

EEEC134 Application Note

FMCW Radar System Test

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Overview

The system technology implemented is classified as frequency modulation continuous wave (FMCW) radar that can detect distances of targets and the speed of a moving object with relatively lower power.

Introduction

This application note presents the testing aspect of RF system. From individual antennas, baseband system and RF system to prototype breadboard radar, lab 6 coffee can radar and completed quarter 2 radar, this report talks about all the test results we achieved. It also gives a description of the circumstances in which those test measurements were taken and how much it affected our results. Potential reasons for any shortcomings will also be discussed and the steps we took to take care of those problems to get better and accurate calculations

Testing

First we had to make sure that the 5.8 GHz antenna we were going to use with our circuit, were fully functional. Checking it on network analyzer we found out our antenna (Fig 1) has a bandwidth of 350Mhz as measured from S11 return loss, shown in Fig 2. The function generator XR2206 was tested to make sure it was giving the triangular wave function with $V_{avg} = 4.1V$ (Fig 3). After soldering all the parts on the baseband board, we started changing the values of potentiometers to get the required values; from 2V to 6V.

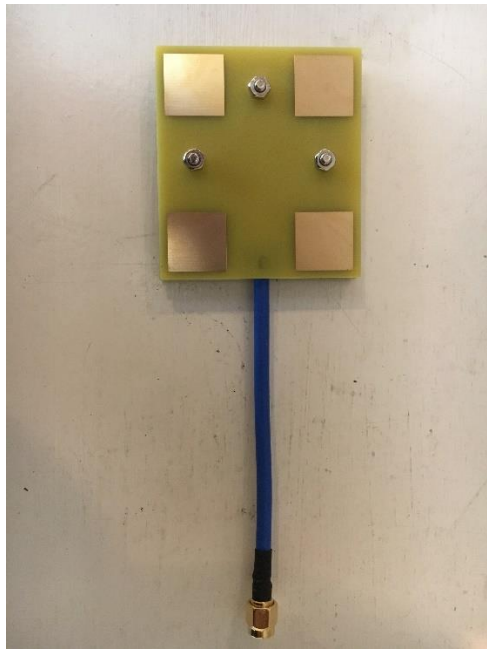


Fig 1: 5.8 GHz antenna. The screws are to hold the three plates of antenna together

