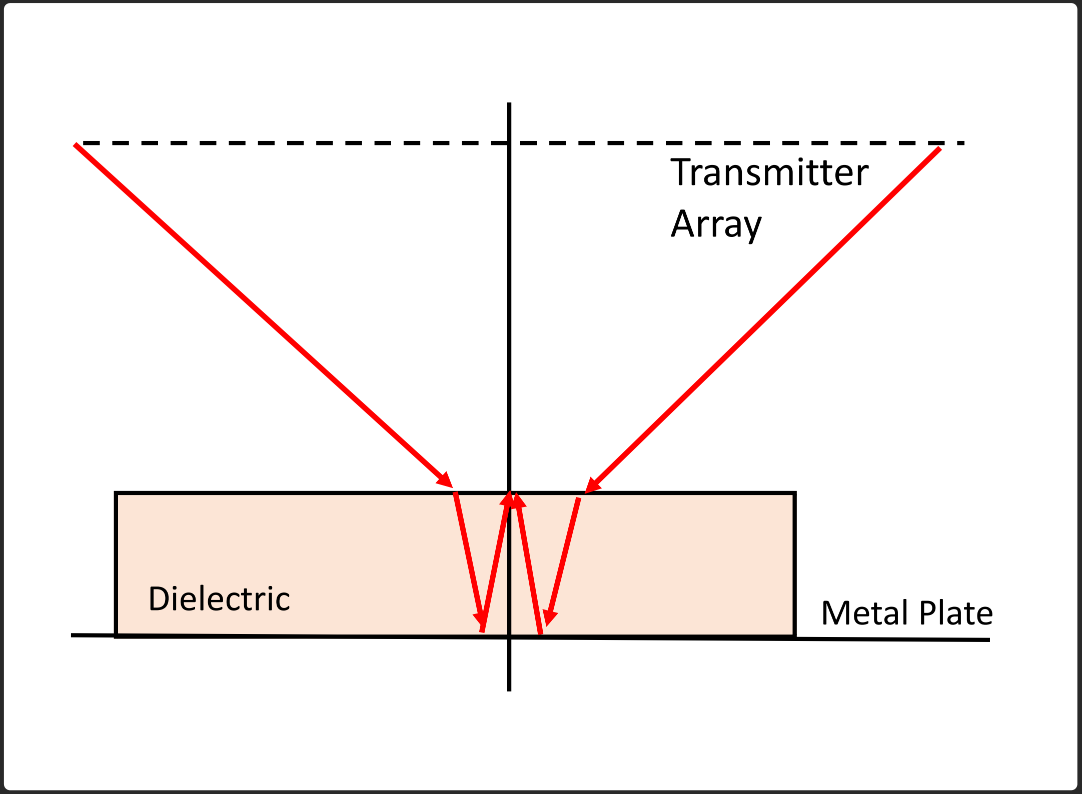
Receiving scattered rays



5 Distinct Scattering Phenomena Emerge

2A. Focus at image of front surface, consider direct scattering from front surface

