

# Improved Millimeter-Wave Radar Concealed-Threat Person Scanning



Northeastern University



**ALERT**

AWARENESS AND LOCALIZATION  
OF EXPLOSIVES-RELATED THREATS

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# Elevator Speech / Conclusions/ Summary / Outline

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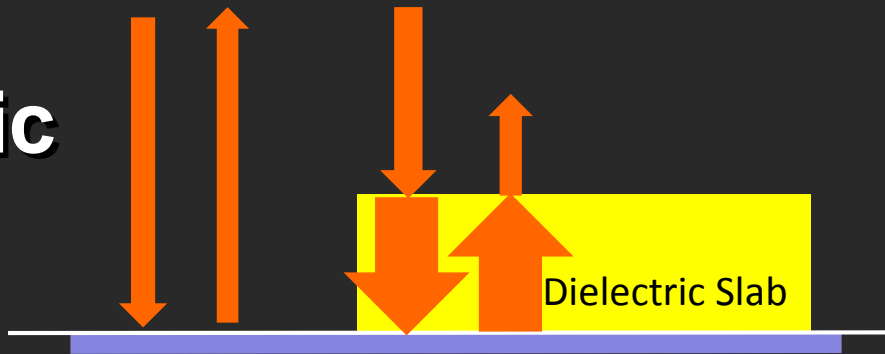
- **Problem Area: AIT passenger screening**
- **Problem: Distinguishing concealed threats on the body (and rejecting non-threats), and doing so on the move**
- **Solutions:**
  1. **Non-metallic materials characterization (determine dielectric constant of non-metals) employing algorithms to exploit depth info for both impulse and focused CW radar – patents pending**
  2. **Cross-sensor multistatic mm-wave radar, with cooperation across hallway – patent pending**
- **SW-WC: Rule out hidden non-threats  $\Rightarrow$  fewer pat-downs, fewer false alarms; less obtrusive screening; screening at walking speed**



# Dielectric (Explosive) Slab on Skin Characterization

Waves travel more slowly through dielectric

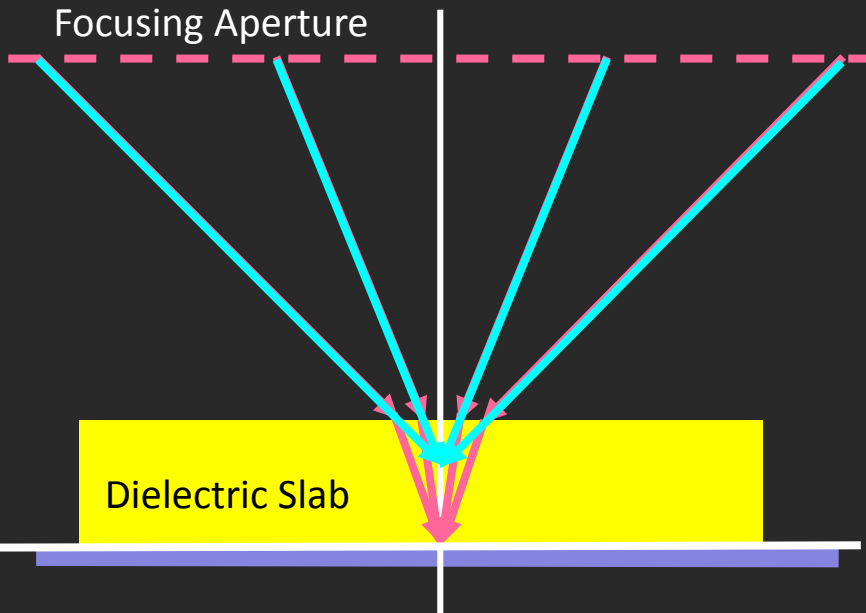
- Delays response from back surface skin reflection, making primary image look farther away (L3 Provision, Rohde & Schwarz)



## Time Domain -- Impulse

- Refracts focused rays, making response appear closer to sensor

## Frequency Domain -- CW



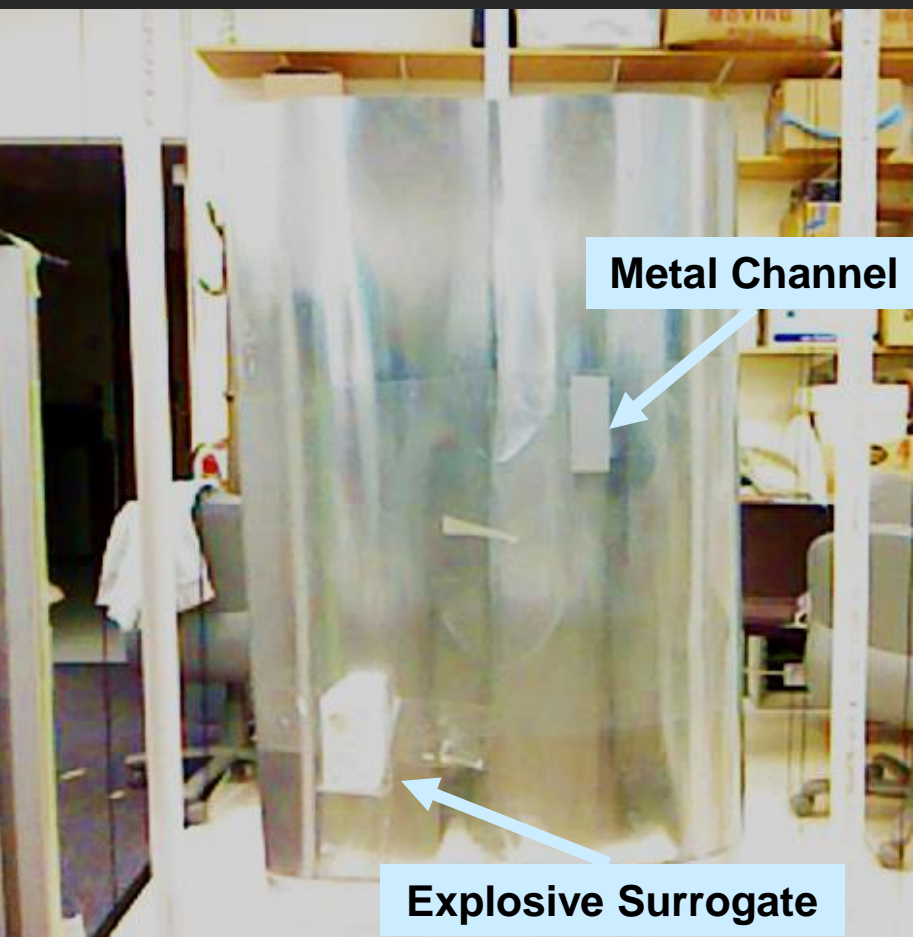
**Determine Thickness and Dielectric Constant**



