FDFD Modeling of Explosive Devices in Discreet Areas of the Human Body

Richard G. Obermeier, Taryn Connor, and Carey M. Rappaport
Work supported by Gordon - CenSSIS, BombDetec, ALERT, and Northeastern University, Boston, MA 02115 (richard.obermeier@gmail.com)

Abstract

As the technological capabilities of explosive threat detection systems have increased over the past few years, terrorists have begun to develop alternative methods for executing suicide bomb attacks. Most recently, the Detroit bomber on December 25, 2009 attempted to detonate an explosive device sewn into his underwear, an area with obvious privacy implications. This document investigates the potential of millimeter-wave radar for detecting explosive devices in sensitive areas of the human body. A 2-D Finite Difference Frequency Domain analysis (FDFD) is used to model innocent and threat target cross-sections located in the pelvic region at a frequency of 3GHz. Preliminary inquiries involve using a priori knowledge to quantify the differences between FDFD scattered field data of threat and innocent targets.

ALERT Structure and State of the Art

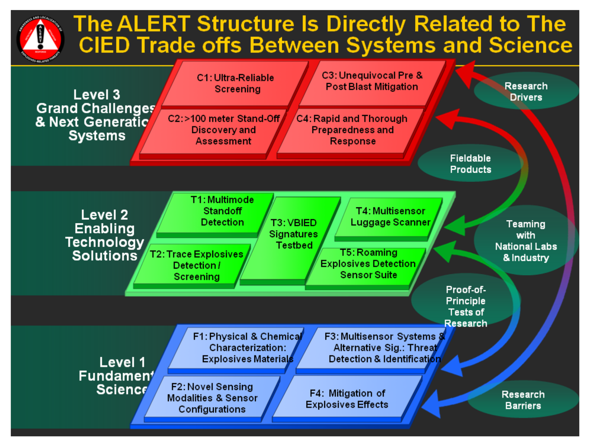


Figure 1: ALERT 3-Level Diagram

- Detection of Concealed Explosives via millimeter-wave radar is part of the Alert 3 Level Diagram: L1-F3, L2-T1, L2-T5, L3-C2
- Full-body imaging scanners are expensive and have obvious privacy issues; single-frequency contour modeling is inexpensive and implements a non-imaging based detection system
- The FDFD simulation specifically seeks to find the fundamental science of the threat detection system (L1-F3)

Single-Frequency Contour Detection System

- It has been proposed [1, 2] that millimeter wave radar has the potential to detect irregular contours along the human body

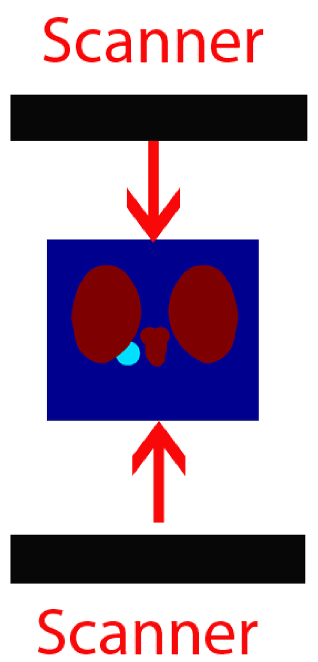


Figure 2: General sketch of our millimeter-wave, single frequency body scanner

- Scanner transmits a signal of a single frequency from front and back and measures the steady-state frequency response
- Response is used to construct a contour model of the target which is implemented in the FDFD computational model, assuming the entire target consists of human tissue
- FDFD modeled data and physical data are compared to determine whether the target is innocent or a threat

Base Geometries

- Simulation geometries were based upon 2-D cross sections of male and female specimens from the Visual Human Project located in the pelvic region

