Building a High Performance, Multistatic Mm-Wave Imaging Radar for AIT

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Abstract

The AIT group is developing a new hardware platform consisting of mechanical and electrical subcomponents for capturing imaging data in a multi-static radar environment.

Using an innovative architecture approach along with novel algorithms the resulting system will provide highly improved resolution compared to leading edge scanners available on the market today.

Relevance

- Bridging the gap between high-performance, commercially available technology components and security requirements
- Improves underlying technology platform as well as algorithms; reduces detection errors and decreases false positive results
- Develops modular, expandable, and scalable infrastructure; can be extended to various Homeland Security relevant applications

Impact

- Resulting platform will be available to validate a multitude of software and mathematical algorithms
- Future advancements in industrial and commercial electronics will be leveraged directly into new revisions of the hardware platform
- The mechanical and electrical platform will advance state-of-the art; expand field of knowledge through graduate student research, conferences, and journals

Technical Approach

Radar Hardware

Data was collected using a step frequency radar that operates between 56.5 – 63.5 GHz for a total bandwidth of 7 GHz. There are separate transmitter and receiver modules, shown in Figure 1, that synchronize using a common clock.

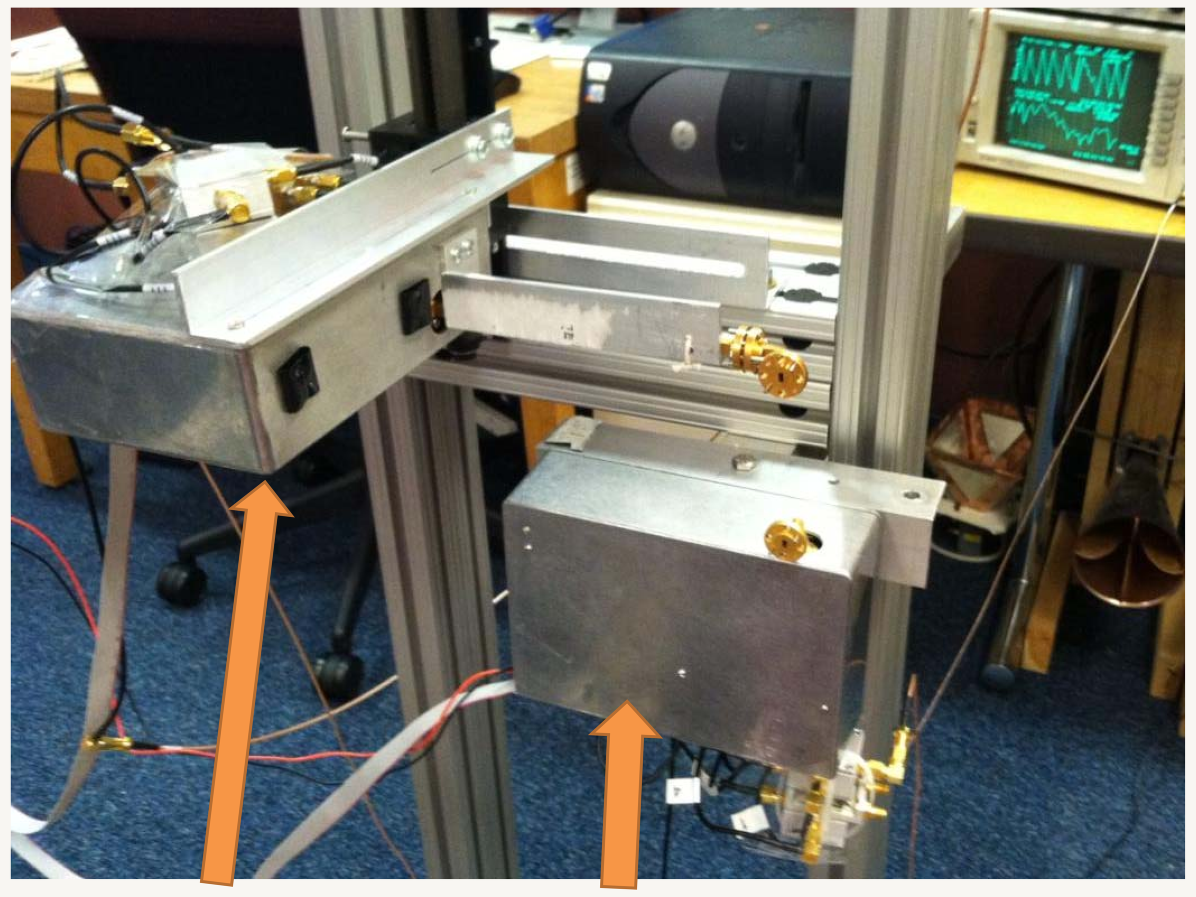

Figure 1 – Transmitter and receiver modules with waveguide output

Phase and amplitude are recorded using a vector network analyzer (VNA). Because frequency mixing and upconversion occurs within the radar modules, the VNA operates on lower frequency 0 – 550 MHz baseband signals.

