Automatic SAR Processing for Profile Reconstruction and Recognition of Dielectric Objects on the Human Body Surface

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ALERT – AWARENESS AND LOCALIZATION OF EXPLOSIVES-RELATED THREATS

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Abstract

Contour reconstruction and automatic identification of dielectric objects placed on the human body surface are the aims of the millimeter-wave SAR imaging processing system presented in this paper. Multiple frequencies, multiple receivers and one transmitter in a portal-based configuration are used to generate the SAR image. Then, the information in the image is used to estimate the contour of the body under test together with the permittivity of the dielectric region. The results presented in this paper are based on synthetic scattered electromagnetic field data generated using an accurate FDFD model [4] and inversion based on a fast SAR inversion algorithm [3]. Representative examples showing the good behavior of the method in terms of recognition accuracy are provided.

Relevance

Concealed objects detection and identification of objects placed under clothing is of interest in homeland security issues [1],[2]. The Millimeter-wave (MMW) radar, used in the system proposed in this work, is able to find concealed threats. The proposed method can also detect the presence of concealed dielectric objects and identify its dielectric constant. The importance of this processing method is clear in the context of the automatic identification of concealed explosive related threats or contraband by using millimeter-wave based scanners.

Technical Approach

Millimeter Wave Radar system configuration

The incident beam is generated with an elliptical reflector antenna capable of providing a narrow beam in elevation (z axis). The scattered field is acquired in two arcs placed above and below the reflector antenna. A 2D SAR image is generated on the slice illuminated by the beam.

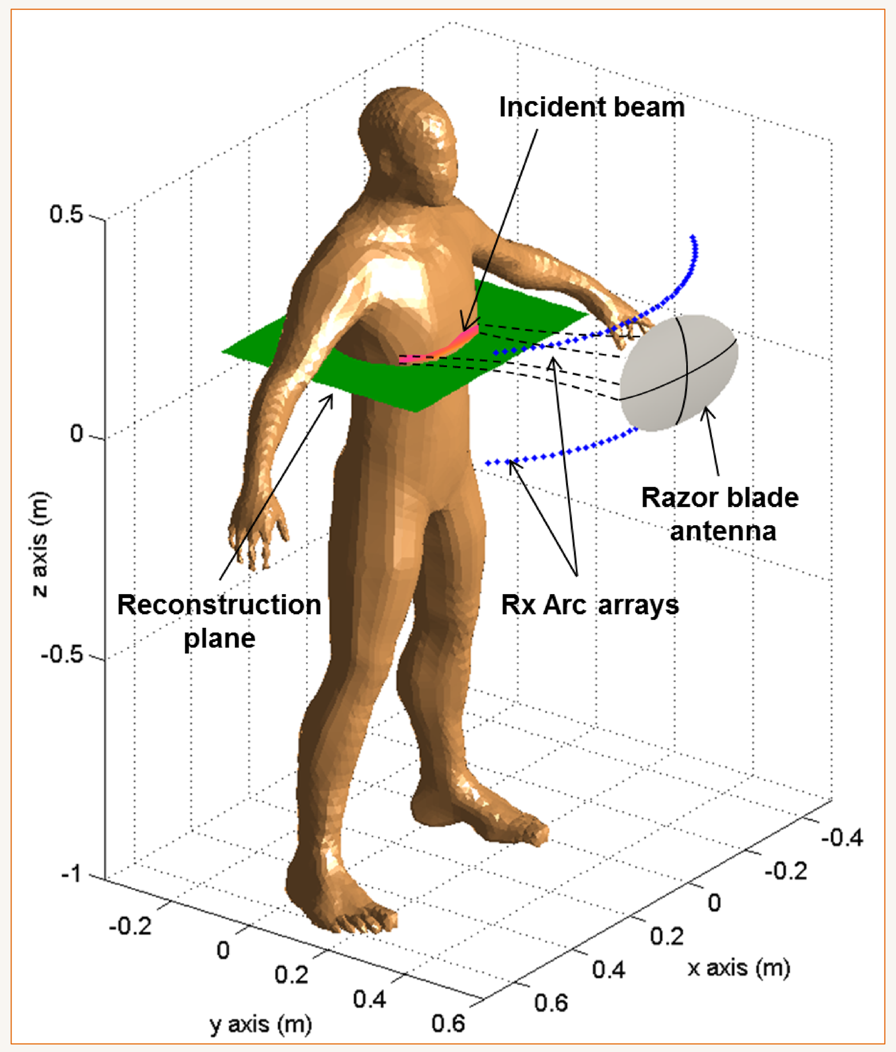


Fig. 1. Proposed mm-wave system setup scheme.

