FMCW Signal Processing for Detecting Explosives-related Threats using Near Field and Standoff MMWR

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Abstract

In this poster the imaging from the microwave frequency modulated continuous wave (FMCW) radar system is investigated with synthetic aperture radar (SAR) processing. The transmitter has a 2-dimensional array which is used to generate 3-dimensional scattering images. These 3-dimensional images are better representations of real objects and can be used to more precisely find anomalies such as explosive threats on the human body.

Relevance

Standoff detection is very important because it can help detect concealed threats on the human body. The mm-waves radar is the ideal modality for standoff detection because it can penetrate clothing, has high resolving resolution and reacts to the dielectric contrast of interest (explosives). The 2-dimensional rail-SAR is an inexpensive stepping stone to mm-wave radar and can be expanded to the next generation of 2-dimensional fixed aperture radar. The SAR processing that is used is a more precise inversion method for generating the 3-dimensional reflectivity images of the objects in the near distance of about 1.5m.

Accomplishments Through Current Year

We have improved the 2-dimensional SAR processing algorithm for 3-dimensional imaging with real measured data. Working with measured data needs consideration of different mechanical and electromagnetic aspects which have been resolved.

Future Work

We will work more on other forms of noise reduction in the reconstruction images and we continue with the 3-dimentional imaging of threat related objects.

Technical Approach

Introduction:

The data that is measured from a 60GHz FMCW radar has been analyzed with a SAR processing algorithm. In this processing method the received signal at each time is considered as the summation of delayed backscattered echoes from all the points in the scene as in Eq.1. The contribution of each point to this signal is proportional to its unknown reflectivity $\rho(m)$.

$$S_{IF}(n) = A(n,m)\rho(m) \qquad \text{(Eq. 1)}$$

The coefficient matrix $A(n,m)$ accounts for the instantaneous frequency $f_c + \alpha t_n$ and the time delay of a pulse to travel from the transmitter antenna to a reflection point and back to the receiver τ_m .

$$A(n,m) = \exp\left(j2\pi(f_c\tau_m + \alpha\tau_m t_n - 0.5\alpha\tau_m^2)\right) \qquad \text{(Eq. 2)}$$

The reflectivity of points can be found from Eq.3 in which the $A^\dagger$ matrix is the pseudo inverse matrix of Eq.4, where * is the transpose conjugate of a matrix:

$$\rho(m) = A^\dagger(m,n)S_{IF}(n) \qquad \text{(Eq. 3)}$$

$$A^\dagger(m,n) = (A^*(m,n)A(n,m))^{-1}A^*(m,n) \qquad \text{(Eq. 4)}$$

In recent research we used a 2-dimensional array in yz plane for the transmitter and a fixed receiver as showed in Fig.1, to produce 3-dimensional reflectivity images.

- The radar has the following parameters: center frequency= 60GHz, bandwidth=9GHz, pulse burst duration= 20ms, and the measurements are in average range of 1.5 meters.
- The transmitter moves along the y direction, in Fig.1 the red lines show the direction of its movement. The receiver is fixed at -1.5 cm.
- The original data was noisy, so in processing a lowpass filter was used to reduce the noise. The improvement made by this filter is illustrated in Fig.2 for a 2-dimensional image of a metallic pole.
- For 3-dimensional volumetric reflectivity maps, the data measured from all the receivers is used to generate 2-dimensional images on the planes parallel to xy plane. Stacking the planar reflectivity maps we can acheive a 3-dimensional iamges which help to detect particular objects.
- The 3-dimensional images from measurements with one metallic pole and two metallic poles are shown in Fig.3a and b.

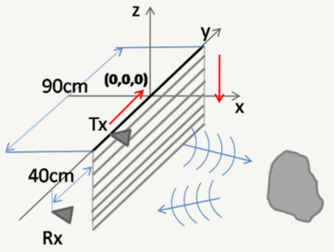
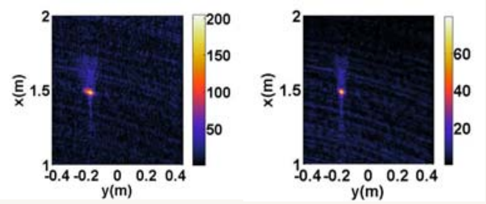
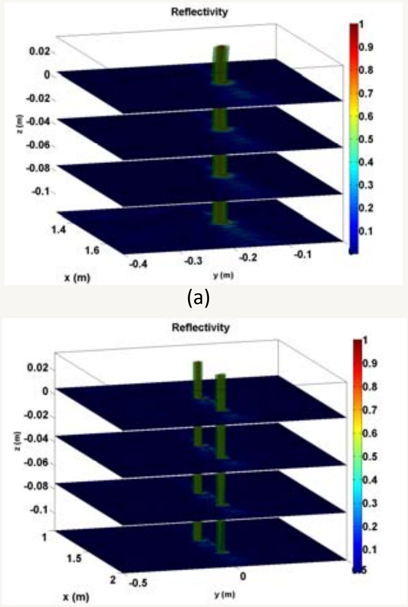


Fig.1 Radar configuration.



(a) (b)

Fig.2 Image from a metallic pole in the scene, (a) not filtered, (b) filtered.



(a)

(b)

Fig.3 3-dimensional image a) one metallic pole. b) two metallic poles with 30cm distance.

Opportunities for Transition to Customer

Our standoff detection system has demonstrated the feasibility of using multiple bistatic data for generating images at nearfield and standoff distances. This prototype is an upgrade to the previous standoff detection for one dimensional aperture. A two dimensional aperture is used to create three dimensional images. Once all aspects of this upgrade is successfully implemented, the system can be easily delivered to any federal agencies like: DHS, ARMY or NAVY, which have presented a great interest in our research, as well as any international partner which is aligned with the U.S. position in the war against terrorism.

Publications Acknowledging DHS Support

1. Fernandes, J., Obermeier, R., Martinez-Lorenzo, J. A., and Rappaport, C., “Simulation results for standoff detection of suicide bombers at millimeter-wave frequencies using a full wave numerical analysis,” *Homeland Security Summit*, Washington, DC, March, 2010.
2. Martinez-Lorenzo, J. A. and Rappaport, C., “SAR imaging of suicide bombers wearing concealed dielectric structures,” *IEEE International Conference on Homeland Security Technology*, Waltham MA, Nov 2010.

Other References

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2. Gonzalez R. C., Woods R. E., Digital Image Processing, Pearson Prentice Hall, USA, 2008.

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