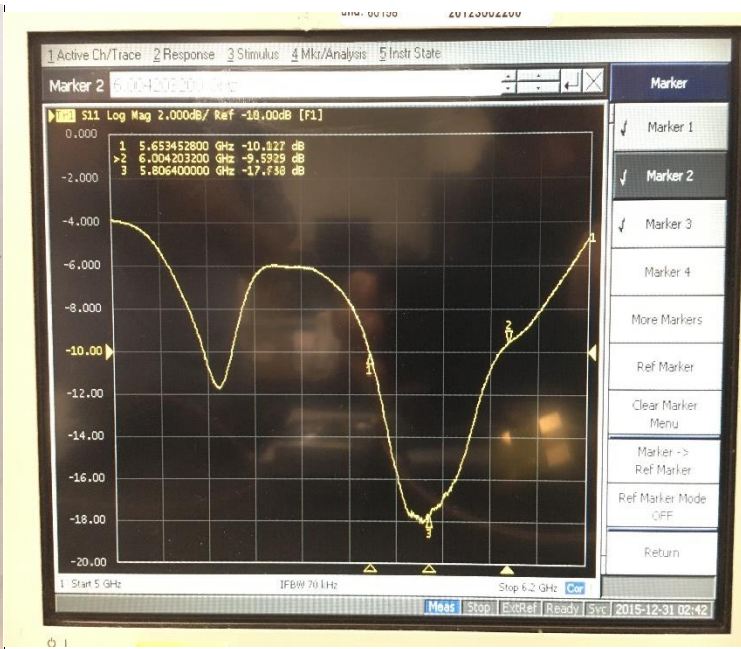


Fig 2: Results of 5.8 GHz antenna on network analyzer

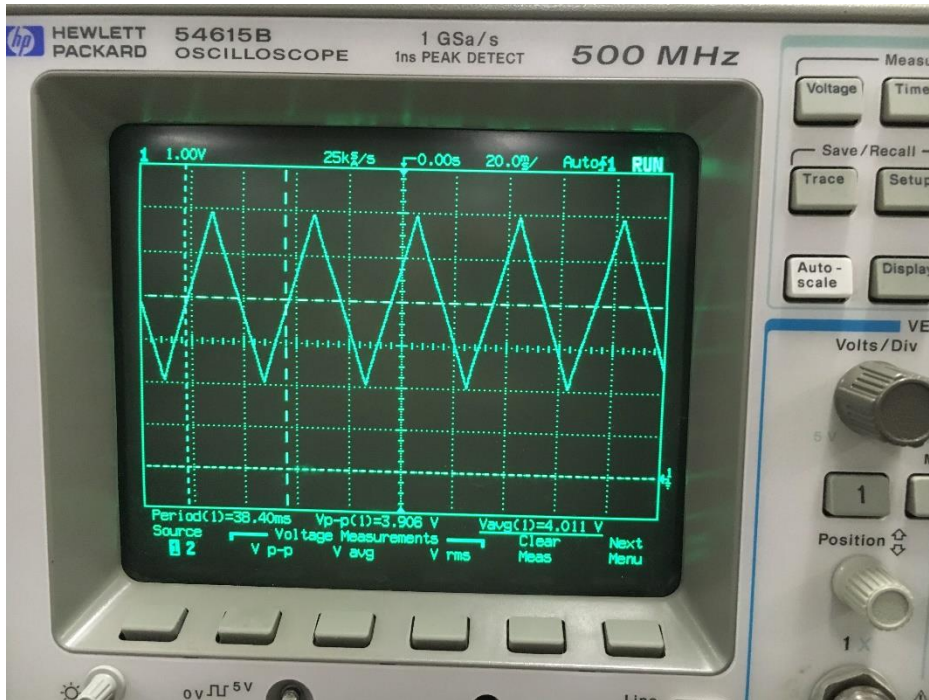


Fig 3: Triangular wave from a functioning XR 2206

While changing the values on the Potentiometers, we were also making sure that the sine wave on the oscilloscope does not get distorted or clipped. We were expecting a power amplification of 100 from our baseband but at the end we were getting a maximum amplification of roughly 20.6, which surely wasn't enough. (Fig 4)