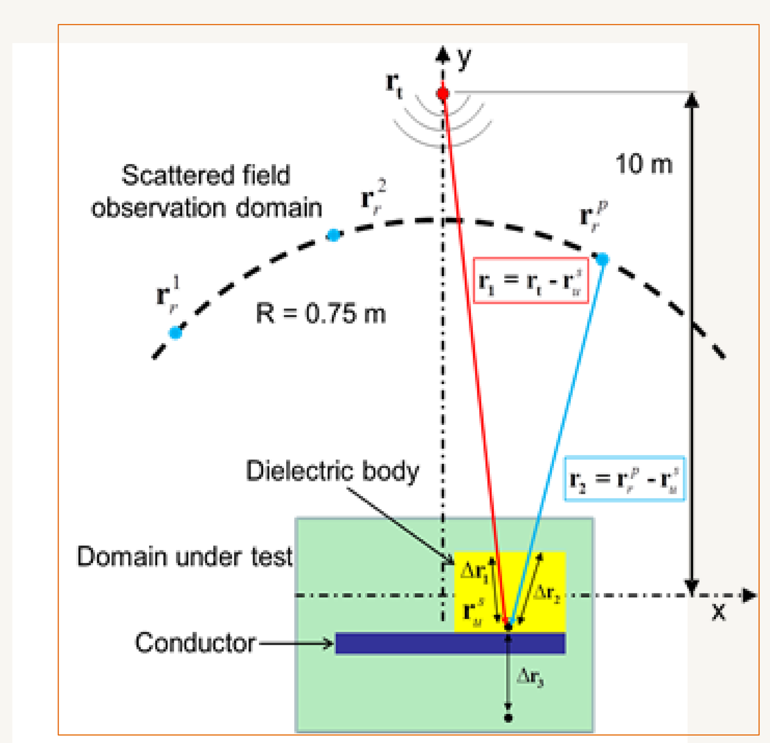


Fig. 2. Measurement setup

Application example and mathematical approach

From the retrieved SAR images, it can be observed that the maximum amplitude values correspond to the positions where the incident field reflects from the skin and dielectric object's surfaces. The SAR imaging artifact of the second reflection, caused by slower wave propagation in the dielectric object provides information to determine its dielectric constant

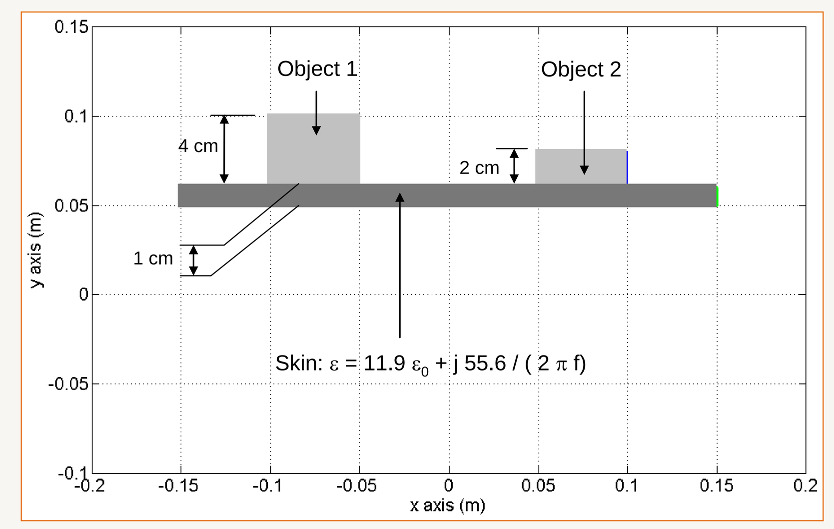


Fig. 3. Geometry and constitutive parameters of the example.