Focusing on transmission



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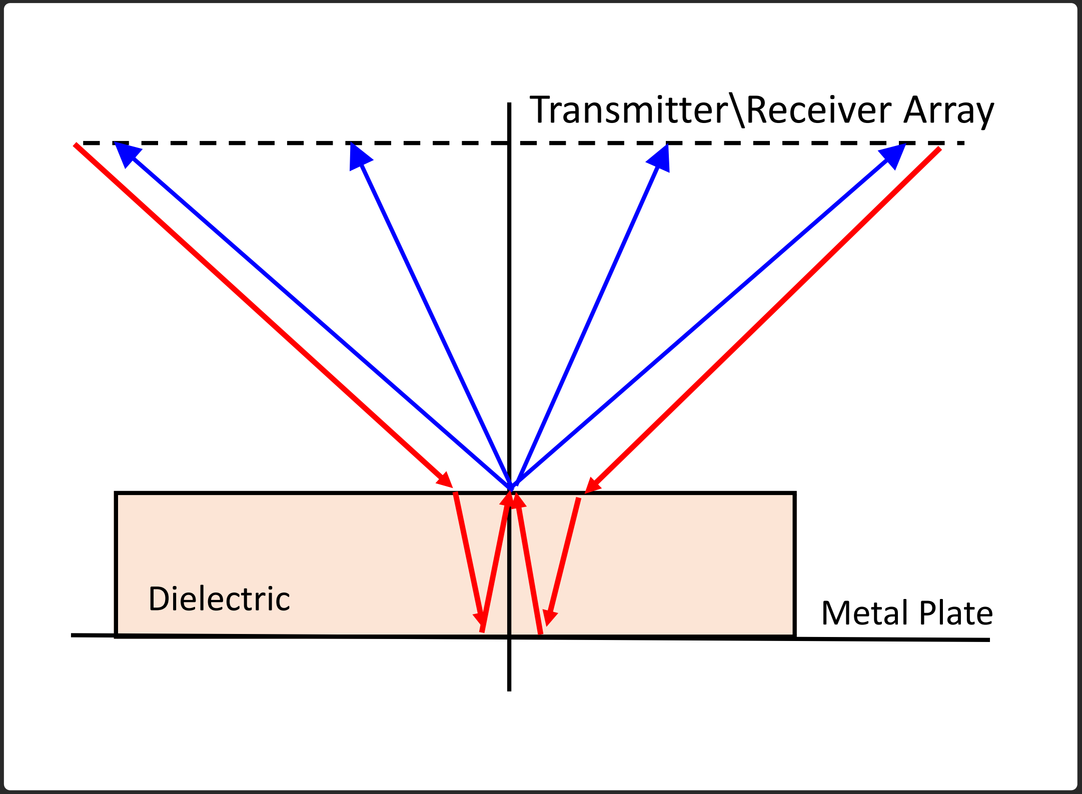