# Body Surrogate Scan

## Clothed Torso Surrogate

## Concealed Objects

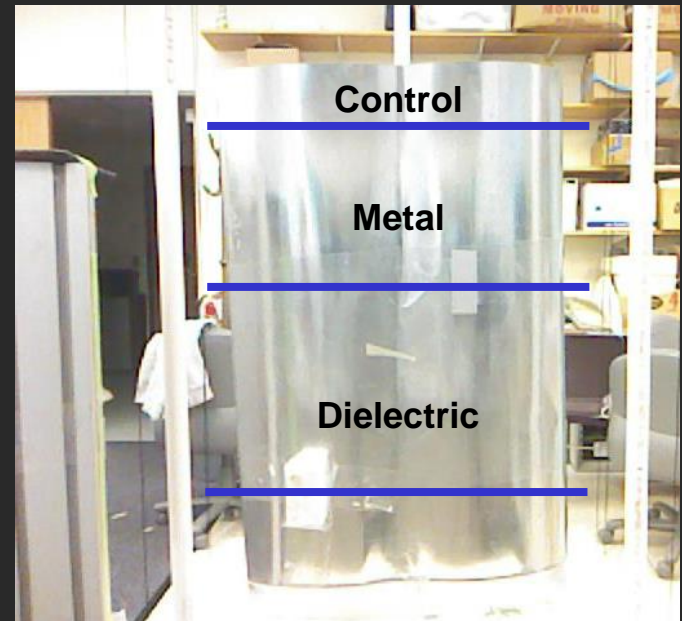
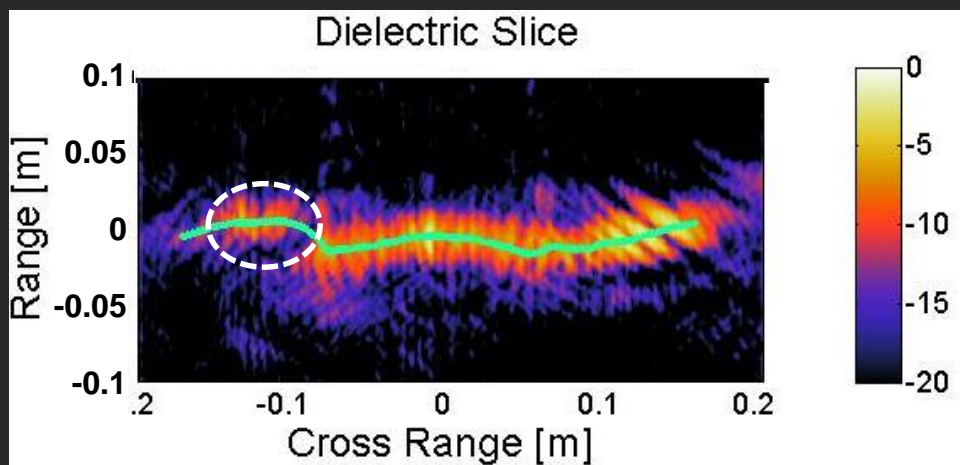
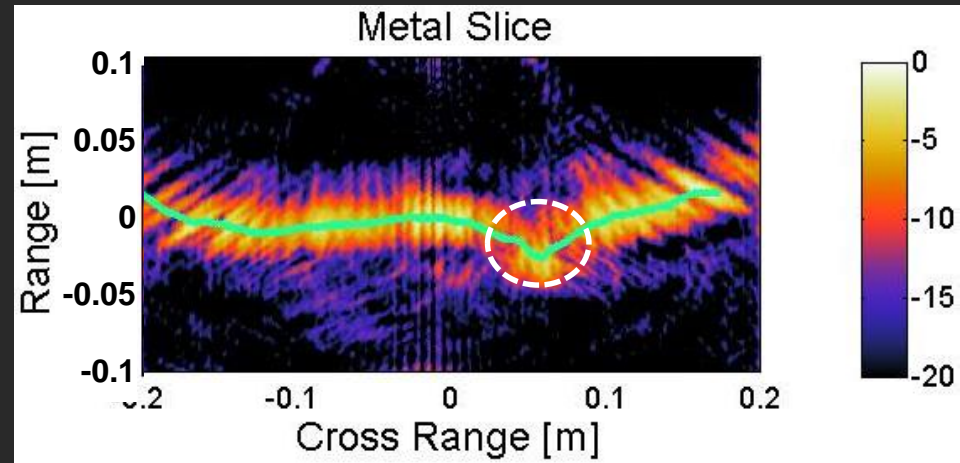
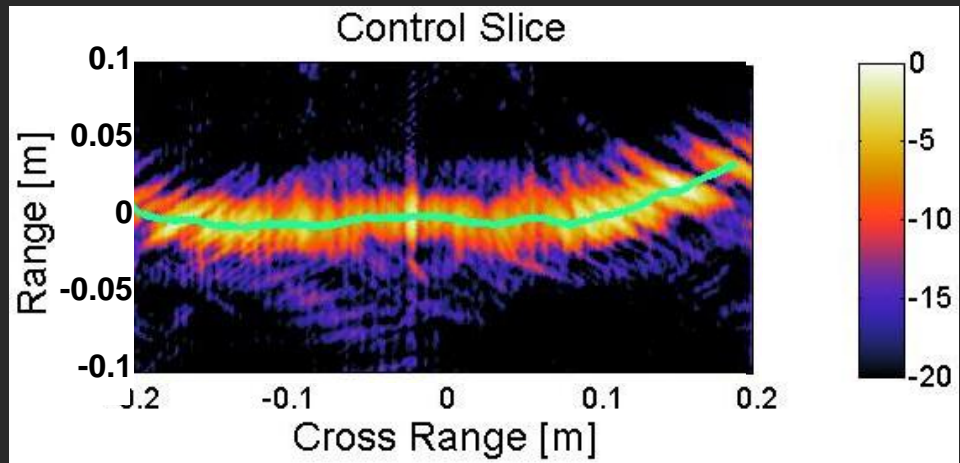