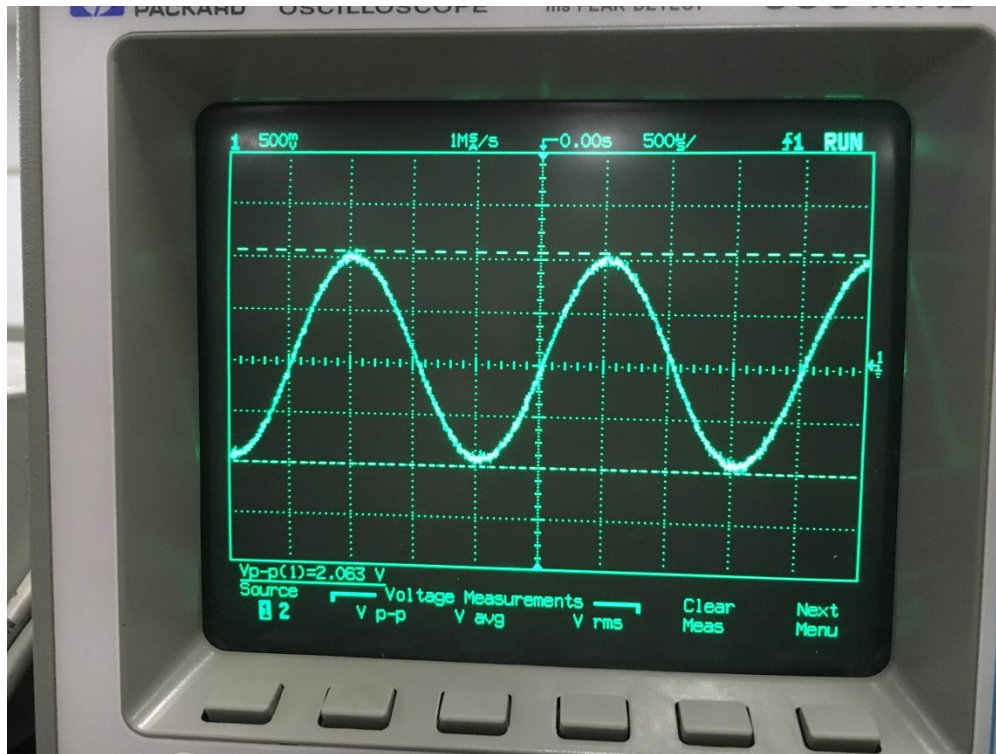


Fig 4: Input $V_{PP}= 0.1V$ and output $V_{PP} = 2.063$, giving amplification of 20.6

We decided to build a prototype of the circuit on the breadboard giving it the ideal conditions such as using different power sources for all the different values of voltages we required. Sure enough it gave the perfect results with the amplification depending on the V_{DD} of the amplifier. This helped us to easily get the amplification of 100. We started removing ideal conditions and used LM317 to produce 2.5V from 5V. The problem was persisting, although we were able to get a bit higher amplification of 25 now. There we learned that our resistors are maxing out and we have to change the 50k POT for 2M POT. After making the change we were able to get a amplification of 45.6, which was roughly half of our expected value but almost double of what we were getting before (Fig 5). After consulting with a few fellow students and doing some research we found out that one gain stage works just as good as two gain stages when it comes to amplification and rather helps with the noise too. We decided to start our experimentation with baseband board as is.

We, then, moved to our RF board and for the sake of simplicity, I will call the boards as B13 and B20 referencing to the amplification value of the majority of the LNAs on the