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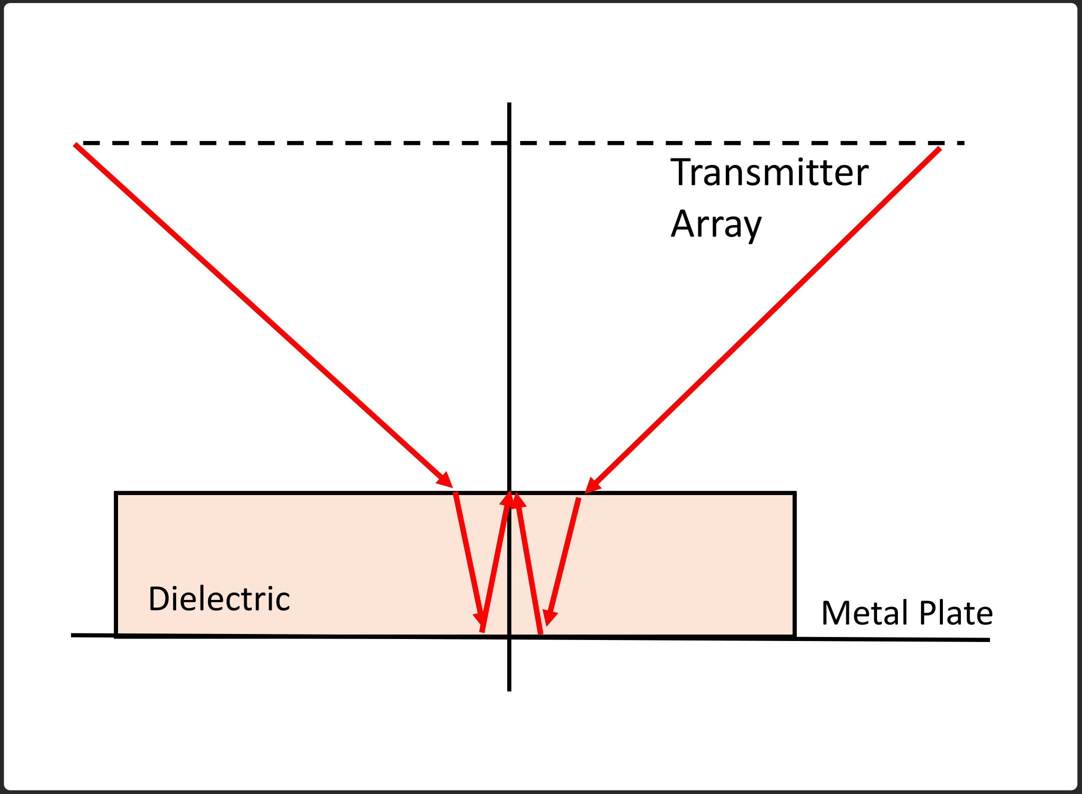