Imaging

Two-dimensional, cross-section images were reconstructed from data collected in a multi-static hardware configuration. Figure 2 and Figure 3 show the reconstructed images of a metal plate by itself and with a piece of 1" square aluminum on the surface, respectively.

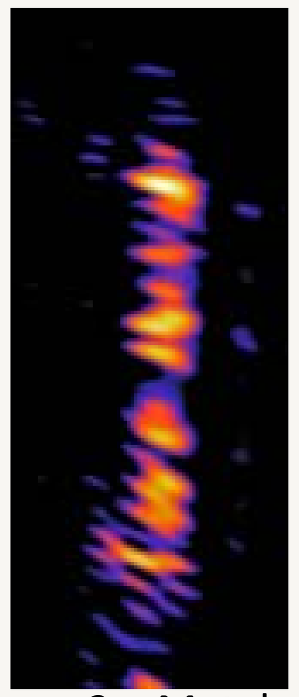

Figure 2 – Metal plate

Aluminum protrusion added to the surface of the plate

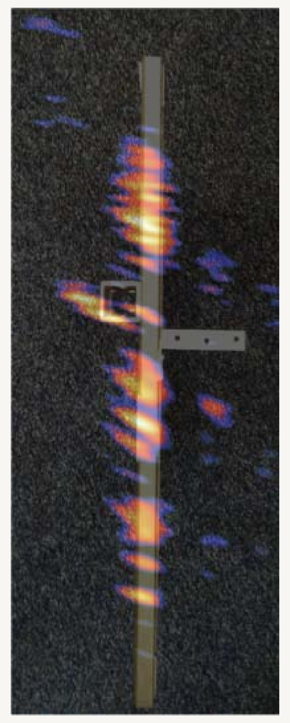

Figure 3 – Metal plate with 1" square aluminum protrusion

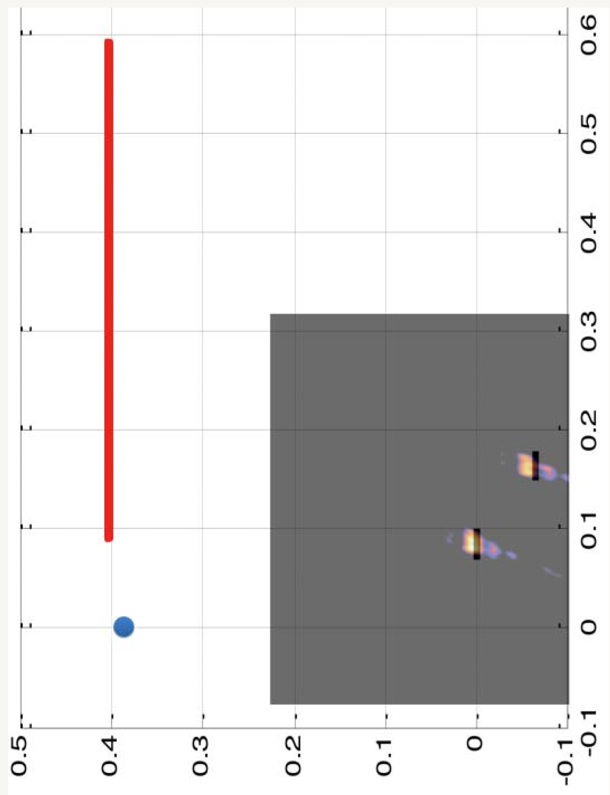

Figure 4 – Metal strips

Figure 4 (left) shows the reconstructed image of two metal strips with height and range offset overlaid on the data collection geometry. The blue dot is the receiver position and the red line is the transmitter motion.

Target Illumination

A custom parabolic antenna will be used for precise target illumination as shown in Figure 5 below. The antenna will illuminate a 1 cm wide strip on the surface of the body allowing for two dimensional reconstruction techniques. The mounted antenna and feed are shown in Figure 6 with the simulated and measured power patterns at the focal distance. The measured pattern closely matches the simulated results and there is a greater than 3 dB power drop off outside of the 1 cm wide beam peak. The first side lobe levels are about 8 dB below the main beam.

