Terahertz Spectroscopic Imaging for Standoff Detection of High Explosives

Michael W. Burke
(925) 422-0192
burke22@llnl.gov

RDX (1,3,5-trinitro-1,3,5-triazacyclohexane), a component in plastic explosives, including C-4 and Semtex-H, is extremely difficult to detect using air sampling due to its low vapor pressure (10 ppt). This project is examining the feasibility of using terahertz (THz) radiation in the standoff detection and identification of this high explosive (HE) compound. Our approach uses emerging spectroscopic and imaging technologies in the THz frequency regime. We propose to first develop a system-level analysis, a system simulation, and an experimental program.

The THz portion of the electromagnetic (EM) spectrum is rich with spectroscopic information about small- and medium-size molecules. RDX-based HE exhibit a distinctive sub-THz signature near 800 GHz that distinguishes them from common background materials (Fig. 1). Since THz radiation can penetrate common dielectric concealants (*e.g.,* fabrics and leather), and provides reasonable spatial resolution for imaging applications, spectral imaging near 800 GHz may provide a solution to the RDX detection problem.

Our primary goal is to assess the utility of THz spectral imaging for the detection of concealed, RDX-based explosives, for reliable RDX screening of people at safe (30- to 50-m) standoff distances. Our approach is to develop a systems concept and multispectral detection algorithms, and simulate the behavior of such a system in the presence of atmospheric absorption, obscurant losses, and system noise. Our final goal is to demonstrate detection of RDX-based explosives at 30 to 50 m through a concealing material, using multispectral imaging.

The algorithm is a two-channel approach that compares the return signal from two points on a target to remove the effects of the intervening atmosphere (Fig. 2), and then compares the return signals to a database of spectral signatures. Our strategy is to collect THz spectral data for materials of interest from both experiments and the literature, and combine it with systems analysis and simulation to assess the viability of the remote sensing capability.

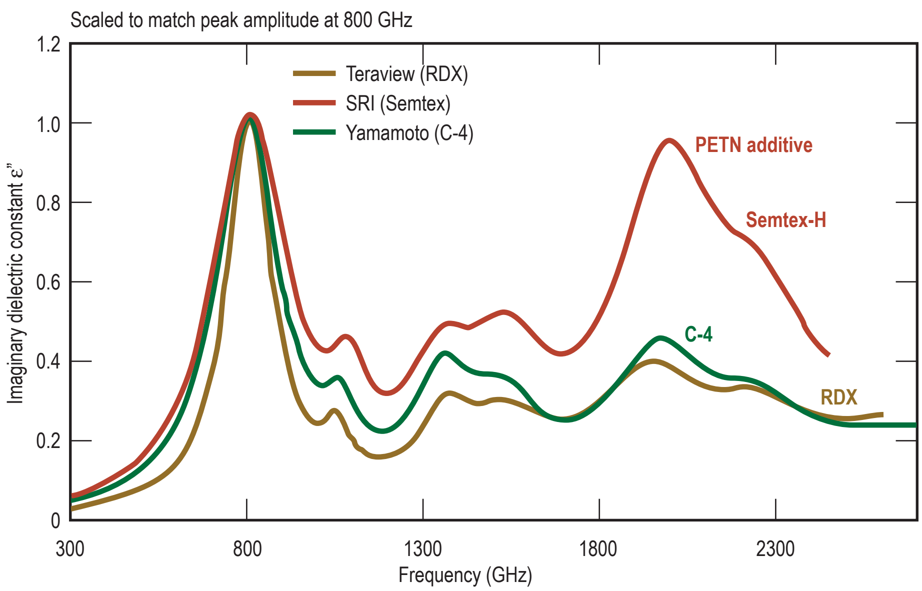

Figure 1. RDX-based HE signature. A distinctive sub-THz signature near 800 GHz distinguishes them from common background materials.

Relevance to LLNL Mission

Explosives detection that enables the interdiction of terrorists is an important capability for LLNL's missions in both national security and homeland security.

