Radar Polarimetry for Security Applications

Dave Tahmoush[#], Jerry Silvious[#]

[#]*US Army Research Laboratory*
Adelphi, MD, 20783 USA

Abstract— **We analyse micro-Doppler techniques and the improved performance that fully polarimetric radar techniques can add. We perform fully polarimetric measurements of the varying micro-Doppler signatures of humans as a function of elevation angle and azimuthal angle in order to try to optimize this type of system for the detection of arm motion, especially for the determination of whether someone is loaded. We determine that polarimetric measurements can isolate and highlight the arm motion for a classification as loaded or unloaded. Second, the azimuthal angle of the motion is a critical parameter to consider in ground-based systems. For choke-point observations where the direction of motion is more controlled, polarimetric radar has the potential to determine who is not loaded inappropriately and who should be checked.**

I. Introduction

Understanding the capabilities and limitations of radar systems that utilize micro-Doppler to measure human characteristics is important for improving the effectiveness of these systems at securing areas. In security applications one would like to observe humans unobtrusively and without privacy issues, which makes radar an effective approach. In this paper we focus on the characteristics of radar systems designed for the estimation of human motion for the determination of whether someone is carrying a weapon.

For observing humans, radar has advantages over other sensors. The transmitted radar signal is insensitive to night and day, while smoke, dust, and fog only slightly reduce the signal. This is why radar can be used in situations where other sensors give low performance or cannot be used at all. Doppler radar can also determine the velocities of the different parts of the human body directly.

Radar can be used to measure the direction, distance, and radial velocity of a walking person as a function of time. Detailed radar processing can reveal more characteristics of the walking human. The parts of the human body do not move with constant radial velocity; the small micro-Doppler signatures are time-varying and therefore analysis techniques can be used to obtain more characteristics [1, 2]. Looking for modulations of the radar return from arms, legs, and even body sway are being assessed by researchers [3, 4, 5]. The equation for computing the non-relativistic Doppler frequency shift, F_d, of a simple point scatterer moving with speed υ with respect to a stationary transmitter is

$$F_d = F_t \frac{2v}{c} \cos\theta \cos\phi \quad (1)$$

where F_t is the frequency of the transmitted signal, θ is the angle between the subject motion and the beam of the radar in the ground plane, ϕ is the elevation angle between the subject and the radar beam, and c is the speed of light. For complex objects, such as walking humans, the velocity of each body part varies over time as the person walks. The radar cross-section of various body parts is also a function of aspect angle and frequency. The Doppler of a moving vehicle is similar to a point scatterer, but humans and animals have a larger spread of velocities due to their bipedal or quadrupedal motion.

We analyse these techniques and focus on the improved performance that fully polarimetric radar techniques can add. We perform fully polarimetric measurements of the varying micro-Doppler signatures of humans as a function of elevation angle and azimuthal angle in order to try to optimize this type of system for the detection of arm motion, especially for the determination of whether someone is carrying a weapon. Fully polarimetric measurements have shown some capability to determine whether someone is armed through their radar cross section (RCS) [6], and the motion of the arm has been shown to help determine whether someone is armed as well [7].

The arm is often bent at the elbow, providing a surface with a double-bounce potential. This is distinct from the more planar surfaces of the body and allows us to separate the signals from the arm (and knee) motion from the rest of the body. The double-bounce can be measured in polarimetric radar data by measuring the phase difference between HH and VV [8]. In this paper we focus on highlighting the arm motion micro-Doppler from the rest of the body micro-Doppler using the double-bounce phase difference.

The rest of this paper focuses on the polarimetric measurement of the arm motion. Section II focuses on the methodology and the data. Section III focuses on the effective angular dependence of the micro-Doppler measurements. Section IV is the conclusion and future work.

II. Method and Data

Measurements of humans were taken at an outdoor radar test range with realistic but low levels of clutter at 34 GHz on a grassy field. The Doppler radar waveform used for this data collection had a range resolution of 2 m and a Doppler ambiguity of 10.45 m/s. Further descriptions of the radar system, test range, clutter, and other parameters are available in [6]. The radar alternated between transmitting the horizontally polarized and vertically polarized signals while also switching the receiver through both polarizations. It was thought that the double bounce of the arms and knees might be perceptible to the radar.

Fully polarimetric radar data can potentially improve the seperability of different parts of human motion. One of the techniques to determine whether someone is loaded is looking at their arm motion [7]. A standard spectrogram of the micro-