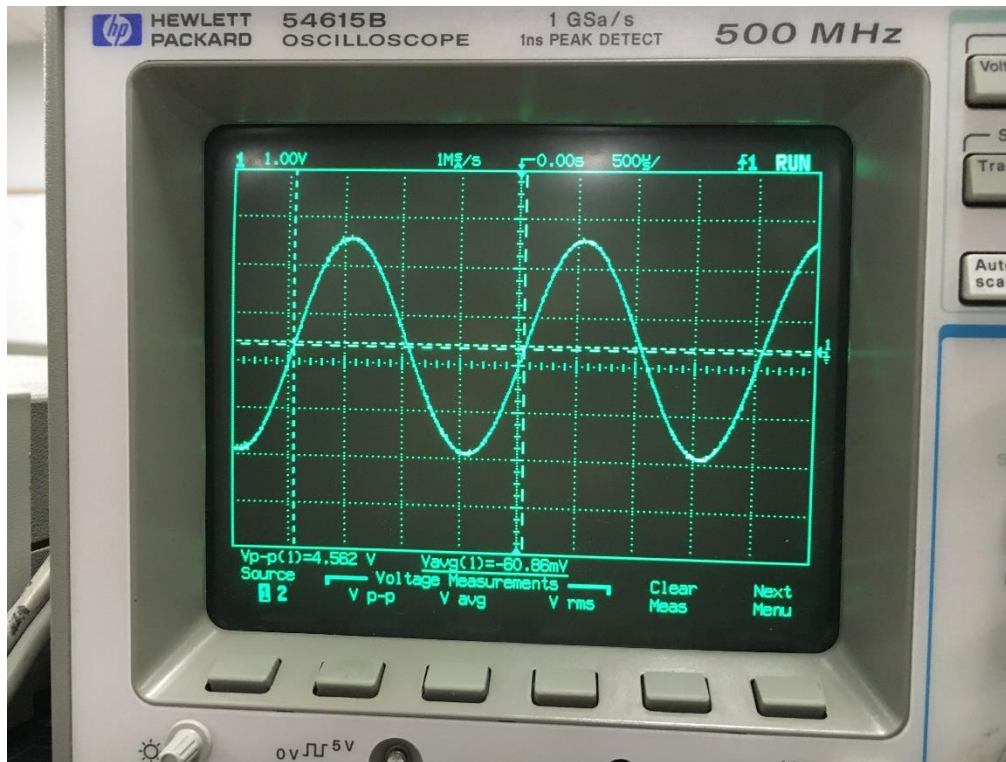


Fig 5: Input $V_{PP}= 0.1V$ and output $V_{PP} = 4.563$, giving the gain of 45.6

board, since that was the only difference the two boards had. We had high hopes with B20 since we were expecting a high amplification from it so we decided to go with it first. We were taking measurements step by step and as soon as we put all the LNAs in the board, the whole board shorted out. Since it wasn't all done the same day, we thought that maybe a random component went bad on the board. So, we replaced all the major components on the board and still the board was shorted. So we formed a hypothesis that the 20 dB LNA are either non-functional or not the best choice for the board since they were very hard to solder in the first place and we were not even sure that they were soldered right. We went ahead with B13 and it kept working. We decided

to use this instead and see how it works in the lab conditions. Spectrum analyzer gave a very positive result and we were getting an amplification of 18 dBm at 5.8GHz (Fig 6) while the 3.3V required to power the VCO to produce the 5.8GHz signal, was at 3.5V (Fig 7)

