2.4 GHz Radar System - Technical Takeaways

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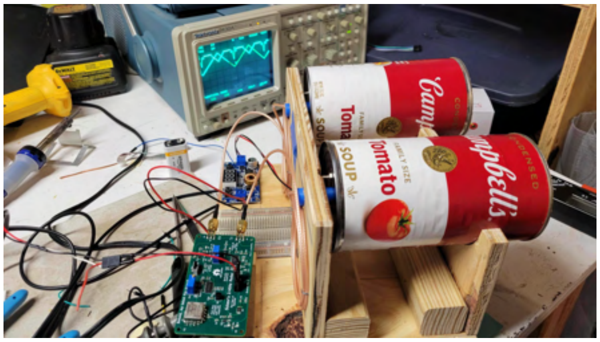
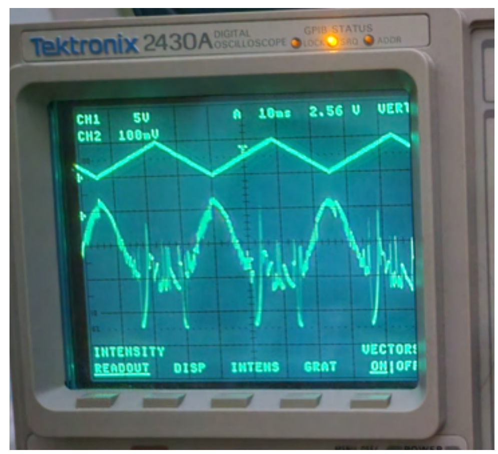
Overview



An early test of my radar system on my oscilloscope

The radar system I designed is a 2.4 GHz, frequency modulated, continuous wave, radar. It features both a ranging mode to detect distance and a doppler mode to detect velocity. It is able to accurately detect range and speed of objects between ~1-30 meters. The system has the approximate footprint of a standard credit card and is able to easily stack with an additional custom board, the “radar computer.” The radar is structurally inspired by the MIT OpenCourseWare “Coffee Can Radar System,” however, it is much smaller, redesigned to use different modern SMD components. More directional aluminum Yagi-Uda antennas with soup can waveguides replace the monopole “coffee can” antennas of the OCW project. The radar computer is based on the Raspberry Pi Pico, runs custom C or Python code and is able to decode and transmit the analog data in real time over USB or RS232 serial. The system can attach to additional computers over either of these buses for integration. I garnered help and support from the DIY radio community on online forums when I had trouble, mostly with my PCB’s RF transmission lines.

RF Topology



The received wave form along with the triangle ramp from the radar

In ranging mode, a custom low-frequency triangle voltage controlled oscillator creates a ramp that drives a microwave VCO. This microwave signal is clamped, amplified by an RF amplifier before being transmitted through the first antenna. The transmitted radio wave bounces off of an object then returns to the receive antenna. The receive antenna captures the signal, it is then amplified by a second RF amplifier. Next, a frequency mixer compares the frequency difference between the transmit and receive signal. The low frequency comparison, along with the original ramp output is amplified by a modified video amp and read by the radar computer’s analog to digital converter. By comparing the change in frequency, taking into account the ramp, it can be determined how long it took the signal to travel, bounce and return. In doppler velocity mode the triangle ramp is disabled and the microwave oscillator is fed a constant voltage. The change in frequency from the comparator now represents the doppler frequency shift created by a moving object. The radar’s printed circuit board has a 4 layer stack up. All connections between RF components are done on the first layer using stitched coplanar waveguides to prevent interference. Unfortunately, I have been unable to do a detailed performance analysis of the system because I lack access to the appropriate test equipment.

Antenna Design

The antennas are based on a generic Yagi-Uda design found around my house. The dimensions are modified to perform well within the desired frequency range. The director and reflector elements were cut from 1/16th inch aluminum and the driver is a custom PCB. The antennas are attached using a 3D printed mount to a soup can waveguide to stop crosstalk. I also have not profiled these antennas for the reasons mentioned above, but from the cursory tests I have done on the radar, they seem to work alright.

CNC routing the antenna reflectors and deflectors I designed

Approximate Cost	$250
Approximate time spent	5 months
Skills developed	- RF/Microwave/Analog Printed Circuit Board Design - Embedded Software Development - RF Antenna Design - 3D Manufacturing