Team Radar Final Report

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Abstract— **During Fall quarter, we built a 2.4 GHz FMCW, frequency modulated continuous wave, radar system. During Winter quarter, we built our own 2.4 GHz FMCW radar with accuracy, less power consumption, less weight, and budget in mind.**

I. Specific Aim

- Total budget of $300
- Able to detect 0.3x0.3 m2 metal plate ranging from 5m to 50m.
- Higher score for higher accuracy, less power consumption, and less weight

II. Design Overview

The quarter two system was designed with both simplicity and backwards compatibility in mind, that is, the RF PCB could be interchanged with the quarter 1 system without any issues, or that parts of the quarter 1 system could be used if either the transmit or receive section were to fail. To this end, the stackable baseband approach was not attempted. During quarter 1, the teensy had given us considerable trouble, often not working during the labs, so the idea of an analog function generator was immediately appealing. It also was expected that this approach would be not only lighter, but consume less power than the teensy-based circuit.

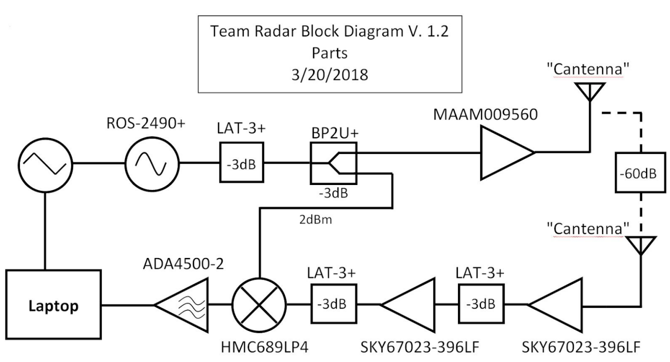

Fig 1. Block Diagram

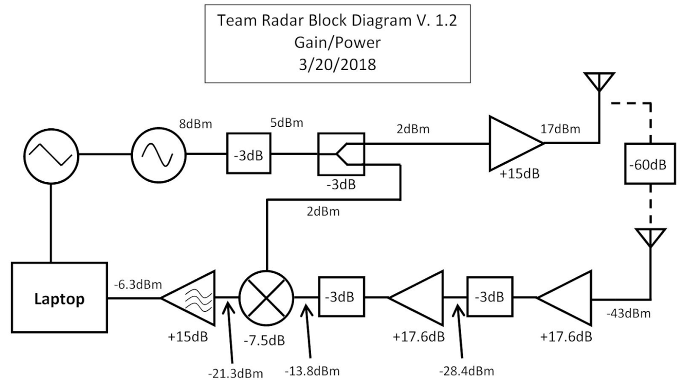

Fig. 2. Gain/power block diagram

ADIsim was used to simulate theoretical values to calculate gain of the transmitting and receiving antennas. Gain of transmitting antenna came out to be 16.5dBm, and gain of -45.5dBm for the receiving antenna.

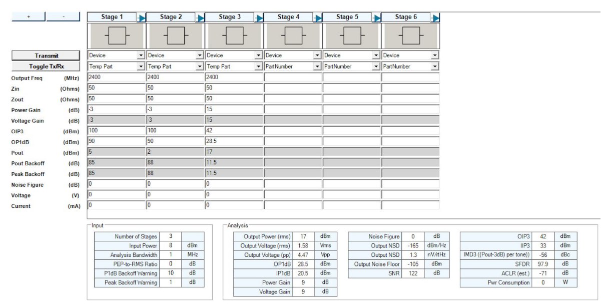

Fig 3. ADIsimRF simulation for the Transmitter

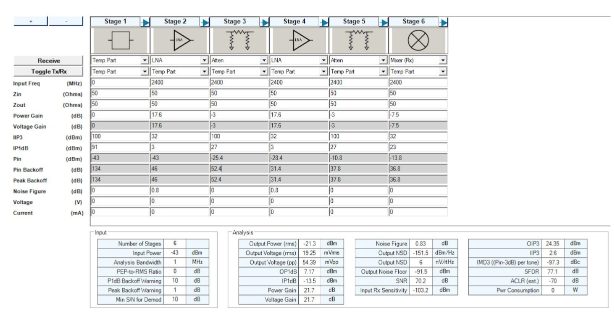

Fig 4. ADIsimRF simulation for the Receiver at 50m

The table below shows the list of major components implemented on our system.