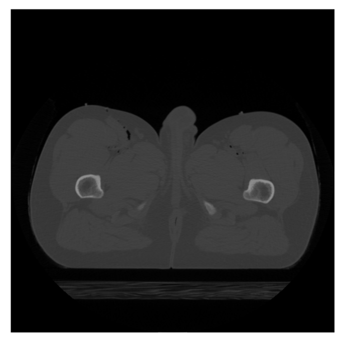


Figure 3: Specimen from the Visible Human Male - Pelvis subset

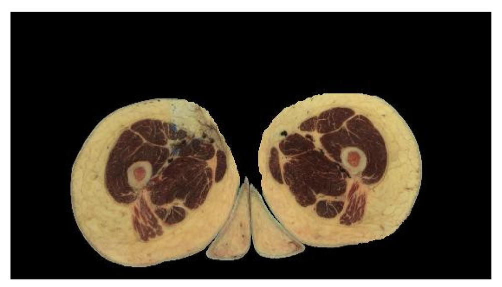
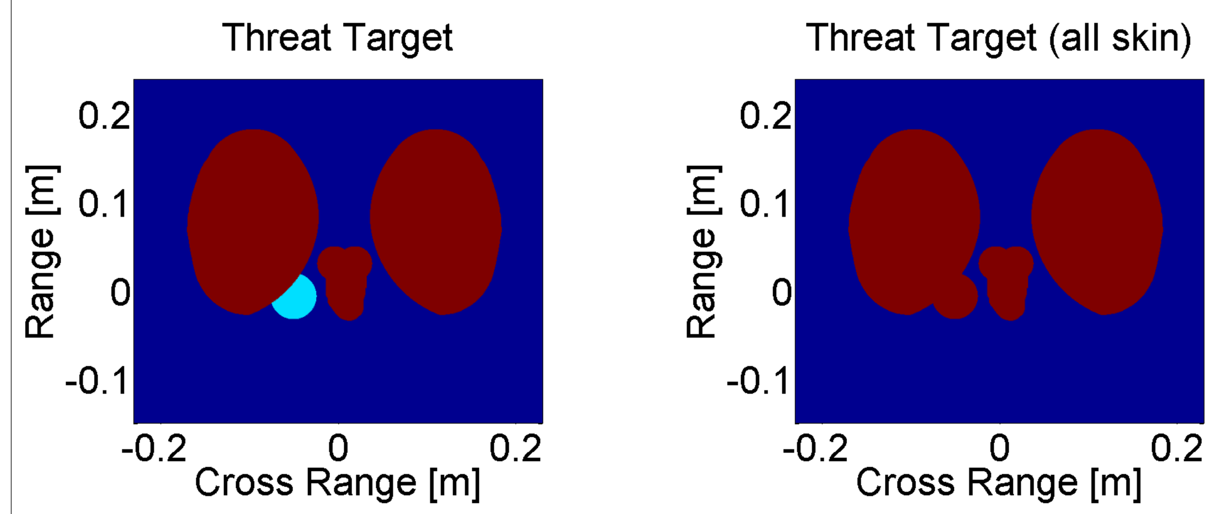


Figure 4: Specimen from the Visible Human Female - Pelvis subset

Simulation Parameters

- Frequency: 3 Ghz
- Transmitter: Uniform Plane Wave, Normal Incidence (Front)
- Explosive Device: TNT ($\varepsilon_r = 2.9$)
- Human Properties: High water content human muscle: $\varepsilon_r = 46$, $\sigma = 2.27$ S/m, Skin Depth ≈ 1.61 cm [3]

Results - Male Target



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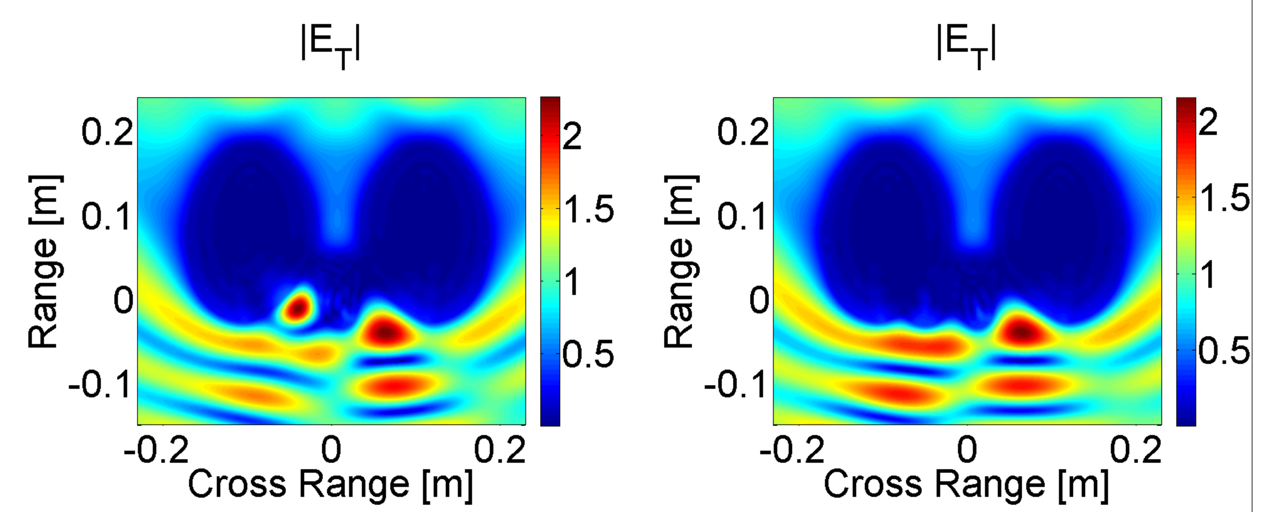