**Metal Channel**

**Explosive Surrogate**



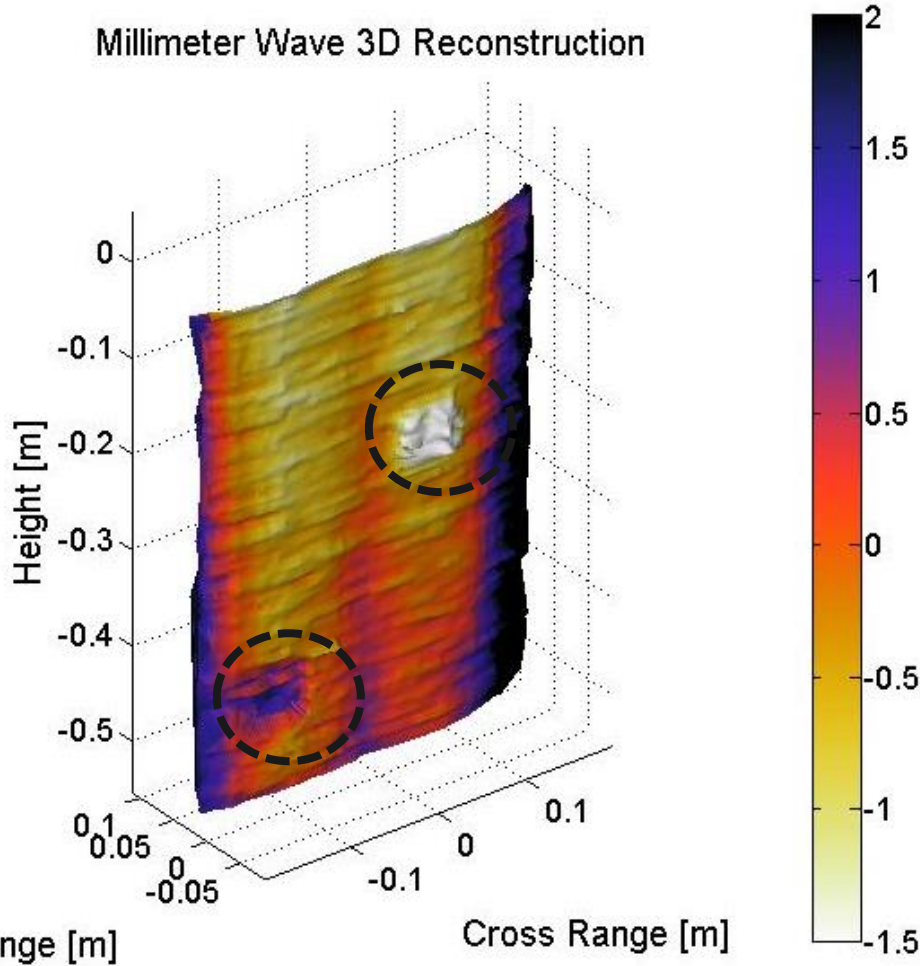
# Distinguishing Anomalies for a Given 2D Slice