Component	Part Number
VCO	ROS-2550-519+
Splitter	BP2U+
Power Amplifier	MAAM-009560
Low Noise Amplifier	SKY67023-396 LF
Mixer	HMC689LP4
Baseband Amplifier	ADA4500-2
Attenuator	LAT-3+ or LAT-2+

III. PCB Design

KiCAD Schematic

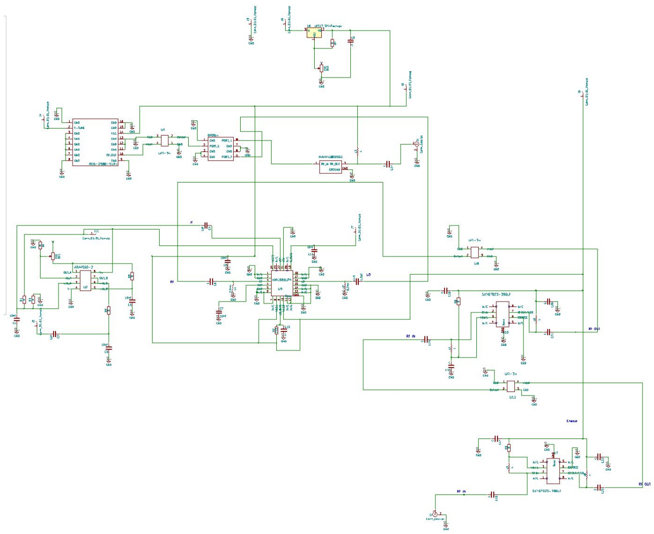

Figure 5. KiCAD schematic

PCB Layout

The initial PCB is shown below in figure 5. We include the RF and baseband PCB's all in one PCB to allow for a simple design as well as to reduce the power loss between boards. The downfall to this option was trying to arrange all components to fit in a compact area without interference and also keeping the RF traces as straight as possible. During our first draft there was a lot of curve in the trace leading to a higher power consumption and out first dimensions were approximately 5.05 in X 4.70 in, which were quite large.

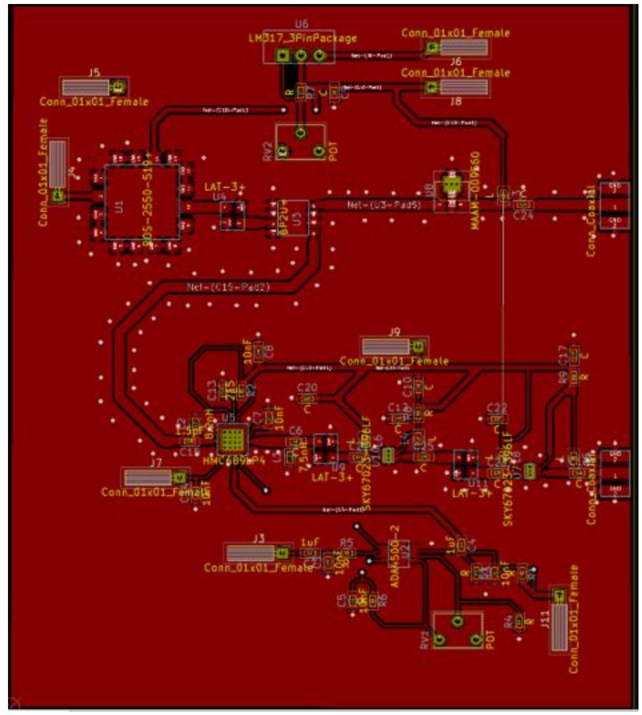

Figure 6.