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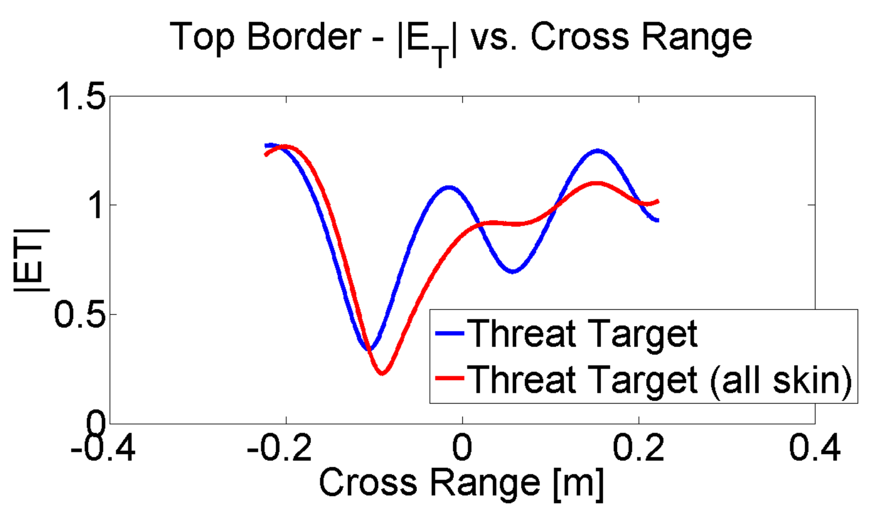
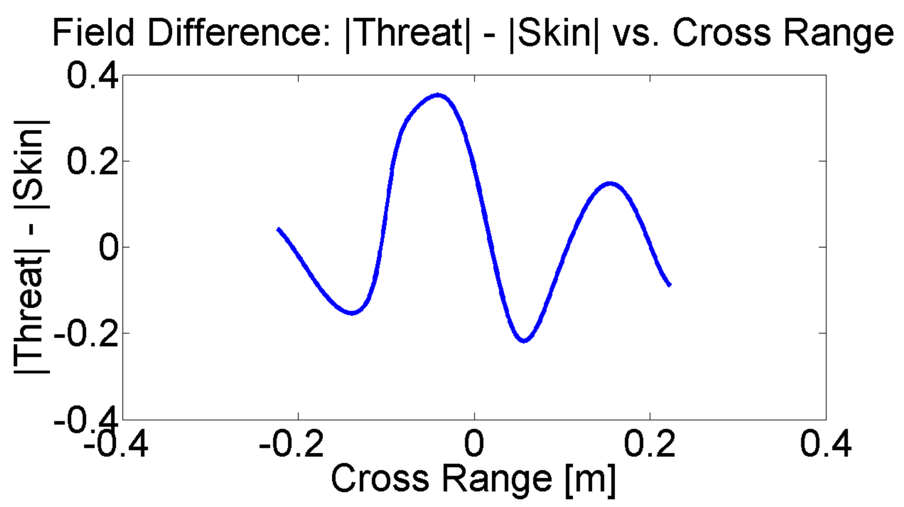
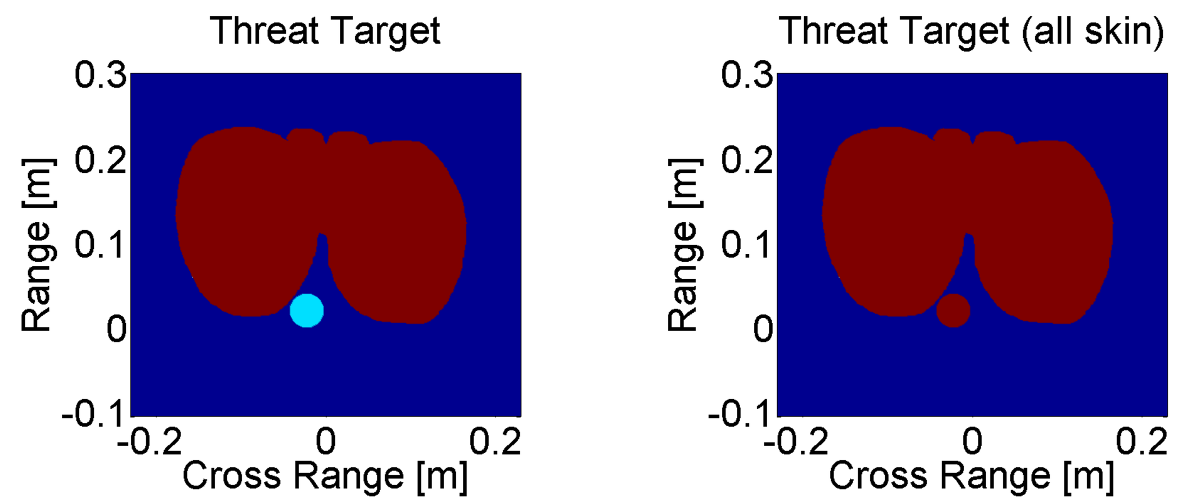