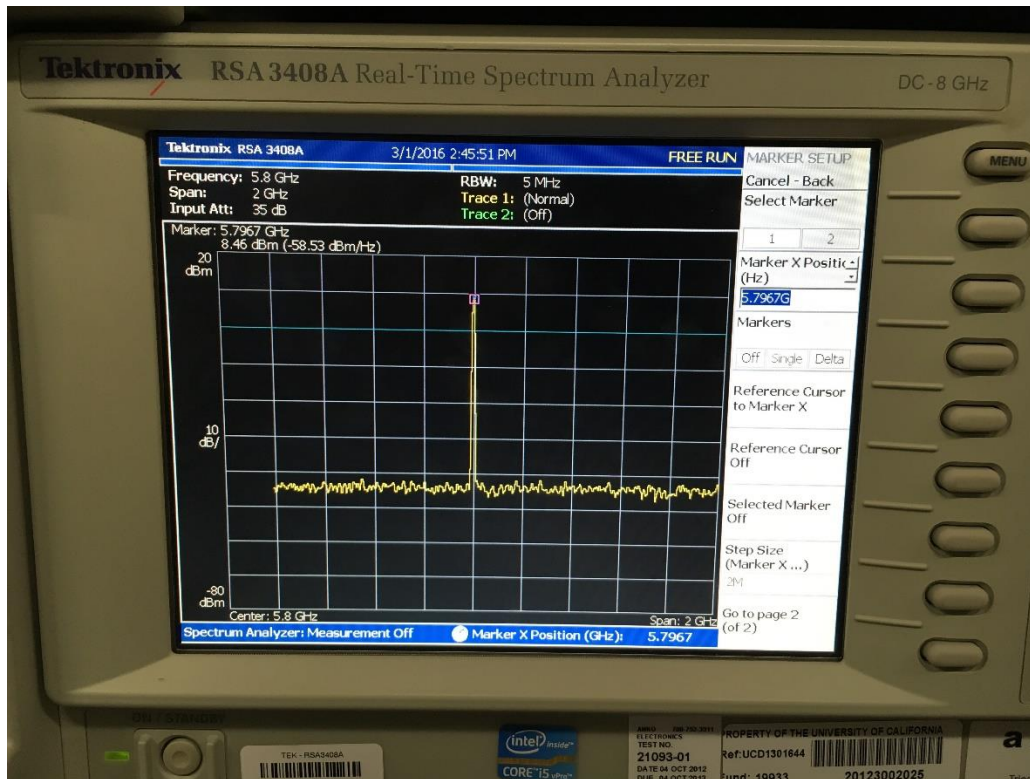


Fig 6: RF board measurements on Spectrum Analyzer

After finding some encouraging results from our baseband and RF boards, we decided to combine the boards together to see what kind of results it would produce. First, we tried to produce some results in the lab room by moving the metal sheet back and forth. We saw it producing some results on oscilloscope as the wave pattern seemed to be changing with every movement (Fig 8).