The second design improved upon these two issues. As can be seen in Figure 6. The components were rearranged in order to have the RF components nearby and in line. This way we were able to have straight, direct RF traces. Our dimensions also dramatically decreased to 2.22in X 3.44in decreasing area to about 32% of the original size. Unfortunately, even after multiple reviews of the PCB, the output from the VCO through the LAT-3+ to the BP2U+ splitter was connected to the wrong pin, and therefore the PCB wouldn't work as intended. Our final PCB looks identical to Figure 6, however, the connections were corrected.

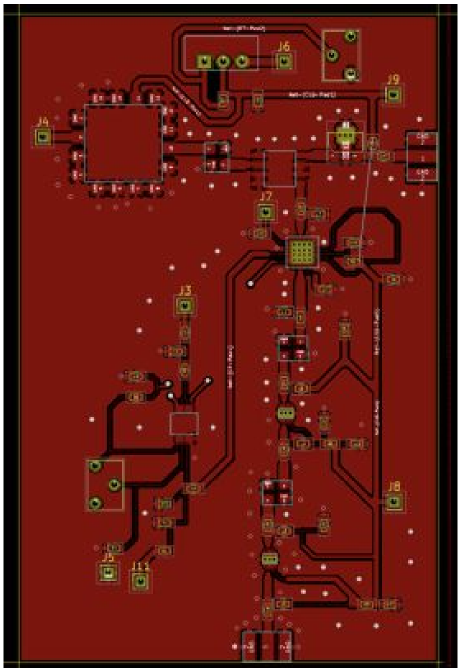

Figure 7. RF PCB

A more detailed view of each section is shown below.