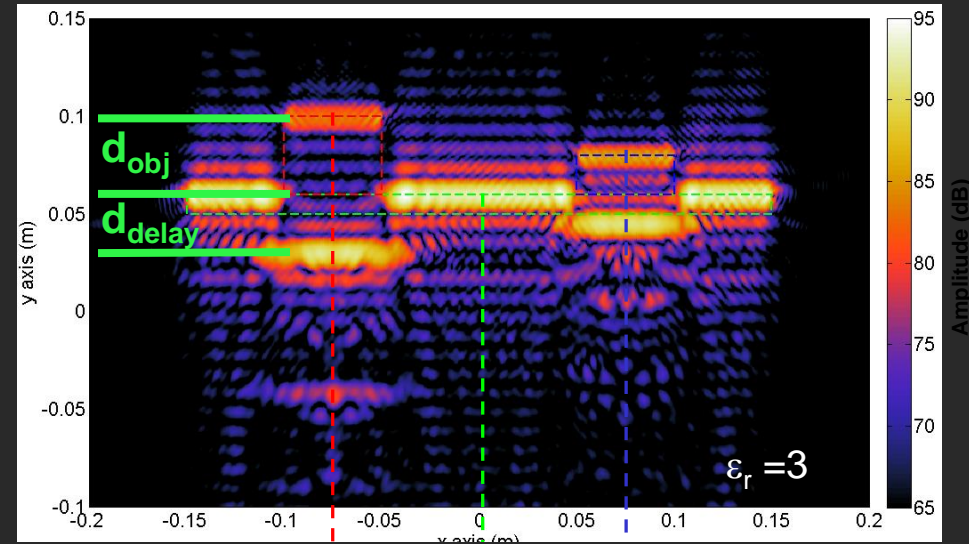
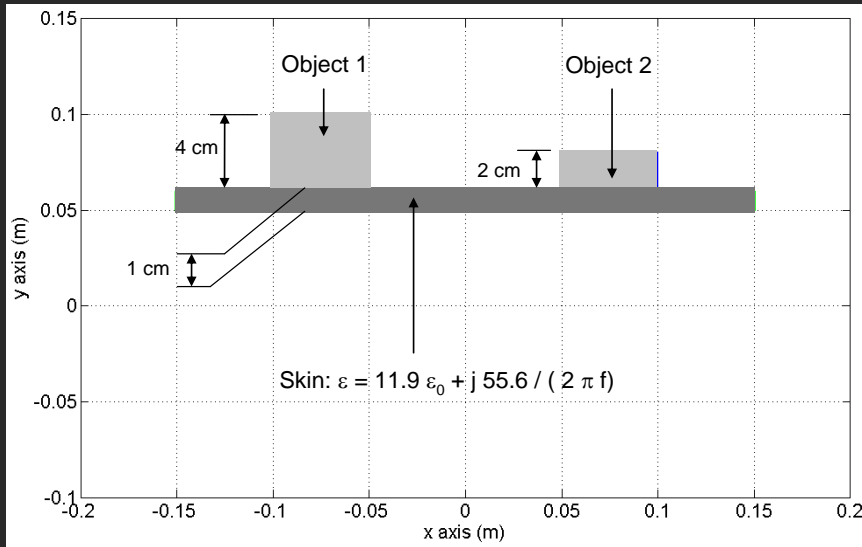
# Stacked 3D Reconstruction

Millimeter Wave 3D Reconstruction





# Determining Object (Slab) Dielectric Constant



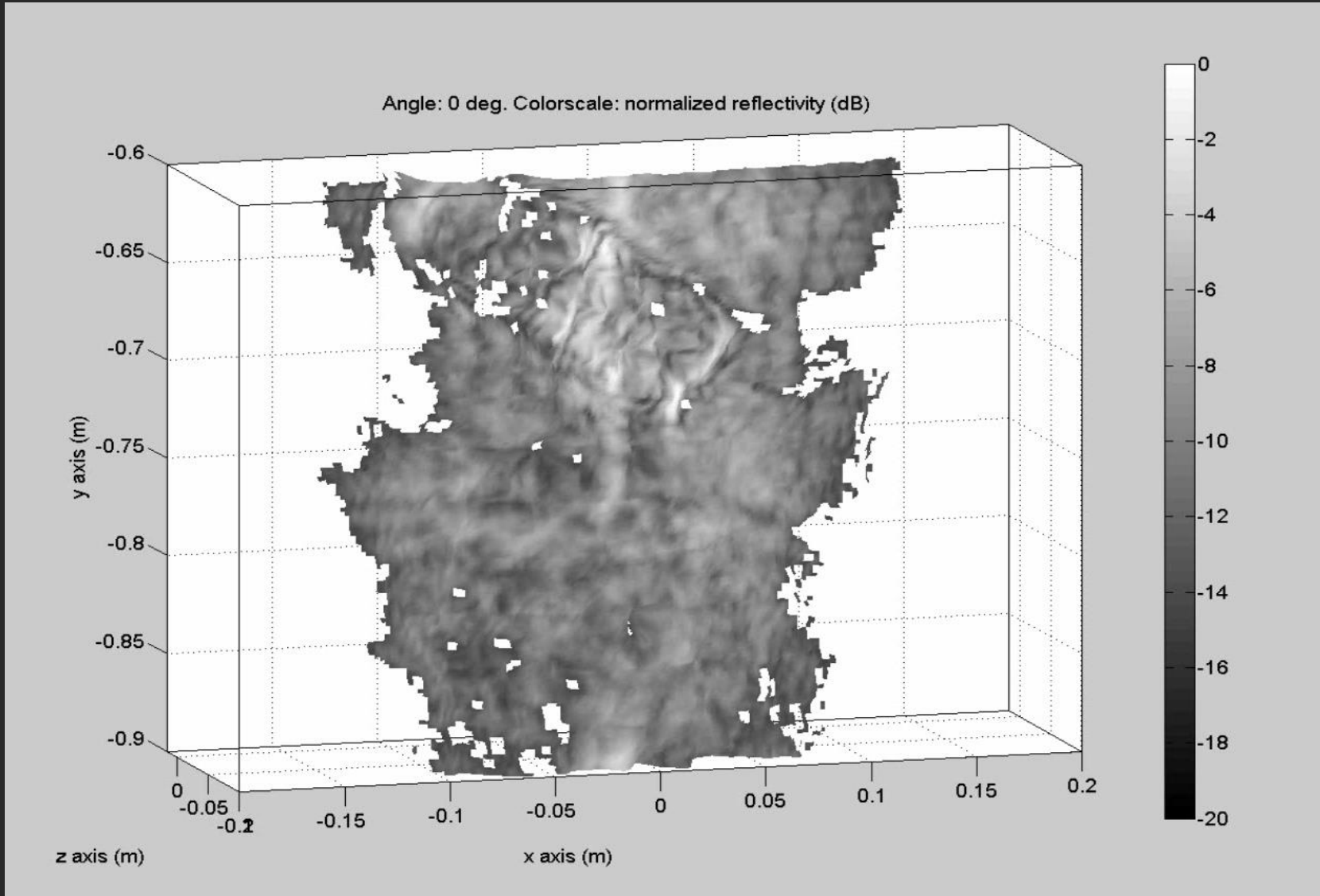
$$\epsilon_r = \left( 1 + \left( \frac{d_{delay}}{d_{obj}} \right) \right)^2$$

$$\epsilon_r = \left( 1 + 3/4 \right)^2 = 49/16$$

Álvarez, Y., \*Gonzalez-Valdes, B., Martínez-Lorenzo, J. A., Las-Heras, F., and Rappaport, C., "SAR imaging-based techniques for Low Permittivity Lossless Dielectric Bodies Characterization," IEEE Ant. Prop. Mag., April 2015, vol. 57, pp. 267 - 276.