Results - Female Target



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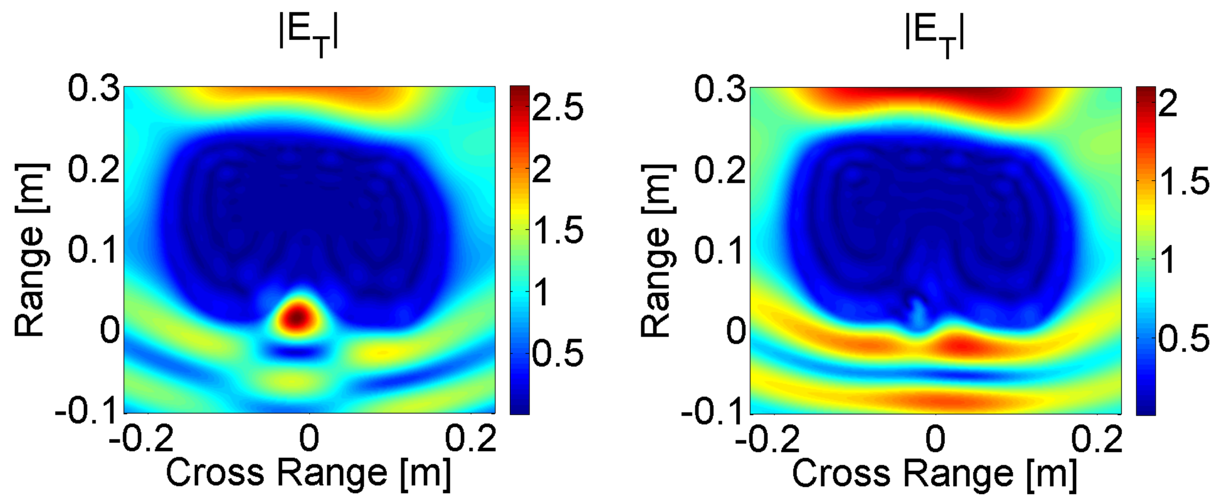