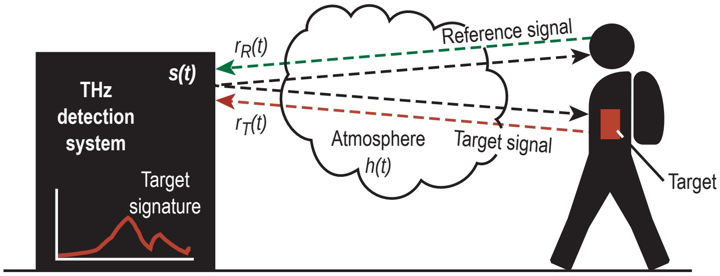

Figure 2. Two-channel approach. The return signals from two points on a target are compared to remove the effects of the intervening atmosphere. The return signals are then compared to a database of specral signatures.

FY2007 Accomplishments and Results

In FY2007, we developed a systems concept (link budget) and supporting algorithms for standoff THz spectral imaging. In particular, we: 1) completed collection of THz data on common HE materials; 2) developed a systems concept and link budget for a THz spectral imager; 3) developed supporting algorithms for THz spectral imaging; and 4) executed several Monte Carlo simulations of system performance.

The algorithms developed were for deconvolving the spectral modifications induced by atmospheric propagation. We simulated the performance of this system using atmospheric absorption data from HITRAN (a standard database of atmospheric absorption properties), and material parameters we obtained.

Results of these simulations show the proposed system can achieve detection of bulk HE at safe standoff distances (~30 to 50 m), even when the explosive is concealed by a few layers of fabric. Simulated receiver operation characteristic curves, which show the probabilities of detection and false alarm, show excellent discrimination of C-4 against innocuous materials such as skin and lactose (Fig. 3).

Related References

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4. Bjarnason, J. E., *et al.*, "Millimeter-Wave, Terahertz, and Mid-Infrared Transmission Through Common Clothing," *Appl. Phys. Lett.*, **85,** p. 519, 2004.

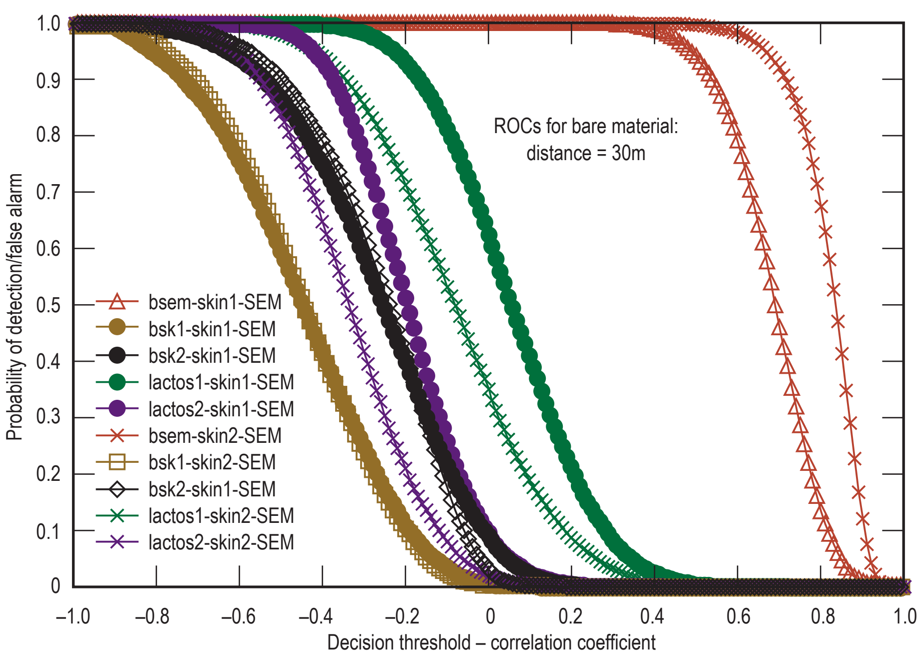

Figure 3. ROC-type curves for different targets (HE, skin, and lactose interferents), no covering material, at 30 m standoff. Skin 1 and 2 and lactose 1 and 2 are four different targets differing in their spectral reflectance.

FY2008 Proposed Work

In FY2008 we will seek outside funding to verify experimentally our algorithms for spectral detection of RDX in the presence of atmospheric losses and concealants. We will first explore near-THz (800 to 900 GHz) imaging at the necessary standoff distances; then, if results are favorable, extend measurements to two lower frequency bands to obtain the required multispectral coverage.