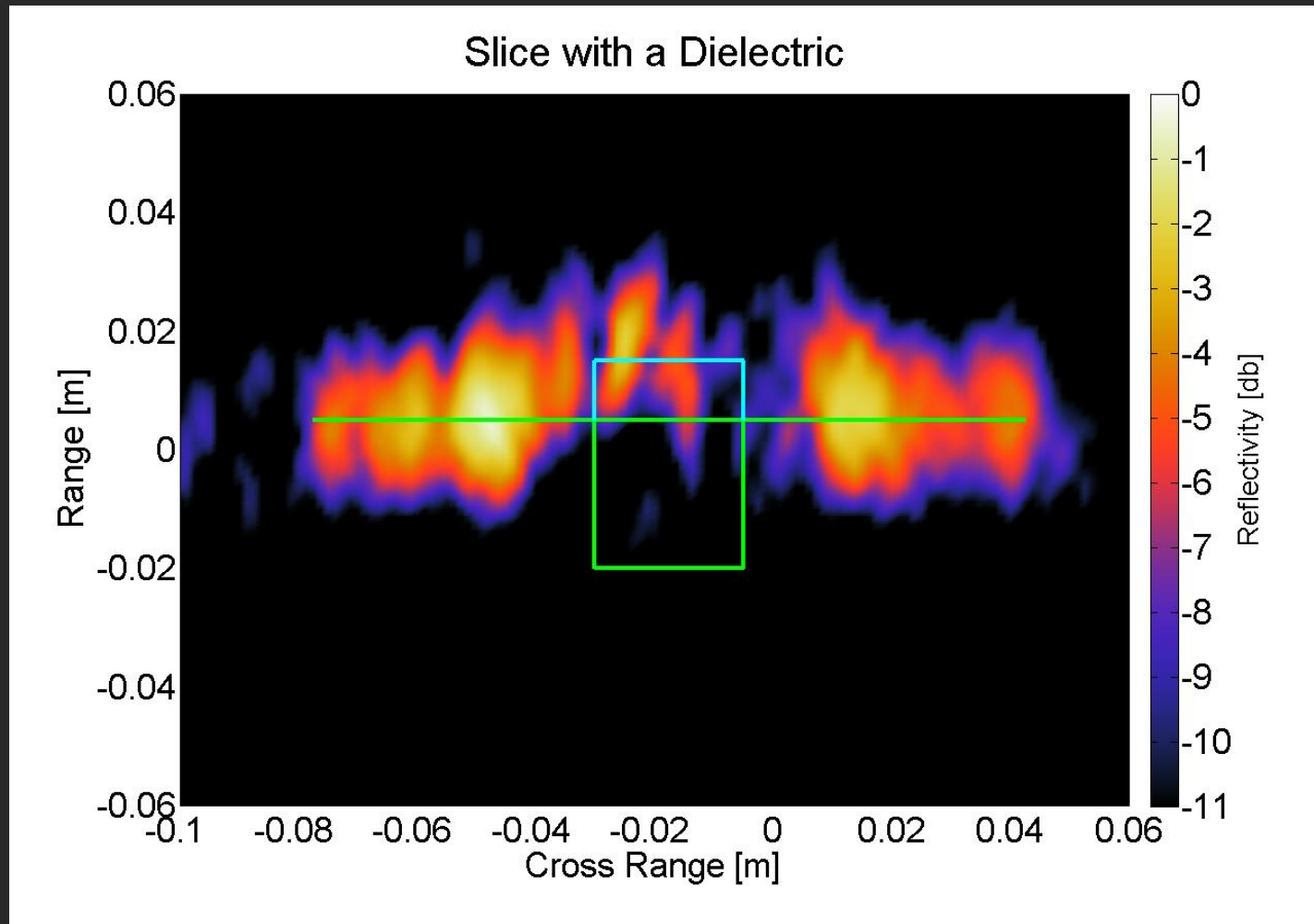
# Non-Metallic Object Characterization – Weak Dielectric on Torso Appears as Depressed Contour





