Imaging at a Stand-off Distance with Terahertz FMCW Radar

***Goutam Chattopadhyay*[1], *Ken B. Cooper*[1], *Robert Dengler*[1], *Nuria Llombart*[2], *and Peter H. Siegel*[1]**

[1]Jet Propulsion laboratory, California Institute of Technology
M/S 168-314, 4800 Oak Grove Dr
Pasadena, CA 91109, USA
goutam@jpl.nasa.gov

[2]Universidad Complutense de Madrid,
Madrid 28040, Spain
nuria.llombart@opt.ucm.es

Demand for new surveillance capabilities for usage in airport screenings and battlefield security check-points has led to the development of terahertz imagers and sensors. There are several advantages of imaging at terahertz frequencies compared to microwave or infrared: the wavelengths in this regime are short enough to provide high resolution with modest apertures, yet long enough to penetrate clothing. Moreover, unlike in infrared, the terahertz frequencies are not affected by dust, fog, and rain.

Several groups around the world are working on the development of terahertz imagers for various applications. One option is to use passive imaging techniques, which were very successful at millimeter-wave frequencies, by scaling in frequencies to terahertz range. However, the background sky is much warmer at terahertz frequencies due to high atmospheric absorption. Since passive imagers detect small differences in temperatures from the radiating object against the sky background, at these frequencies passive imagers do not provide enough scene contrast for short integration times. On the other hand, in an active imager, the object is illuminated with a terahertz source and the resulting reflected/scattered radiation is detected to make an image. However, the glint from the background clutter in an active terahertz imager makes it hard to provide high fidelity images without a fortunate alignment between the imaging system and the target.

We have developed an ultra wideband radar based terahertz imaging system that addresses many of these issues and produces high resolution through-clothes images at stand-off distances. The system uses a 675 GHz solid-state transmit/receive system in a frequency modulated continuous wave (FMCW) radar mode working at room temperature. The imager has sub-centimeter range resolution by utilizing a 30 GHz bandwidth. It has comparable cross-range resolution at a 25m stand-off distance with a 1m aperture mirror. A fast rotating small secondary mirror rapidly steers the projected beam over a 50 x 50 cm target at range to produce images at frame rates exceeding 1 Hz.

Fig. 1 shows a radar image taken in 1 second using our 675 GHz FMCW radar at 25m stand-off distance. In this talk we will explain in detail the design and implementation of the terahertz imaging radar system. We will show how by using a time delay multiplexing of two beams, we achieved a two-pixel imaging system using a single transmit/receive pair. Moreover, we will also show how we improved the signal to noise of the radar system by a factor of 4 by using a novel polarizing wire grid and grating reflector.

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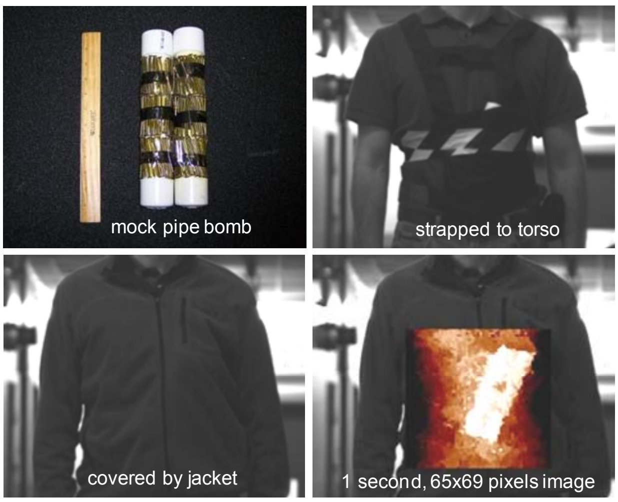

Fig. 1: Through-clothes concealed weapon imaging with a 675 GHz FMCW radar at 25 m stand-off distance.

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