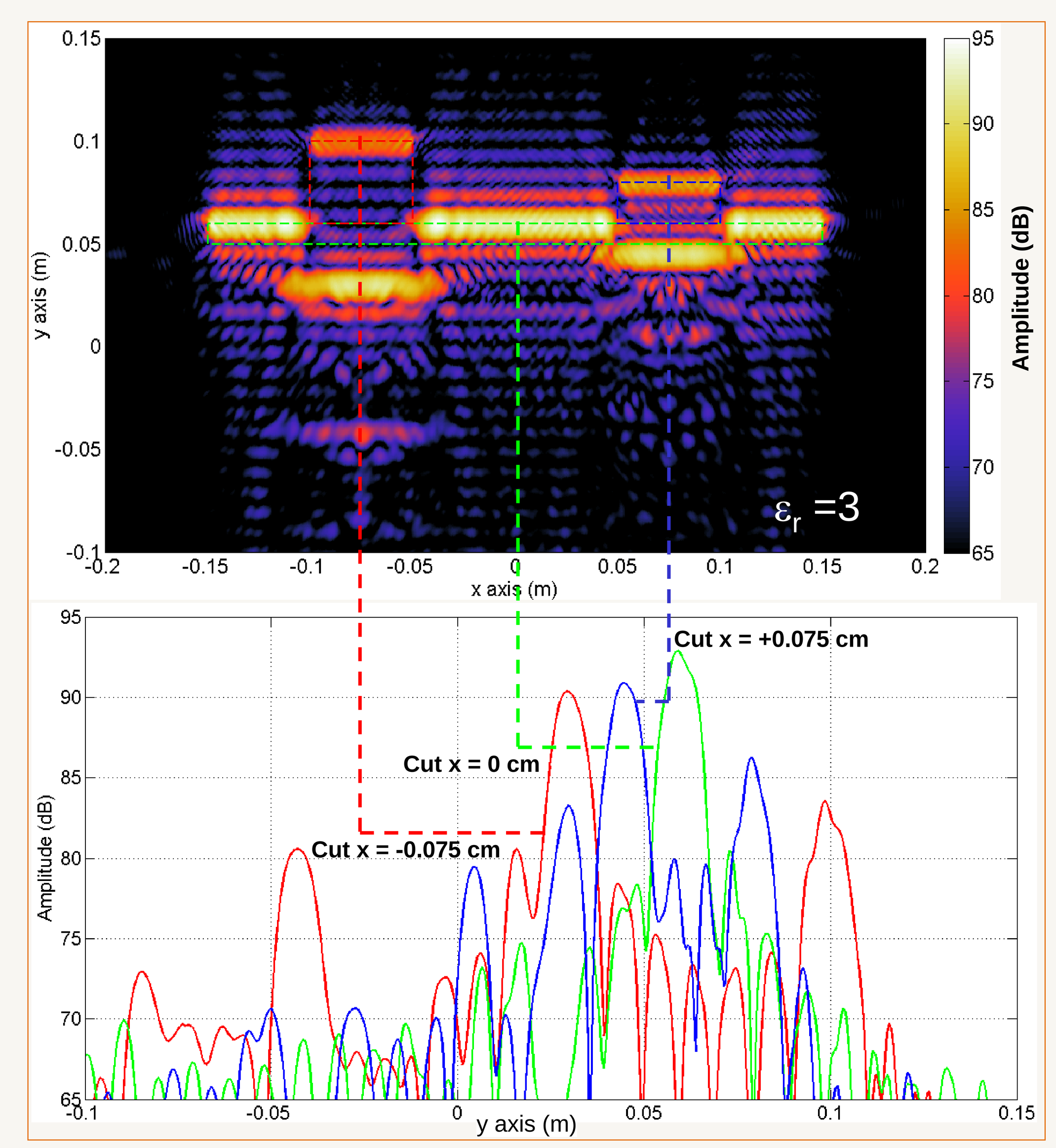
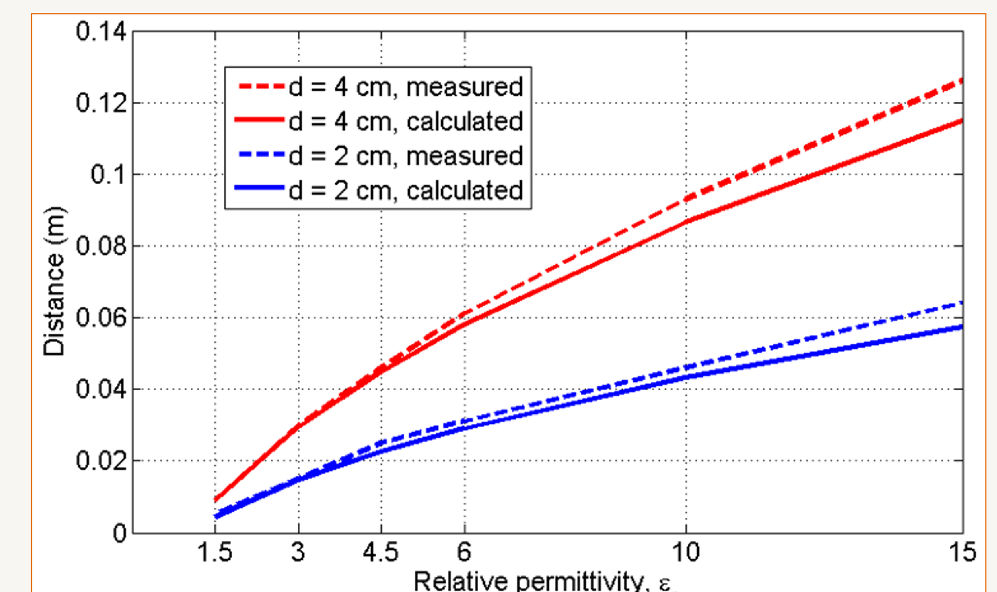