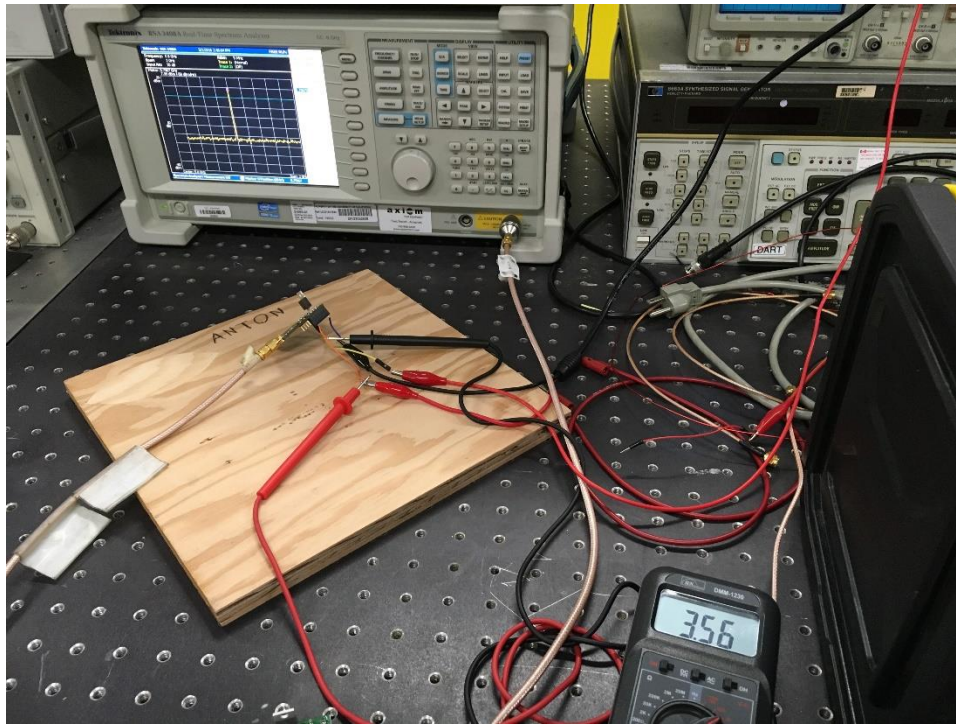


Fig 7: RF board during testing. We can see the voltage at VCO is 3.56V

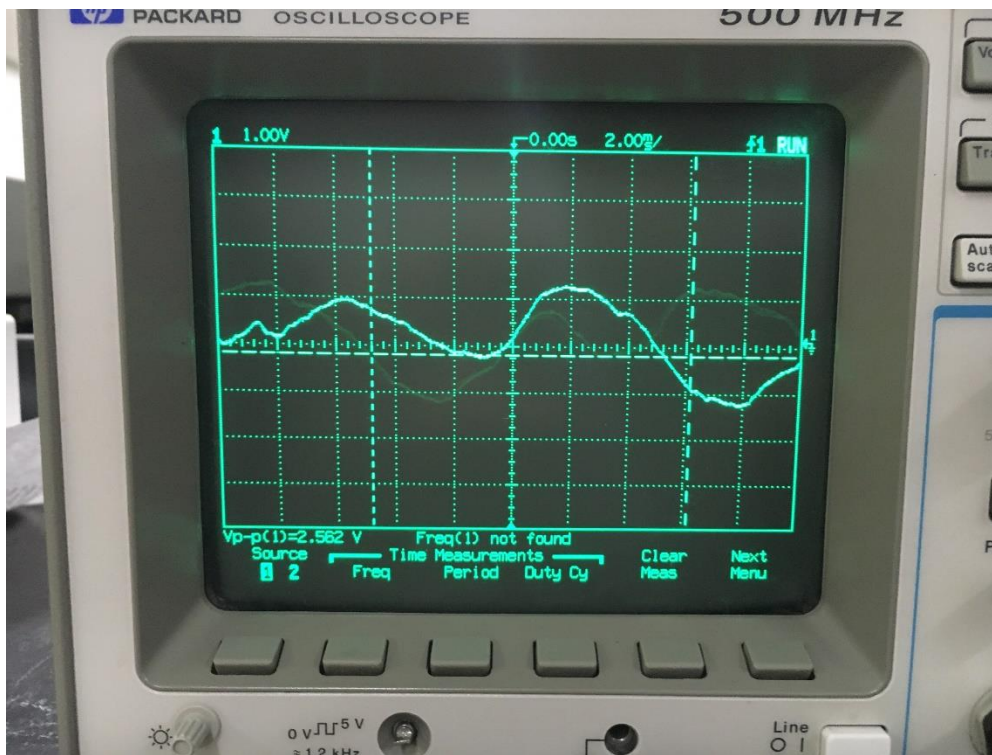


Fig 8: Wave patterns on the oscilloscope. The speed with which the patterns were changing, sometimes made it hard to have an exact value of frequency at that point.

5.8 GHz Patch Antenna Radar

03/03/2016: We went out for testing our radar for the first time in the field. For power source, we were using a portable car battery charger which gave a voltage of 12.5V. We added a fuse at the positive terminal of the battery charger to make sure the circuit stays safe in case the current gets really very high. Fortunately, the current value stayed fine and circuit seemed to be working but no optimal results were gained that day. As a matter of fact, the very first results gave no specific parameter and appeared just like noise in the circuit (Fig 9). It appeared like all the incoming signal was being diverted and nothing was being registered for the calculations but noise.