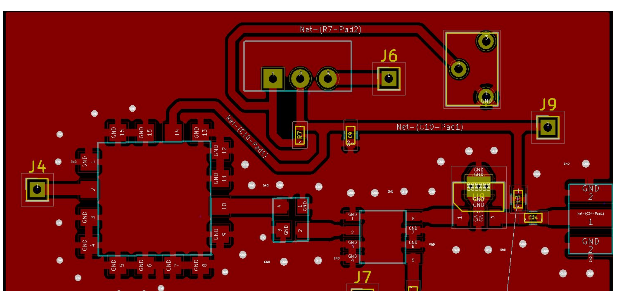

Fig 8. Transmitter section

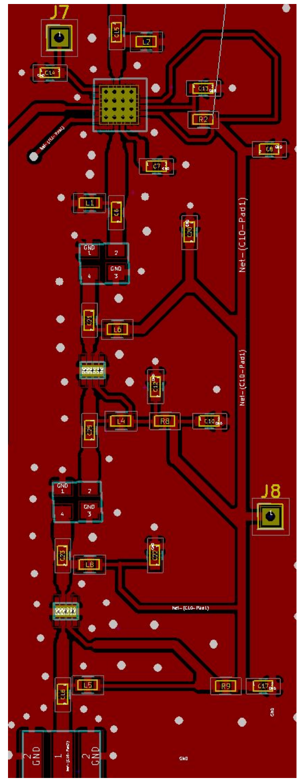

Fig 9. Receiver section

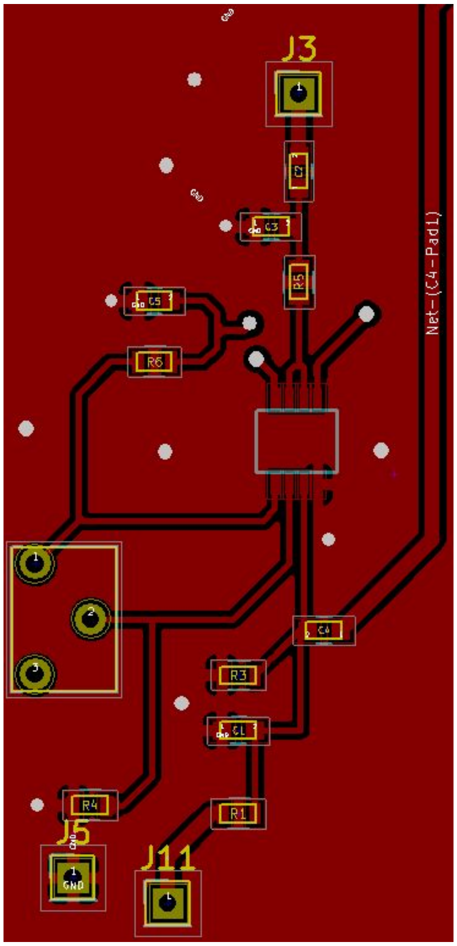

Fig 10. Baseband Amplifier

Analog Function Generator

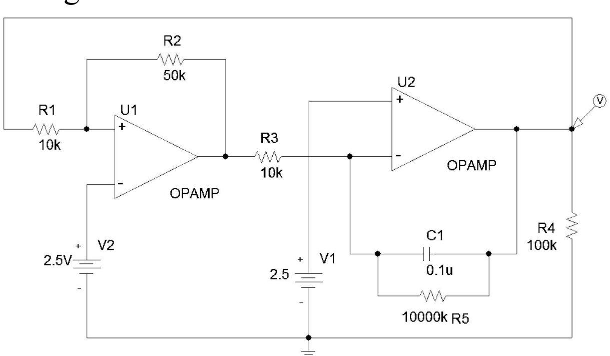

Figure 11. simplified schematic of triangle wave generator

We used an analog function generator instead of the teensy because we were having issues during quarter one and were worried about the reliability of the teensy-based implementation during testing. As pictured in Figure 7, the Vpp deviated from the quarter one value (40ms) and we were using approximately 10ms increasing the frequency from 25Hz to 100Hz.

Antenna

Both receiving and transmitting antennas were made out of coffee cans. The length of copper feedlines were adjusted so that the antennas radiate at approximately 2.4GHz.

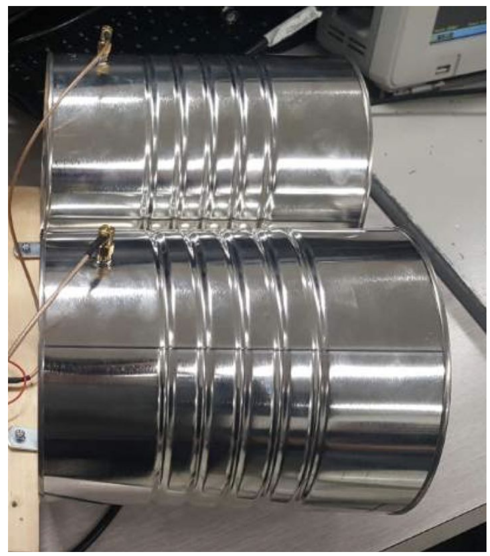

Fig 12. Coffee Can Antennas

Design Implementation

The PCB shown in figure 6 did not actually work as intended. The first major issue identified, but never resolved, was that the output power of the transmitter was about 8-9 dBm, much less than the intended 13-15 dBm. Where the power was being lost was not identified, however since it did not seem to be a critical issue it was left alone.

After construction, an oscilloscope was used to search for any baseband signals at the output of the mixer, however none were found except at extremely high input power. It was discovered by accident that the mixer would function as intended if and only if pins 3 and 4 were DC coupled, say with a 10k resistor as used. The reason for this is unclear, but a working theory is that it provided a DC path to ground through inductor L1, though

there was not time to fully investigate this issue. Once the system was found to work satisfactorily, no further changes were made. Additionally, the baseband amplifier was modified so that the ground for the feedback loop went back to a LT1009 zener diode, instead of using a voltage divider-based biasing. This got rid of an issue with the baseband amplifier amplifying the DC bias in addition to the signal. The schematic for the baseband amplifier then was identical to the gain stage in the lab 1 filter, except that the filter was a unity gain buffer with a first order low pass filter.
Images of the final PCB implementation are shown below.

