Lab Exercise: Measurement of Human Motion Micro-Doppler Features

Experiment Objectives:

Measure and extract micro-Doppler features of three different human motions (i.e., walking, hopping, and boxing) using the time-domain PulsON® 410 UWB radar sensor.

Compare the above measurement results with vector network analyzer (VNA) measurements.

Part I: Introduction

It is well-known that a Doppler frequency shift is introduced due to the relative motion between the radar and the target of observation. For example, as a human subject moves towards a radar the torso will predominantly introduce a positive frequency shift (positive Doppler) and as a human moves away, the torso will introduce a negative Doppler. (See Figure 1) The Doppler frequency shift relates directly to the radial velocity and can be mathematically represented as:

\[ f_D = \frac{2v_r}{\lambda_c} \]

Moreover, as the human body consists of different parts (e.g., torso, arm, leg, etc.) and they are moving at different velocities during the same movement pattern (e.g. walking), you would expect the appearance of multiple Doppler-shifts. The frequency response of these smaller motions, such as arms and legs, are referred to as micro-Dopplers (see Figure 2). For example, if you swing your arms as you walk towards a radar, the swing towards the radar will give a positive Doppler, and away will be a negative Doppler. These micro-Dopplers can provide valuable information for target recognition and classification.

For this lab, you will measure and extract micro-Doppler features of 3 different human motions using the Time Domain P410 UWB radar sensor, and verify your results with vector network analyzer (VNA) measurements. The motions are walking with arm swing, hopping on one foot, and punching in front of you as you walk towards and away from the radar (see Figure 3). You need to measure the time-varying range profiles, and process your
measurement data by use of Fourier transform (FT) and Short-time Fourier transform (STFT). For comparison, you will also use the VNA to check your results.

![Figure 3: Motions: Walking, Hopping, and Boxing](image)

**Part II: Micro Doppler Experiment**

**2.1 Required Equipment**

Hardware: Laptop, P410, Vector Analyzer (Agilent N5230C), Horn Antenna (TDK HRN-0118), RF absorber

Software: Time Domain MRM-RET, MATLAB

**2.2 Experiment 1: Time Domain UWB Measurements**

Attach the Horn Antennas to the Time Domain P410 (Figure 4) and set the following parameters in the MRM-RET software:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PII</td>
<td>8</td>
</tr>
<tr>
<td>Quanta</td>
<td>5</td>
</tr>
<tr>
<td>Scan window</td>
<td>29295 ps</td>
</tr>
<tr>
<td>Scan start</td>
<td>20000 ps</td>
</tr>
<tr>
<td>Scan interval</td>
<td>7500 µs</td>
</tr>
<tr>
<td>Number of scans</td>
<td>3000</td>
</tr>
</tbody>
</table>

Have someone in your lab group stand about 4.5 meters away and perform one of the above actions as you record. Once all three motions have been completed and saved, load the data in MATLAB. The data should have 3000 rows and 480 columns- each row increases by 7500 µs, and each column by 61 ps. You should be able to plot the range profile using the formula: \( R = \frac{ct}{2} \). Take the difference between each scan for a clearer image. Plot the time-varying range profile for each motion.
Example Experiment #3: Micro-Doppler of Human Motion
Developed by: Willis Troy, Baylor University
Acknowledgments: Dr. Yang Li, Dr. Mike Thompson

Figure 1: Horn Antennas provides directivity; RF absorber minimizes cross talk and unwanted reflections

You already have the data for the Doppler measurements for the motions; it just needs to be processed. To process the data, take the FFT across each scan to generate the radar band. Extract the 4 GHz signal from the radar band to be processed by the Short Time Fourier Transform (STFT). For the STFT, we use MATLAB’s Spectrogram command. Choose a relatively small window size and a window of your choice, plot the results. Perform this for all three motions.

2.3 Experiment #2: VNA Verification

To verify our results with the Time Domain P410, we are going to use a Vector Network Analyzer (VNA), specifically the Agilent N5230C. A VNA is used to measure the network parameters of electrical circuits, such as scattering parameters, and as an instrument costs far more than the P410 ($75K compared to $2.0K).

To use the VNA as a radar, we will need to set it to different modes depending on what we want to measure. To measure range we will need to set the VNA to the stepped frequency mode, and to measure the Doppler we will need to set it to the continuous wave mode.

To measure range, we will need to set the frequency range to 3-5 GHz and 201 data points per scan before recording. To plot the range measurement, use the inverse Fourier transform on the s21 data. Perform all three motions for each setting and plot.

However, for the Doppler we need a constant frequency (4 GHz), and we will take 10000 scans over 20 seconds. Perform all three motions for each setting, record, and perform the STFT on the data.

2.4 Lab Report

1. Turn in the plots for all range measurements and Doppler measurements.

2. Can you extract the micro-Doppler features from your results? Identify the corresponding body parts.

3. Can you tell a difference between the Doppler features for each motion using the P410? If so, why?

4. Does the VNA verify the P410 range and Doppler profiles? If not, can you explain why?

5. In our experiment, why does the P410 have a smaller Doppler range than the VNA?