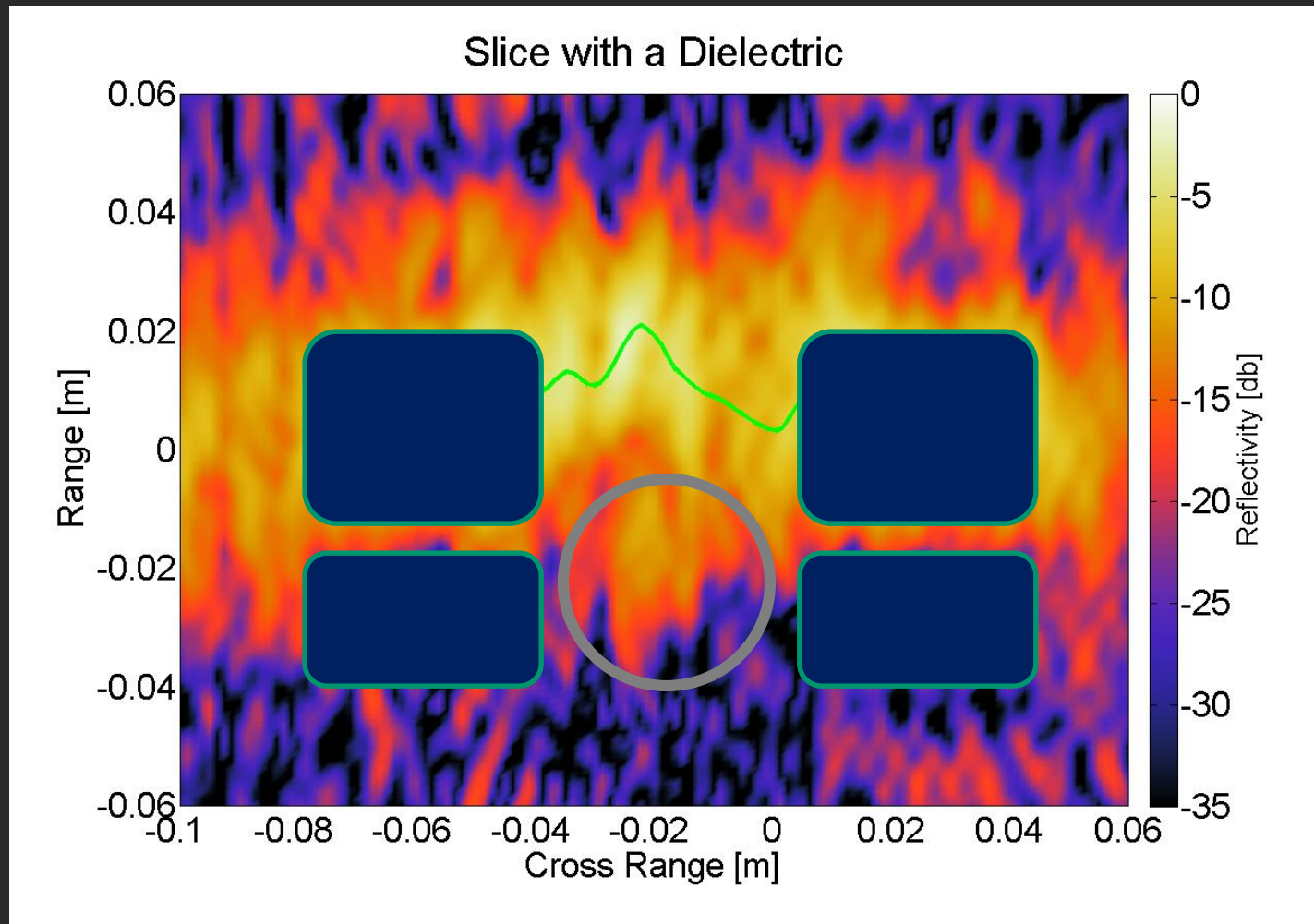


# Weak Dielectric on Skin Characterization – Searching For the Weak First Reflection

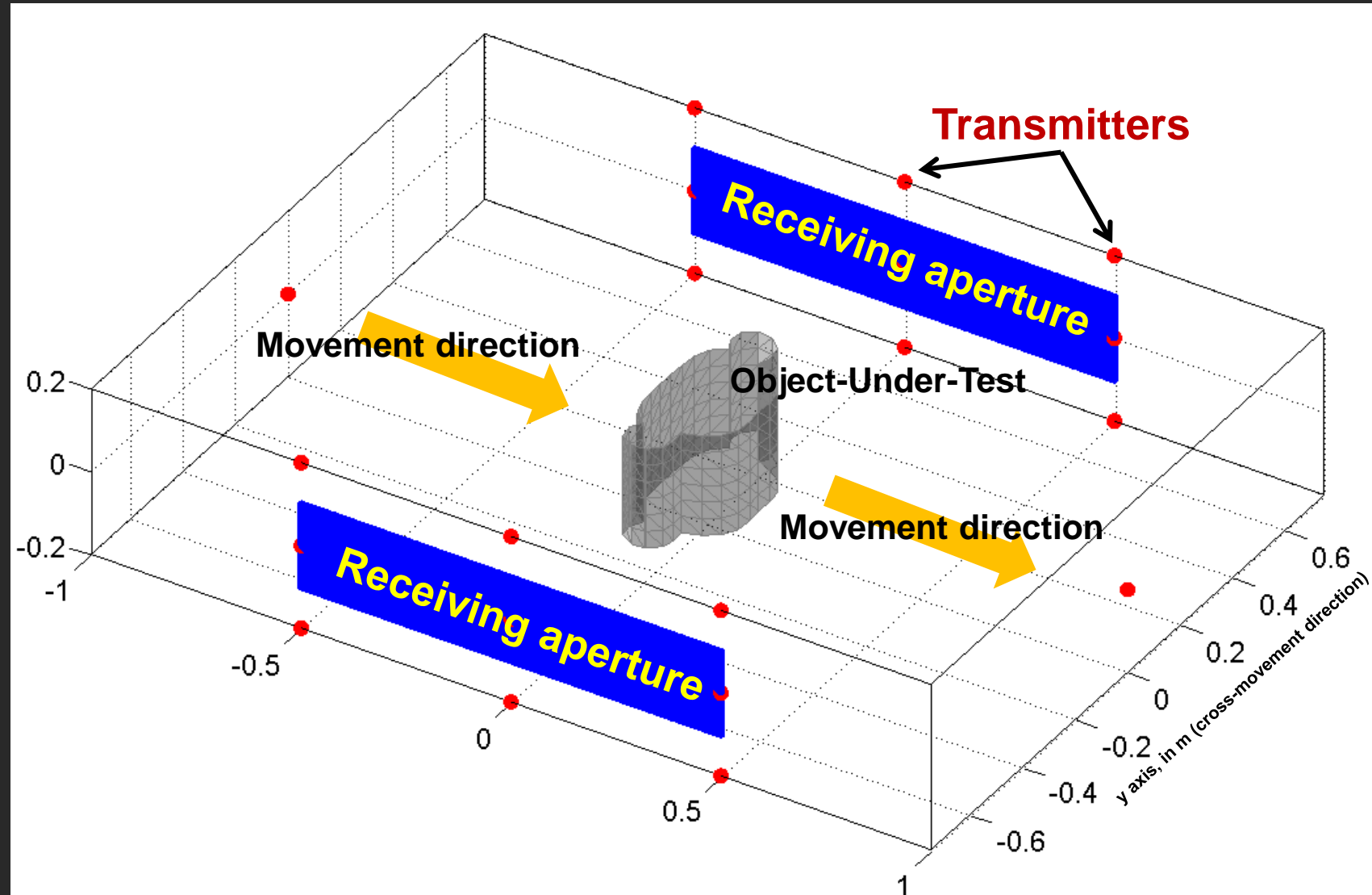