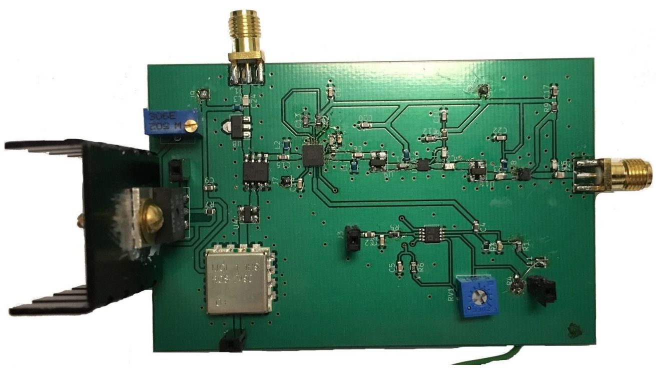

Fig 13. Completed RF PCB

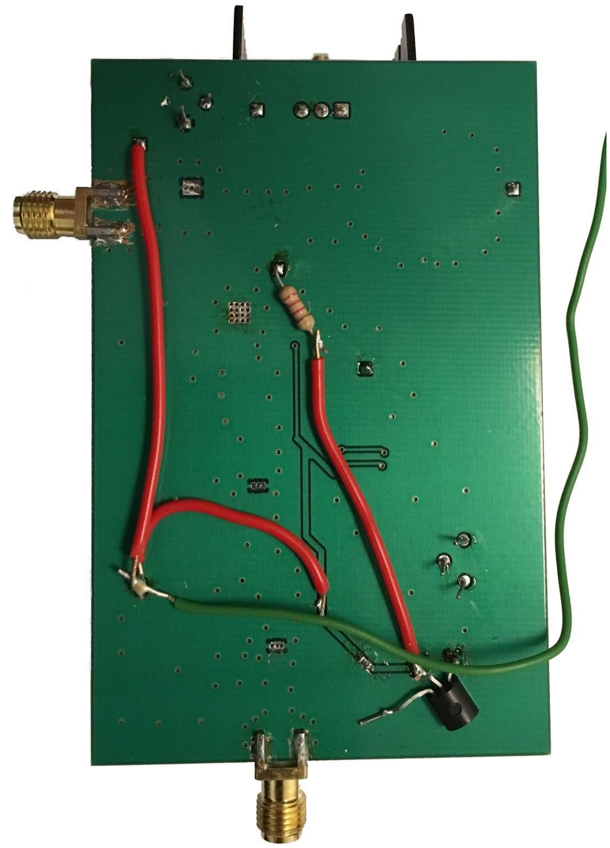

Fig 14. Completed RF PCB

Fig 15. Completed Radar System

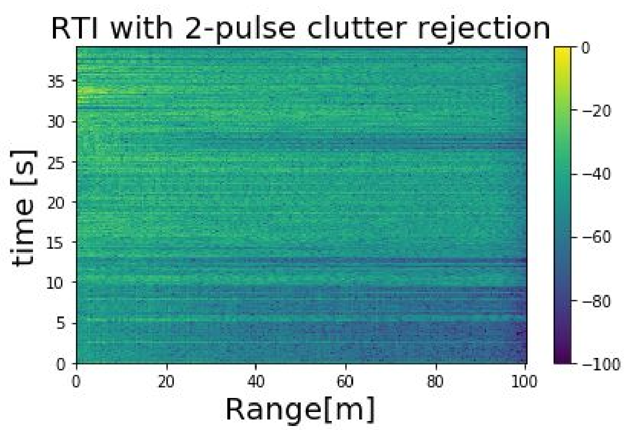

Fig 16. RTI Plot

We initially attempted to test the radar inside Kemper Hall, in the long hall outside the ECE main office. However, as can be seen, there was far too much interference and stray reflections for any meaningful results to be gathered.