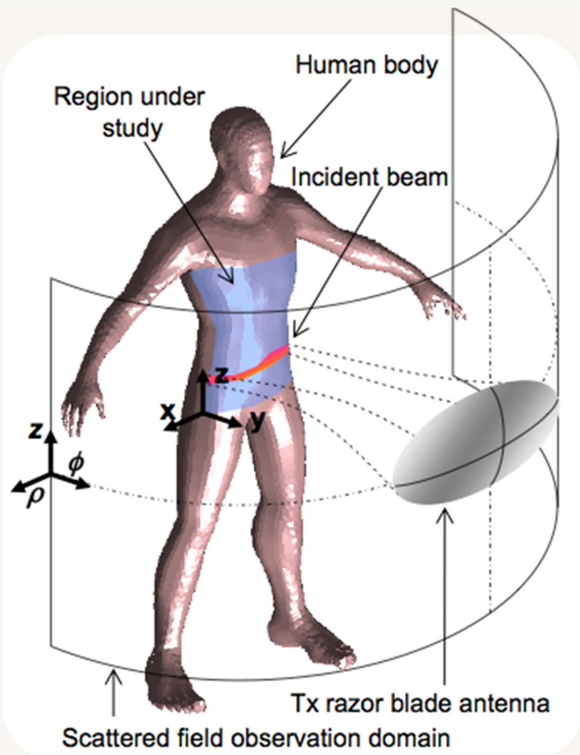

Figure 5 – Parabolic Antenna

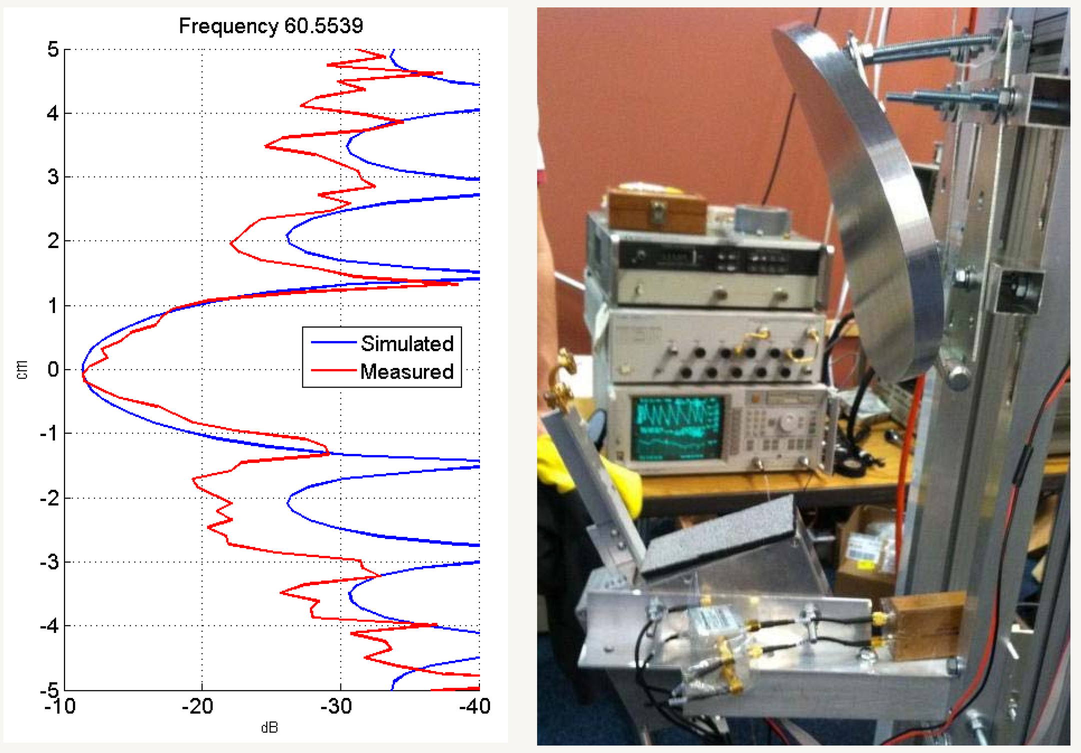

Figure 6 – Antenna with radiation pattern

Accomplishments Through Current Year

Over the course of the last year, this project has grown from a concept with simulations and minimal hardware to a functioning, imaging radar built on an imaging testbed. We have collected 2D multi-static data and successfully reconstructed target objects. The same algorithm with a new geometry can be used in stacking 2D images to create a 3D image. A custom, novel antenna has also been designed, built, and characterized with results indicating performance on par with the simulated data.

Future Work

We have proven the capabilities of the radar hardware, antenna, and imaging algorithm and now need only to integrate them to create three-dimensional images. Once integrated, we will be able to perform calibration to further improve image quality. We will also work to incorporate new data acquisition hardware for faster collection times.

Publications Acknowledging DHS Support

C. Rappaport and B. González-Valdés, "The Blade Beam Reflector Antenna for Stacked Nearfield Millimeter-Wave Imaging," IEEE Int'l Symp. On Antennas and Propagation, Chicago, IL, July 2012

Other References

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[2] 60GHz Technology for Gbps WLAN and WPAN: From Theory to Practice, SK Yong, Alberto Valdes-Garcia, 2011
[3] C. H. Park, T. S. Rappaport, "Short-Range Wireless Communications for Next-Generation Networks: UWB, 60 GHz Millimeter Wave PAN", 2007

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