# Weak Dielectric on Skin Characterization – Establishing Front and Back Reflections

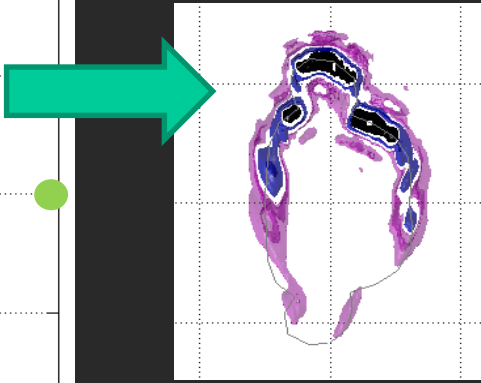
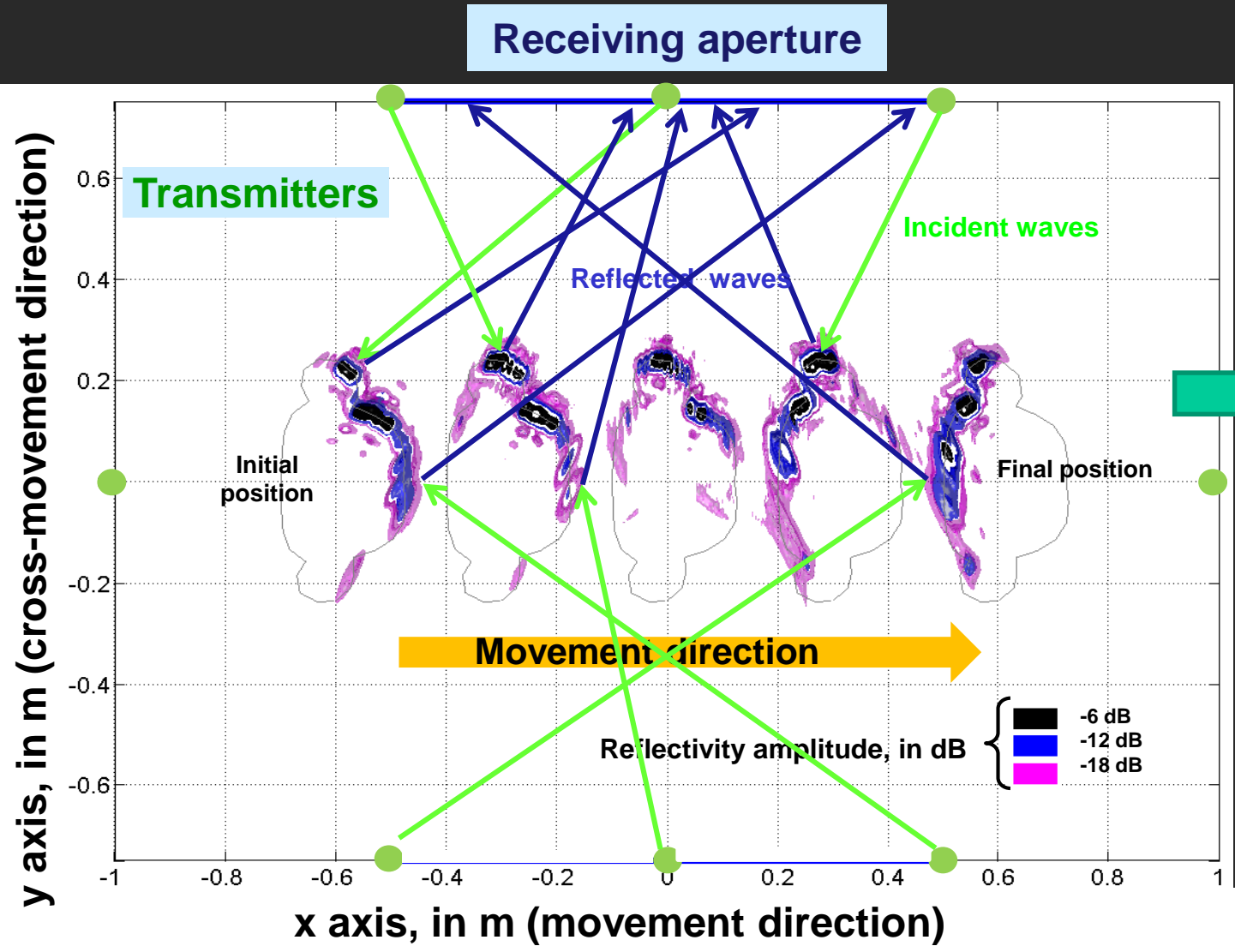