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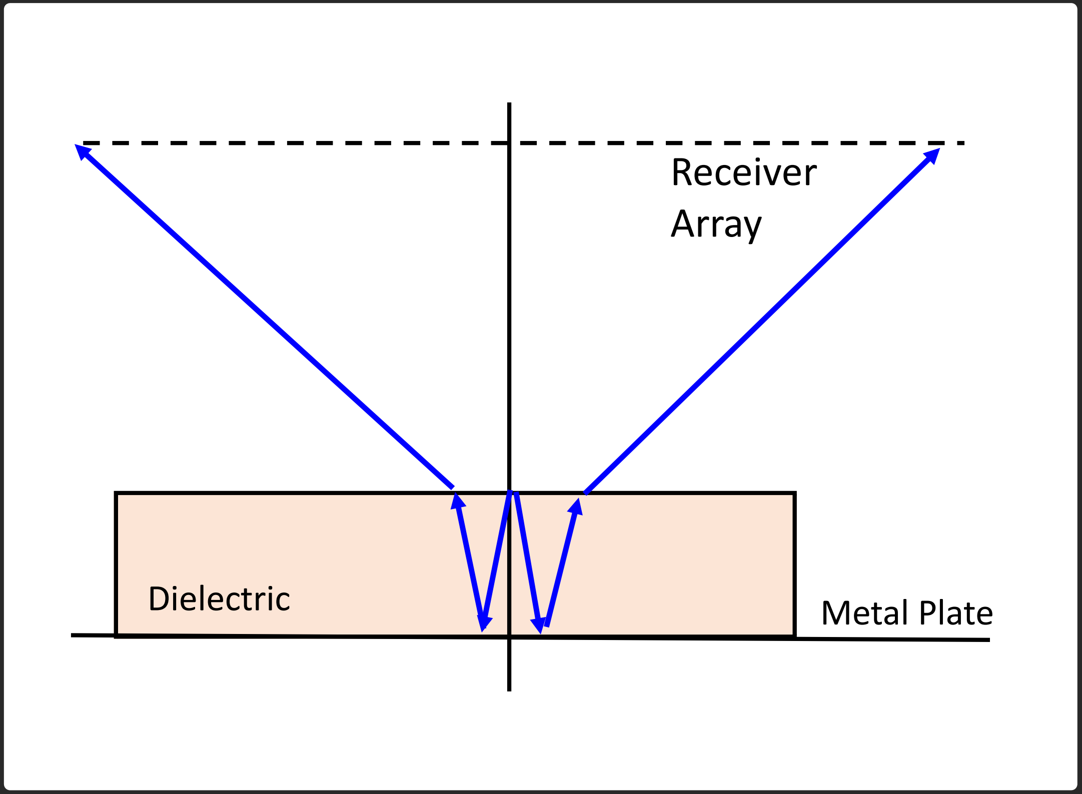
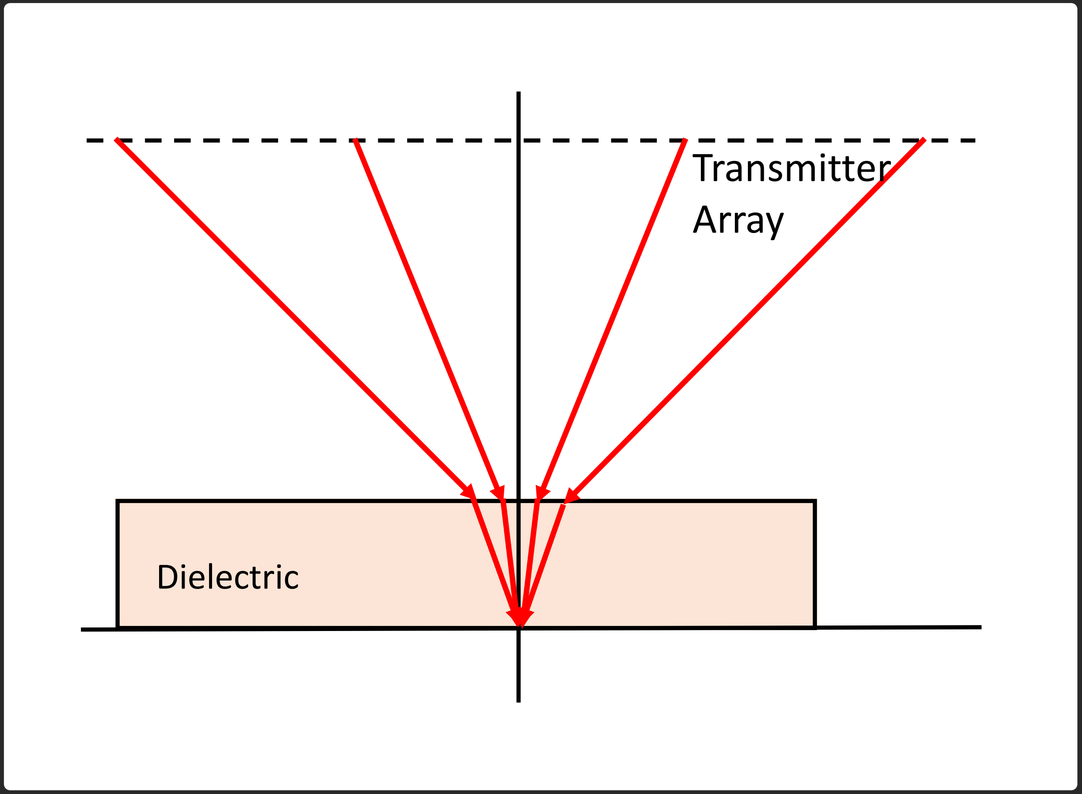