The level of background noise was significantly reduced by increasing the spacing between the antennas, and inserting a metal foil between the two can antennas. To mechanically support the foil, it was sandwiched between two pieces of cardboard and held down with a binder clip. We believe there was significant cross-talk between the antennas in lieu of this shielding which was also interfering in our results.

Due to the lack of time, no further tests were performed before competition day.

IV. Competition Day

Our competition final set-up is shown below.

Fig 17. Completed Radar System

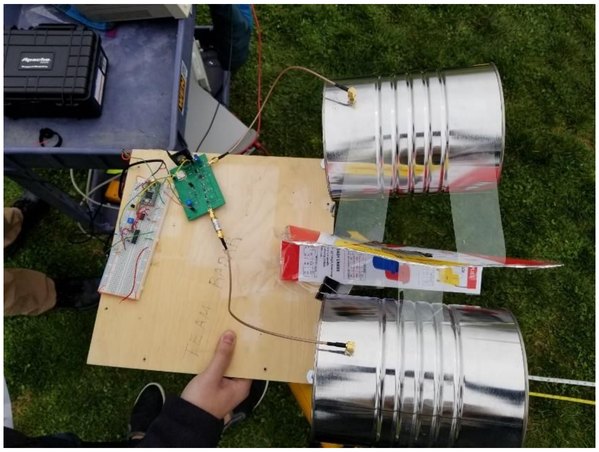

Fig 18. Completed Radar System

Our results from audacity after being run through the Spyder code is shown below. A more distinct line was drawn in red to extrapolate the distance from the data.

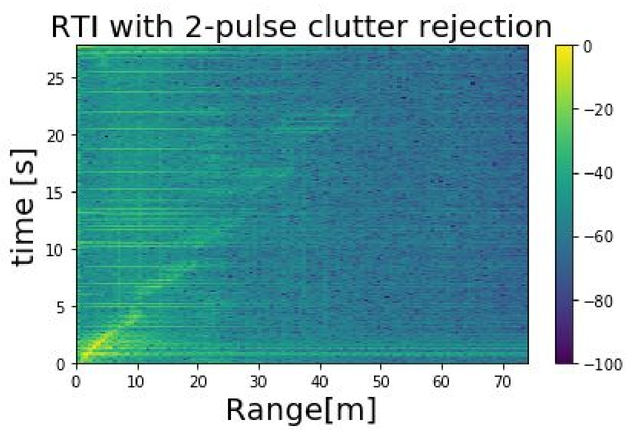

Fig 19. RTI Plot for the competition

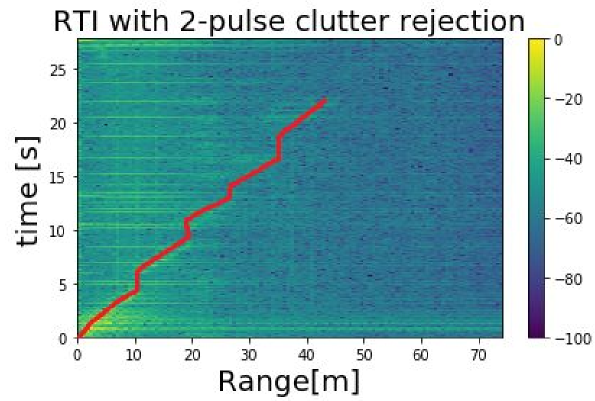

Fig 20. Highlighted RTI Plot for the competition

From this data we estimated the distance of the 5 measurements, which can be seen in the table below. Using the equation for accuracy of our measurements vs. the actual distance. We calculated our accuracy which ranged from an error of 1.57%-9.34% with an average of 5.6% error from the actual distance than our measured values. This was determined with the equation $\mathrm{P_{dc}} \times W \times \prod_{i=1}^{N}\left(\frac{\hat{L}_i - L_i}{L_i}\right)$.

Actual Distance	measurement
42.672	42
33.2232	35
25.6032	28
18.288	20
9.7536	10