Fig. 4. SAR image (top) and cuts along y-axis for $\varepsilon_r = 3$



$$d_{echo} = d_{obj}\left(\sqrt{\varepsilon_r}-1\right)$$

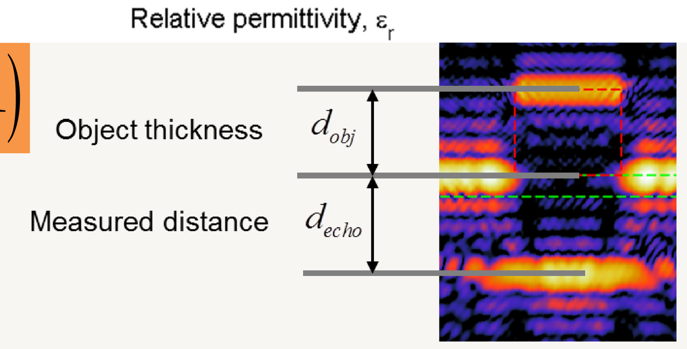


Fig. 5. Calculated and measured distance at which the echo due to the reflection between the dielectric and skin interfaces is located.

Linear relationship between image features and dielectric object permittivity and size

$$\varepsilon_{r,est} = \left(1+\left(d_{echo}/d_{obj}\right)\right)^2$$

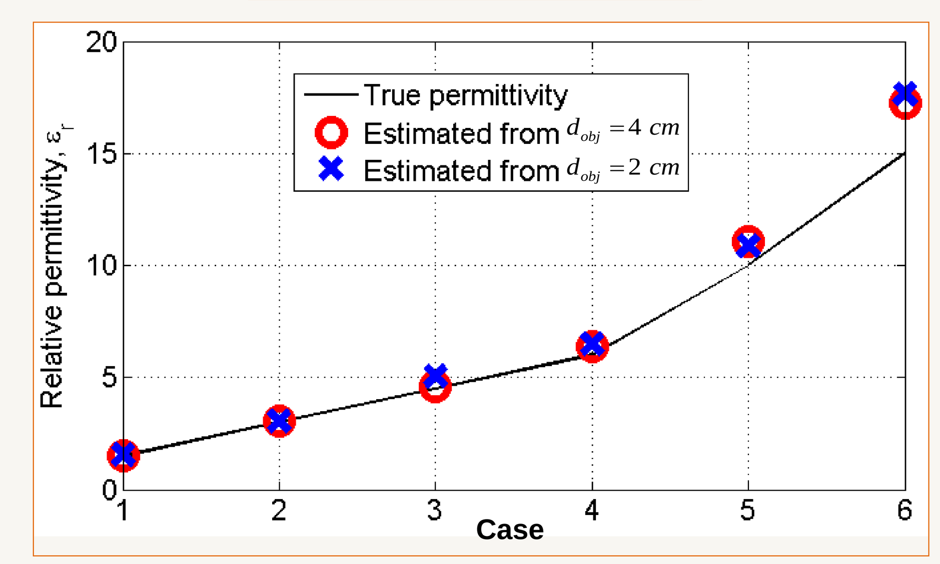


Fig. 6. Relative permittivity. Theoretical and estimated from the SAR image distance among echoes

Embedded objects

The dielectric effect in the SAR image can be also identified for embedded objects.

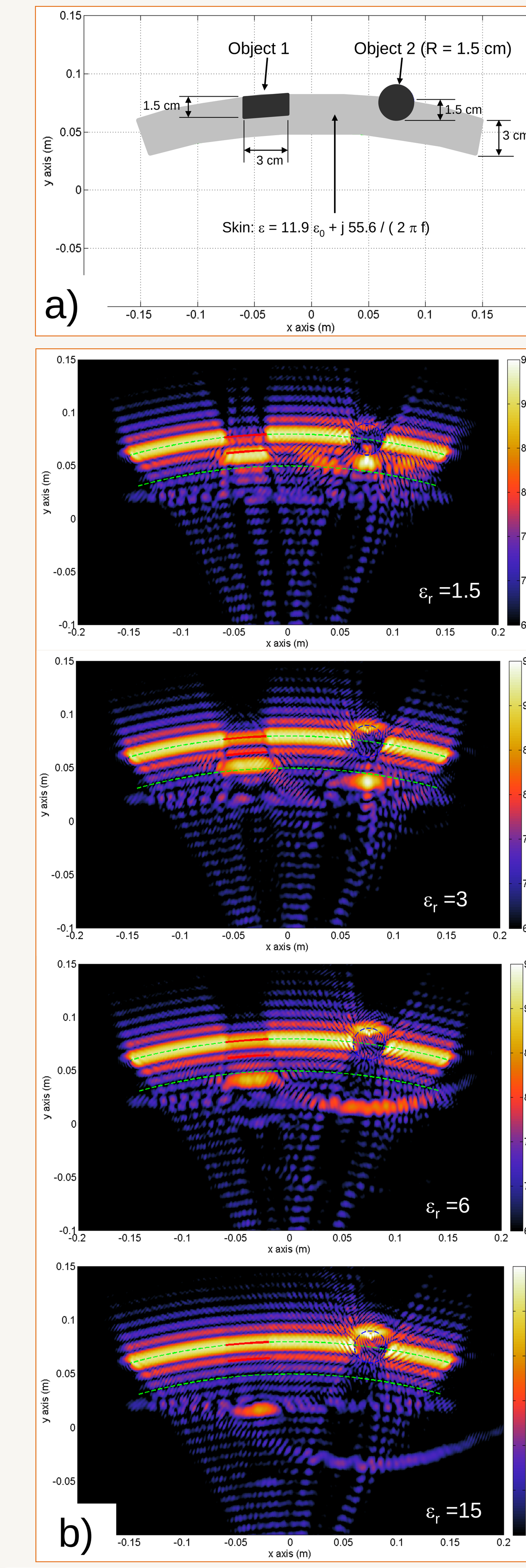


Fig. 7. embedded objects example. a) Geometry b) SAR images for different relative permittivity values

Opportunities for Transition to Customer

The dielectric constant recognition procedure presented in this work is an important feature of the hybrid X-ray/MMW radar whole body imaging system being developed under ALERT funding. This system will be able to substantially improve the image quality of current X-ray or MMW systems and, at the same time, detect the presence of concealed dielectric objects and identify its dielectric constant. The transition to TSA agents can be quickly implemented.

Future Work

1) Experimental testing using our Advanced Imaging Technology testbed.
2) Development of a fully automated recognition algorithm in real time, capable of identifying dielectric objects and, if possible, providing an estimation of the permittivity (e.g. for plastic explosives detection).
3) Improvement of the algorithm for cases where the first reflection is weak.

References

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