5 Distinct Scattering Phenomena Emerge

3. Scattering from illuminated bottom surface

Focusing on transmission



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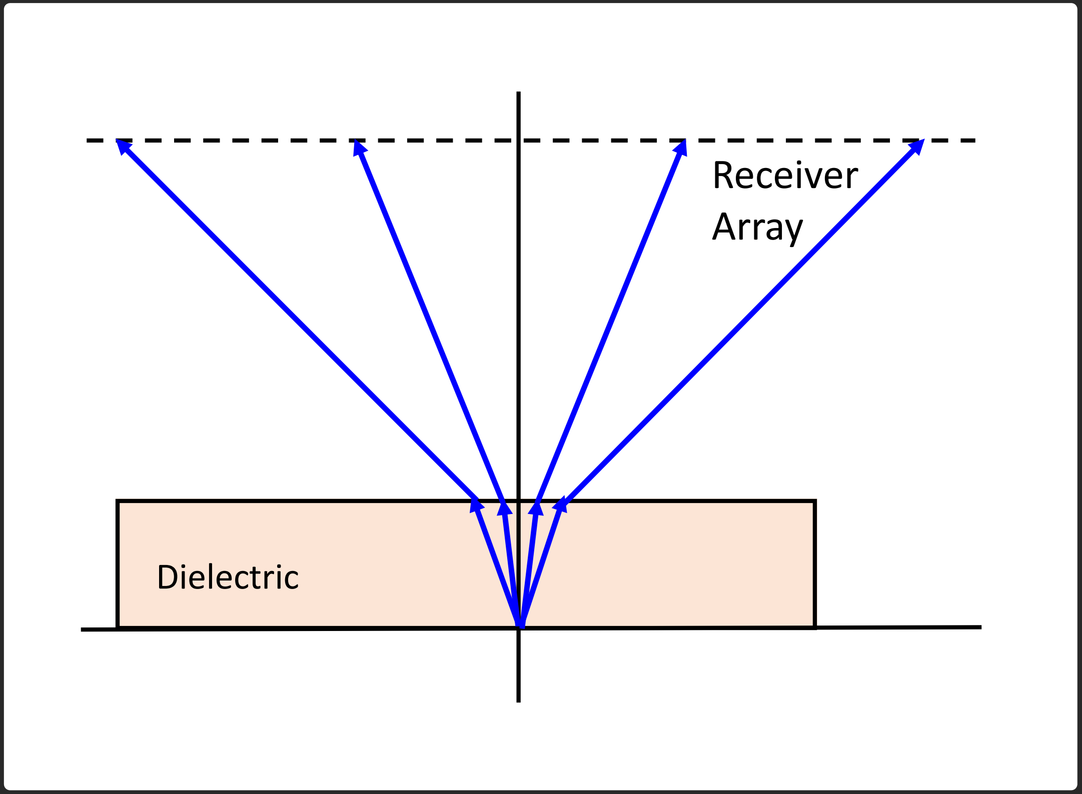
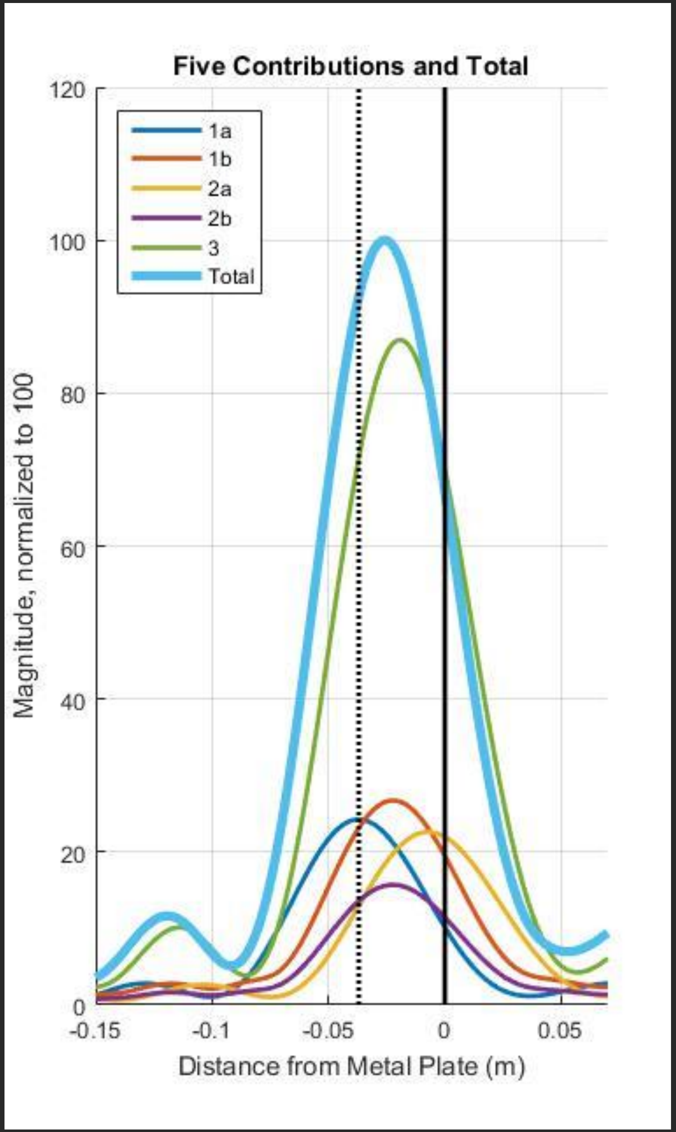