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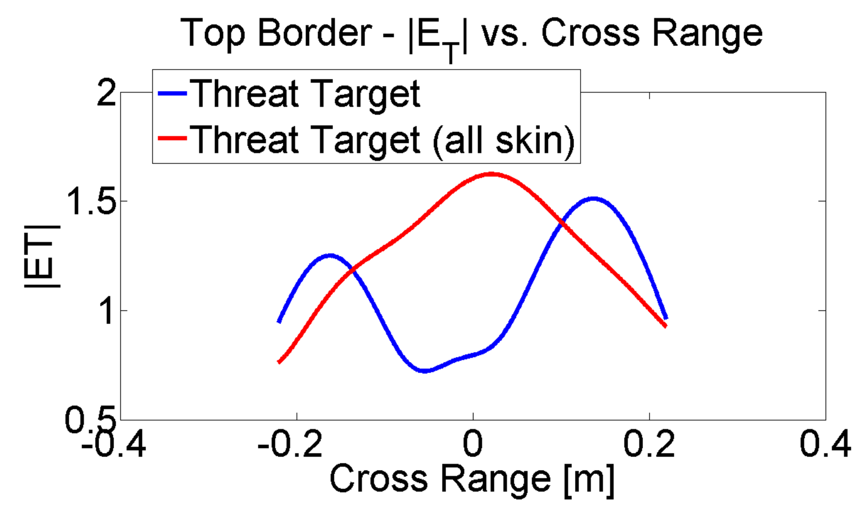
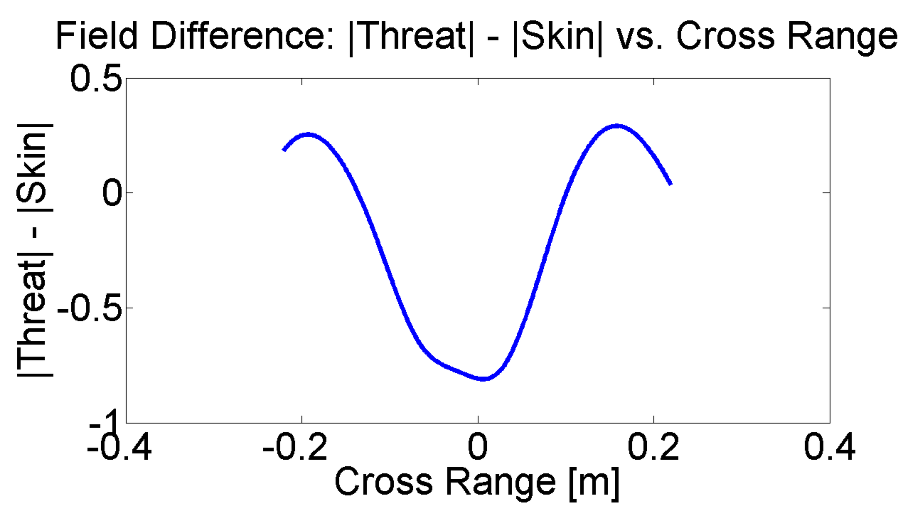
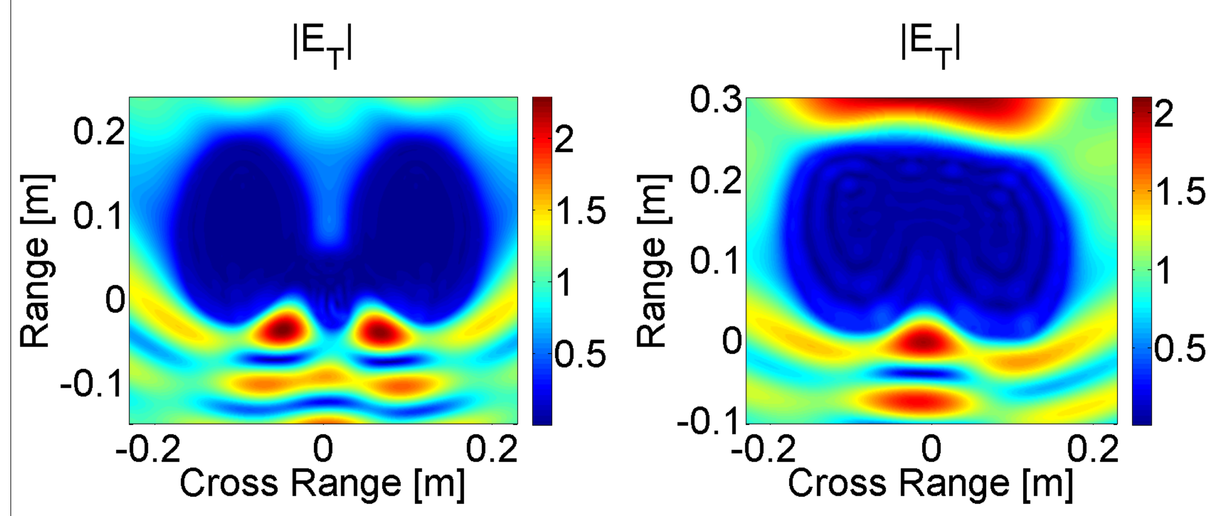