# Hallway, "On-the-Move" Person Scanning Concept – How to Scan Subject's Front and Back





# Imaging results for 5 Body Positions Left (top) Receiving Aperture Only

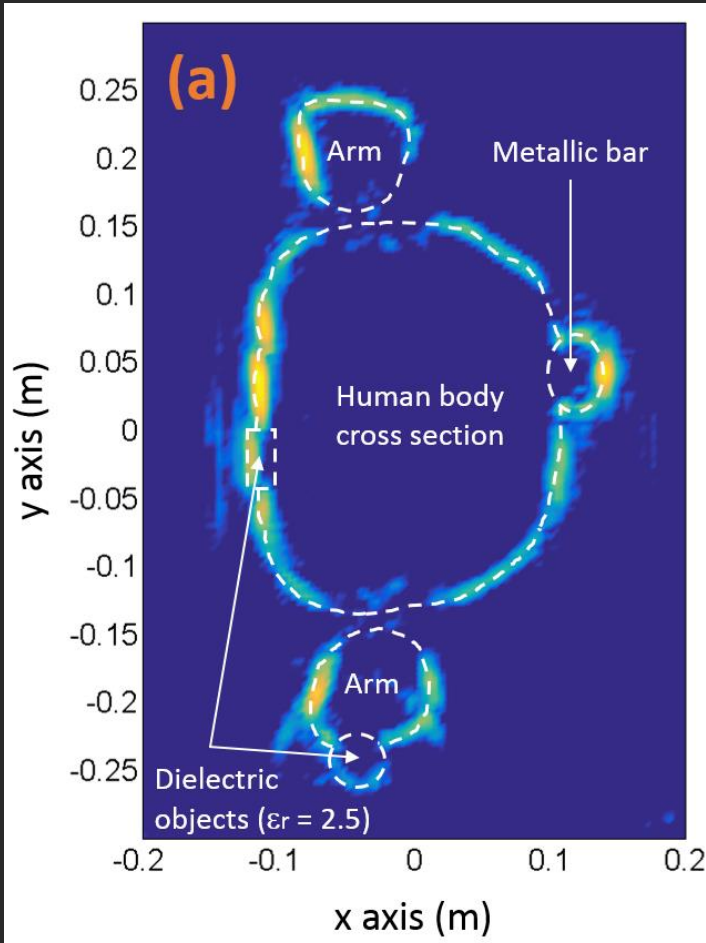


Combination of all images

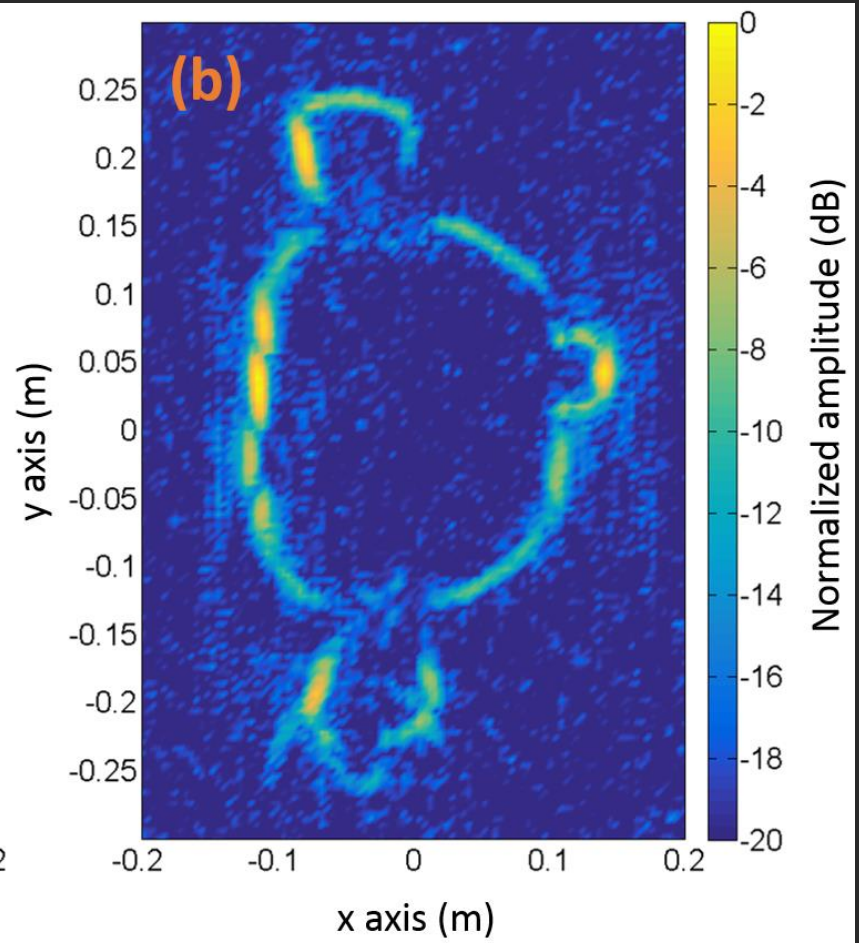


# Combined Image for 5 Body Positions

No Added Noise



-20 dB SNR



Gonzalez-Valdes, Alvarez, Rodriguez-Vaqueiro, Arboleya-Arboleya, Garcia-Pino, Rappaport, Fernando Las-Heras, and Martinez-Lorenzo, "Millimeter Wave Imaging Architecture for On-The-Move Whole Body Imaging," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 6, pp. 2328-2338, June 2016.



# Conclusions

- **Dielectric characterization on skin**
  - Identify depressions for time domain radar
  - Focal point advancement for continuous wave sensing
- **Hallway detector concept**
  - Cooperation between two sides of hallway to image front and back (as well as sides)
  - Transmit on both sides, receive on both sides

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