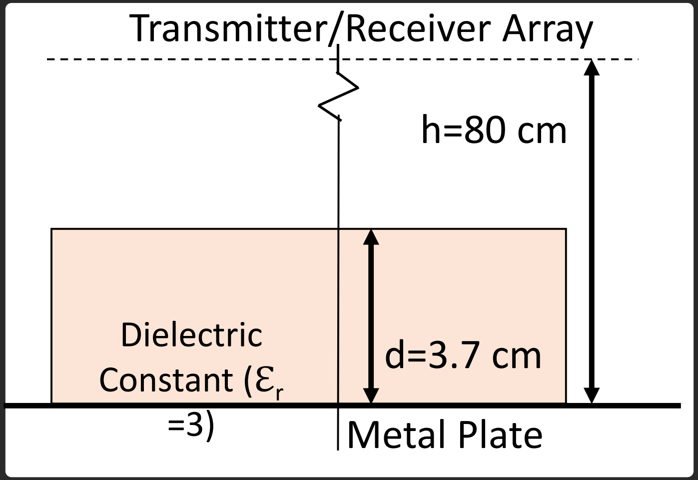
Adding up the Phenomena

- Calculate path length and phase, and then add along focal line to give signal returned
- Places of maximum signals in phase with each other will be peaks

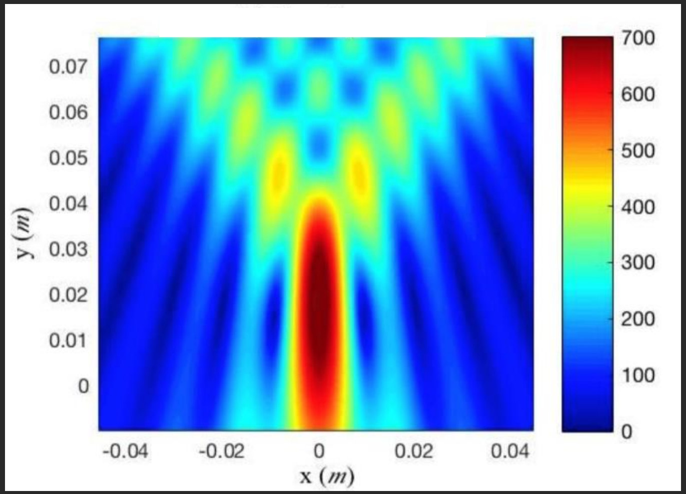


2D FDFD Simulation Total Field Magnitude

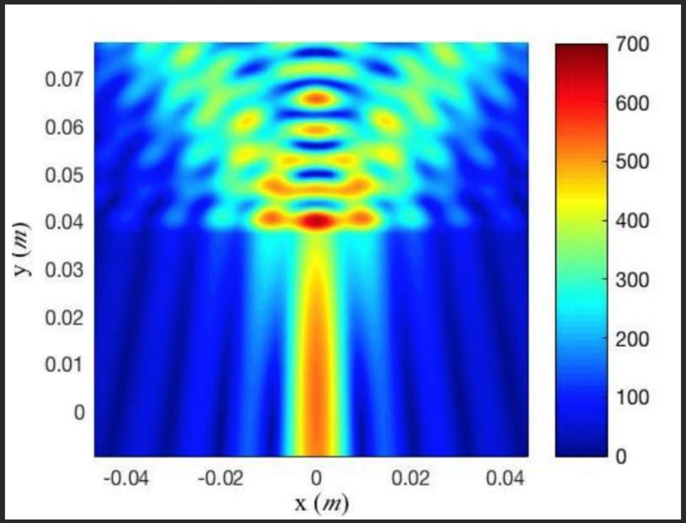
(a) Schematic of the problem



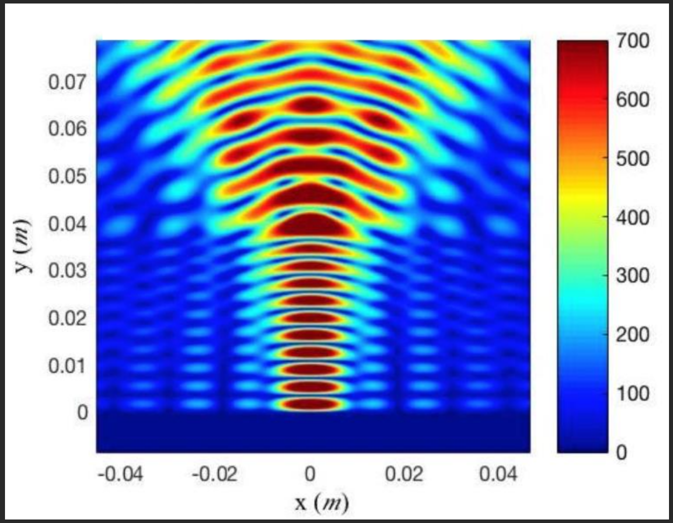
(b) Free space



(c) Half dielectric space



(d) Dielectric on metal background



Comparison to Actual Value

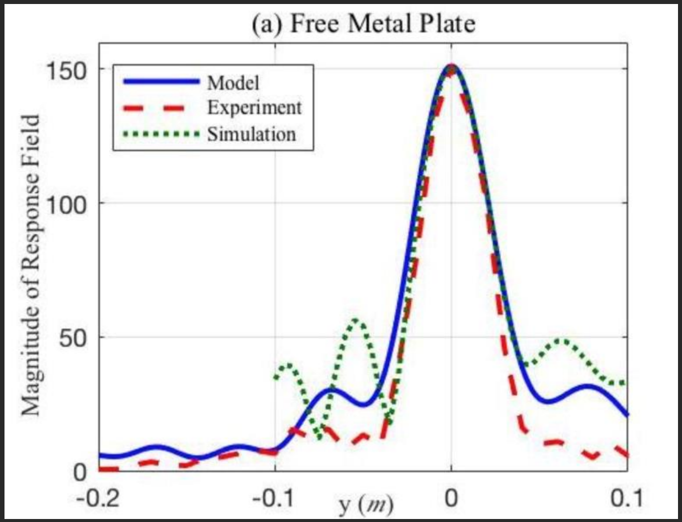
Comparison between ray-based model, 2D FDFD simulation and measurement from eqo:

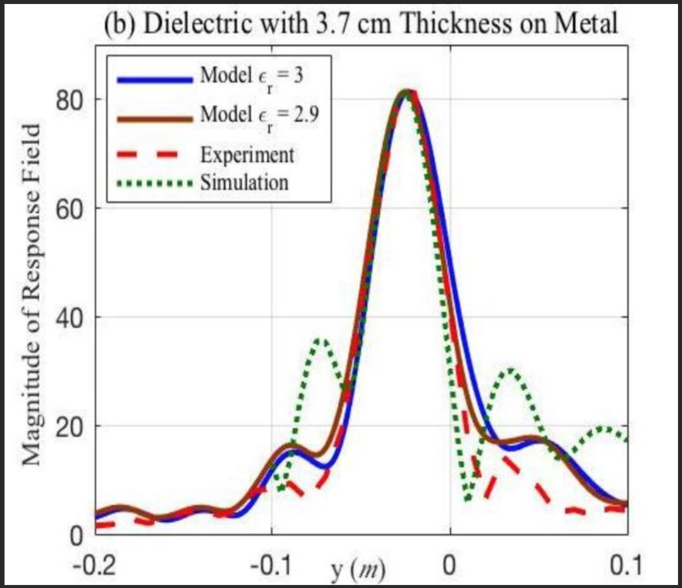
Good agreement

- Displacement from anticipated maximum
- Half power width of signal pulse in range

Less accurate

- Sidelobes: difference between 2D modeling and 3D measurement





Next Steps

- **Use the developed forward model for simple inverse model to determine slab dielectric constant and thickness**

- **Inversion Problem**

From Scanner

- Displacement of peak from nominal ground plane range
- 3dB width of peak
- Change in magnitudes of curves

Determine

- Dielectric slab thickness
- Dielectric constant

Conclusions

- Ray-based model of five scattering phenomena simplifies analysis
- Able to characterize material properties (thickness, dielectric constant) of potential threat material
- Thickness, extent, and dielectric constant (from 2D scans) can rule out non-threats
- Potential for faster, safer checkpoints