Drone Scout
Development Team

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Overview

• Drone Scout is a millimeter wave radar system capable of detecting a small UAV or drone in a targeted area.

• By analyzing the micro-doppler signatures of a drone’s propellers in the radar return signals, we can determine the presence of a drone along with some of its features.

• An external HDMI display will show the following:
  – Spectrogram plotting the frequencies found in the signal and their magnitudes with respect to time
  – Report of the features detected in the radar’s target
Applications

• Defend against possible military and terrorist attacks
  – Large drones carrying dangerous payloads:
    • Explosives
    • Biological weapons

• Protect government and civilian privacy
  – Smaller drones equipped with:
    • Cameras
    • Microphones
    • Other sensors
Micro-Doppler Effect in Radar

- Mechanical vibration or rotation of an object that may induce additional frequency modulations on the return signal of a radar.
- The reflection from a propeller would cause an increase and decrease in frequency at any given time.
Micro-Doppler Signatures of Drones

Fres = 326.9739 Hz, Tres = 7.85 ms
Hardware
Xilinx Zynq-7000 SoC: PYNQ-Z1

- ARM Cortex-A9 processor (dual-core)
- Artix-7 FPGA
- 512MB DDR3 Memory
- External interfaces:
  - Arduino shield connector
  - PMOD ports
  - HDMI input/output
  - USB 2.0 (Host)
ADC: Pmod AD1

- Features two AD7476A analog-to-digital converters and anti-aliasing filters.
- Two channels, each with 12-bit precision
- 1 MSPS throughput rate
- SPI interface protocol

- The radar signals are expected to be 1 kHz – 20kHz depending on the speed of the drone’s propellers.
- We will be sampling the ADC at 80 kHz.
PCB: Radar-PYNQ Interface
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LGS mmWave Radar

- **X-Band Radar (7 to 10 GHz)**

  - 7 to 10 GHz
  - +14dBm
  - ZN2PD2-14W-S+ (0.5 to 10.5 GHz)
  - Narda 4925 (7 to 12.6 GHz)
  - WR112 +15dB 7 to 10 GHz
  - 7 to 11 GHz
  - PE2055 (6 to 12.4 GHz)
  - ZN2PD2-14W-S+ (0.5 to 10.5 GHz)
  - ZX05-14+ (6 to 12.4 GHz)
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  - DC to 500 KHz
Software
Data Acquisition
1. Main program interrupts the MicroBlaze telling it to record $N$ samples with a sampling frequency of $FS$. 
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4. Now our Python program can read the samples from DDR and analyze them.
Signal Processing: STFT

- Short-time Fourier Transform (STFT) is used to determine the frequency and phase of a signal as it changes over time.
- Procedure: Divide a time-domain signal into “frames” of equal length and then computes the FFT on each frame separately.
• Short-time Fourier Transform (STFT) is used to determine the frequency and phase of a signal as it changes over time.
• These results will be processed further to characterize the area captured by the radar.
Feature Detection of Radar Target

• STFT features:
  – Maximum doppler frequency
  – Number of peaks, troughs, and zero-crossings

• Drone features:
  – Presence of a drone or UAV
  – Propeller tip velocity
  – Rotations per minute (RPM)
  – Propeller blade length
  – Number of propellers
  – Number of blades
Feature Detection

- Maximum doppler frequency
- Number of peaks, troughs, and zero-crossings
Drone Features

- Presence of a drone or UAV
  - If $f_{doppler,max} < 100$, then no drone
  - If $f_{doppler,max} > 100$, then possibility of drone
- Propeller tip velocity
  - $v_{tip} = \frac{1}{2} \times f_{doppler,max} \times \lambda_{carrier}$
- Rotations per minute (RPM)
  - Compare peaks/troughs/zero-crossings to time axis
- Propeller blade length
  - $L_{blade} = \frac{60 \times v_{tip}}{RPM \times \pi \times 0.0254}$
- Number of blades
- Number of propellers
Demo: Radar Operation
Acknowledgments

• LGS
  – Duane Gardner
  – Martin Fay
  – Rory McCarthy

• UCSB
  – Dr. Yogananda Isukapalli
  – Brandon Pon
  – Carrie Segal