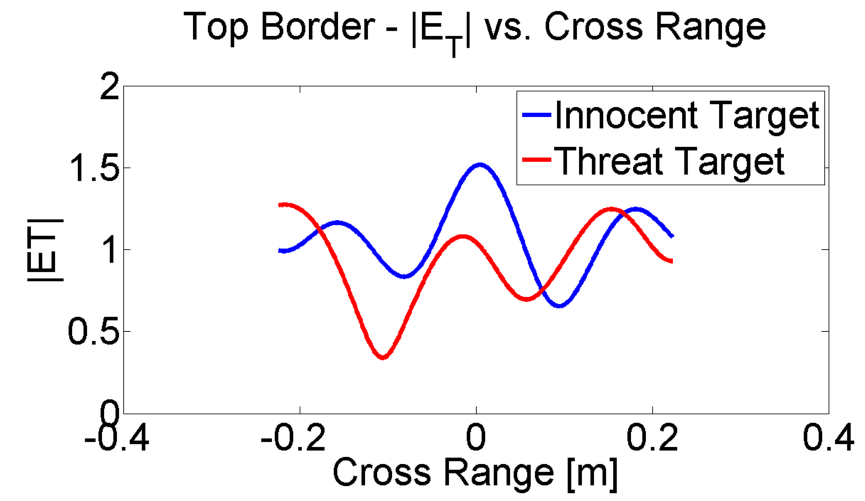


This material is based upon work supported by the U.S. Department of Homeland Security under Award Number 2008-ST-061-ED0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied of the U.S. Department of Homeland Security.

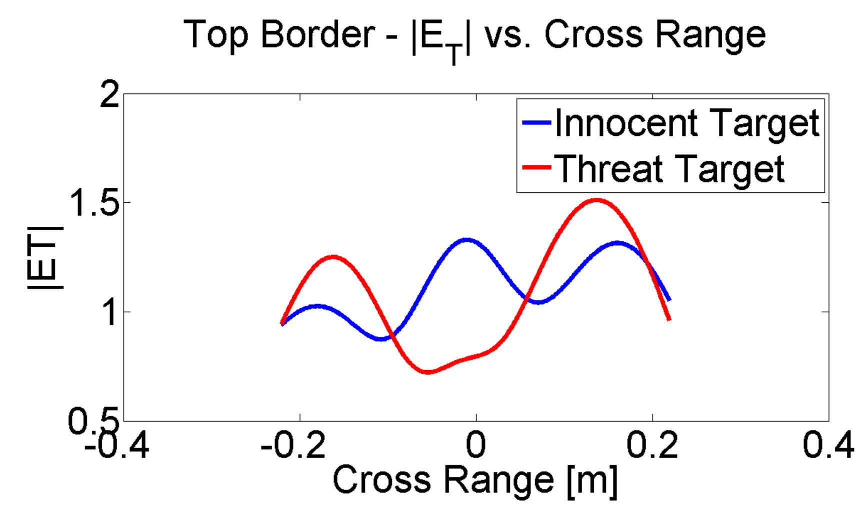
Innocent vs. Threat Target



Male



Female



Conclusions

- Innocent and Threat targets are distinguishable at 3GHz
- Responses of regular threat and "skin" threat targets at 3GHz are noticeably different
- Assuming ideal contour construction, the system is able to detect unnatural responses

Future Work

- Integrate contour construction algorithms into FDFD modeling
- Develop methods to differentiate between threat object and inaccurate contour construction

References

[1] Martinez-Lorenzo, J. A., Rappaport, C. M., et al. , "Standoff Concealed Explosives Detection Using Millimeter-Wave Radar to Sense Surface Shape Anomalies". , AP-S 2008, IEEE AP-S International Symposium, San Diego, CA, USA, Jun. 2008.

[2] Martinez-Lorenzo, J. A., Rappaport, C. M., Sullivan, R. and Pino, A. G., "A Bi-static Gregorian Confocal Dual Reflector Antenna for a Bomb Detection Radar System". , AP-S 2007, IEEE AP-S International Symposium, Honolulu, Hawai'i, USA, Jun. 2007.

[3] Johnson, C,C, Guy, A.W, "Nonionizing electromagnetic wave effecits in biological materials and systems". , Proceedings of the IEEE, vol. 60 no. 6, pp. 692-618, Jun. 1972.