Simulating millimeter-wave FMCW radar for standoff detection of body-worn explosives using full wave FDFD modeling

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Abstract

The channel response of various targets is modeled and used to simulate different frequency modulated continuous wave (FMCW) radar configurations used for the detection of suicide bombers. The 2D finite difference frequency domain (FDFD) analysis is used to obtain the channel response of arbitrarily complex targets. The received signals of simulated FMCW waveforms are calculated and synthetic aperture radar (SAR) images are created using data from the full wave analysis. The waveforms and SAR images created show differences in threat and non-threat targets which may facilitate target identification.

Introduction

The main objective is to simulate a portable radar system to detect irregular contours and materials on the surface of a human body [1].

Model description

• Significant advantage to developing a wide-aperture multistatic radar.
• Multiple transmitters controlled simultaneously to illuminate small portion of the target chest, see Figure 2.
• Inverse relationship between the size of the reflector and beamwidth of the radiation pattern. Use of higher frequencies ⇒ smaller reflector (more portable).

Figure 2: General sketch of a van-based, high resolution radar system for standoff detection of potential suicide bombers.

Results

Simulation Parameters:

- Bandwidth, \(B = 50 \text{GHz} \)
- \( N_f = 64 \), number of frequencies over \( B \)
- \( \Delta f = \frac{B}{N_f} = 125 \text{MHz} \)
- Uniform plane waves at 13 different incident angles per frequency
- Range resolution \( \Delta r = \frac{c}{2B} = 0.001875 \) [cm]
- Maximum unambiguous range \( R_{\text{max}} = \frac{c}{2B} = 1.2 \text{m} \)

• Presence of pipes on target causes a large spread of power in SAR images due to more complex scattering, as was indicated in previous experimental data.
• Frequency response of threat target varies more sharply and is not periodic, as was indicated in previous experimental data.

Figure 6-9: (a) Top image is the geometry used for the FDFD analysis. (b) Middle image is the superposition of SAR image power as a function of incident transmitted angle, \( \sum_{i=1}^{N_f} |r_i(t)|^2 \), where \( r_i(t) \) is the SAR image power. (c) Bottom image is the standard deviation of normalized pixel power as a function of incident transmitted angle.

Figure 4: Mutual coupling analysis.

B. Full geometry field data.
C. Superposed field data of metal rectangle and dielectric layered ellipse (simulated separately).
D. Full geometry field data with superposed field data subtracted.
E. Dielectric layered ellipse field data.
F. Metal rectangle field data.

Figure 8: Male and female SAR reconstructed images.

Figure 9: Female and male SAR reconstructed images.