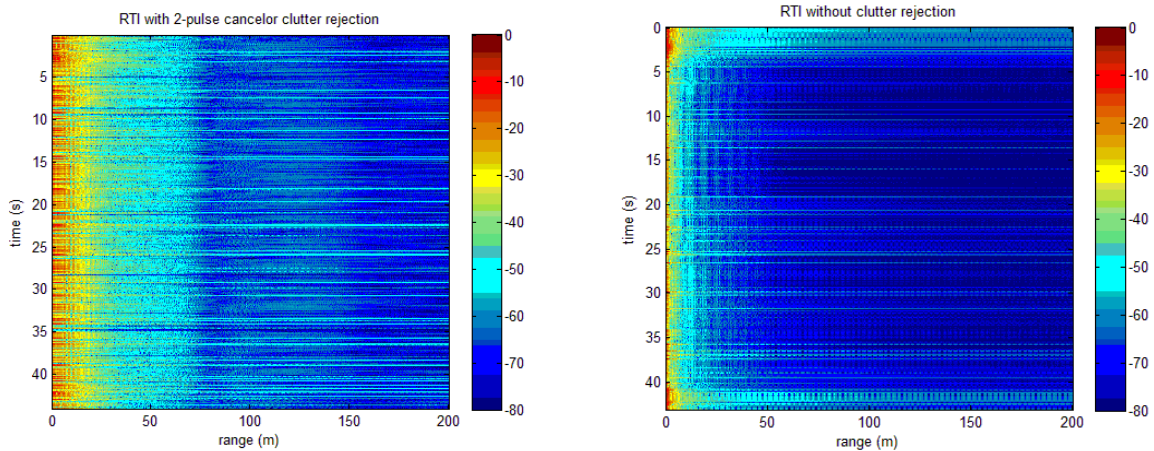


Fig 9: No encouraging results after the first test

03/08/2016: We thought about the top two layers of the antenna and that maybe they were reasons for diversion. We removed the layers to improve the directivity and took the circuit in the field and voila, we had a working radar (Fig 10). Although, the signal was very faint but still a curve in the graph could be seen, specifying a moving metal object. At this point, we had also added a heat sink to the VCO on our RF board since it was getting extremely hot and we were afraid it would burn out anytime.

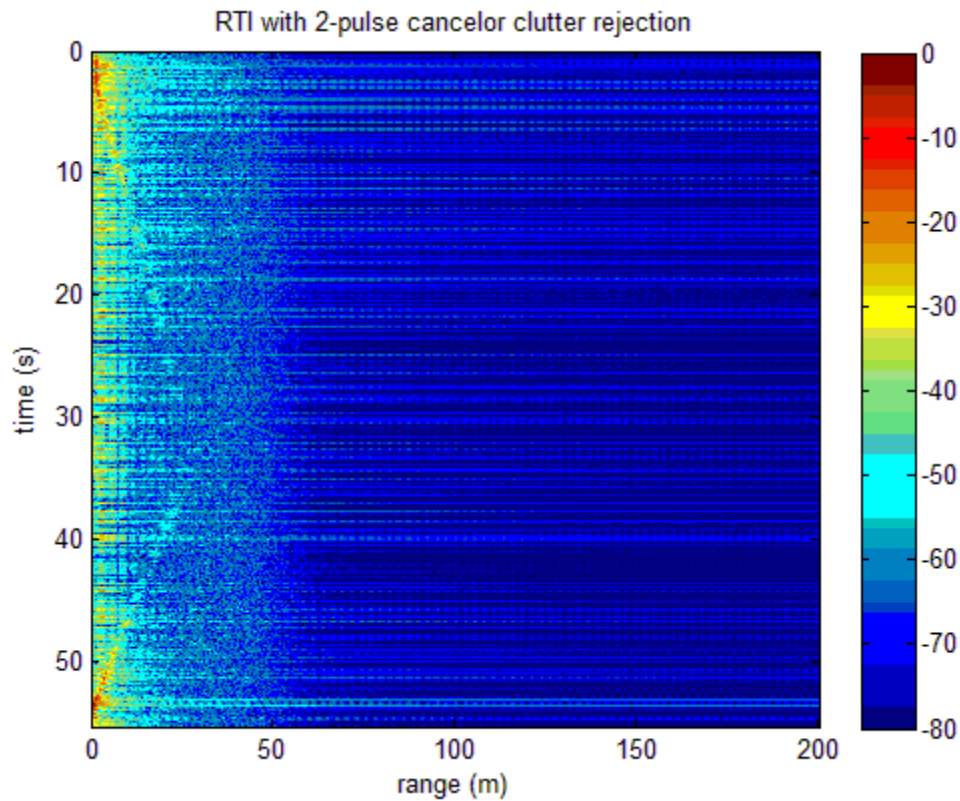


Fig 10: A faint curve showing that the radar was picking up some movement.

03/18/2016: Next time we came to the field to continue testing and see what needed to be improved, we had another baseband board ready to go with identical power amplification but with a limiter added after the low pass filter to limit the voltage entering the audio jack to make sure the audio jack stays safe. With the new baseband, radar gave absolutely zero results and all we saw was noise with a small speck which looked like a signal at the bottom left hand corner. We, then, tried to make the circuit work with the old baseband and still no result but noise. Our RF board was just not working anymore (Fig 11). After trying to swap some parts and failing to make the RF board work, we decided to work on the Lab 6 Coffee-Can radar as a backup plan in case we were not able to revive our RF board.

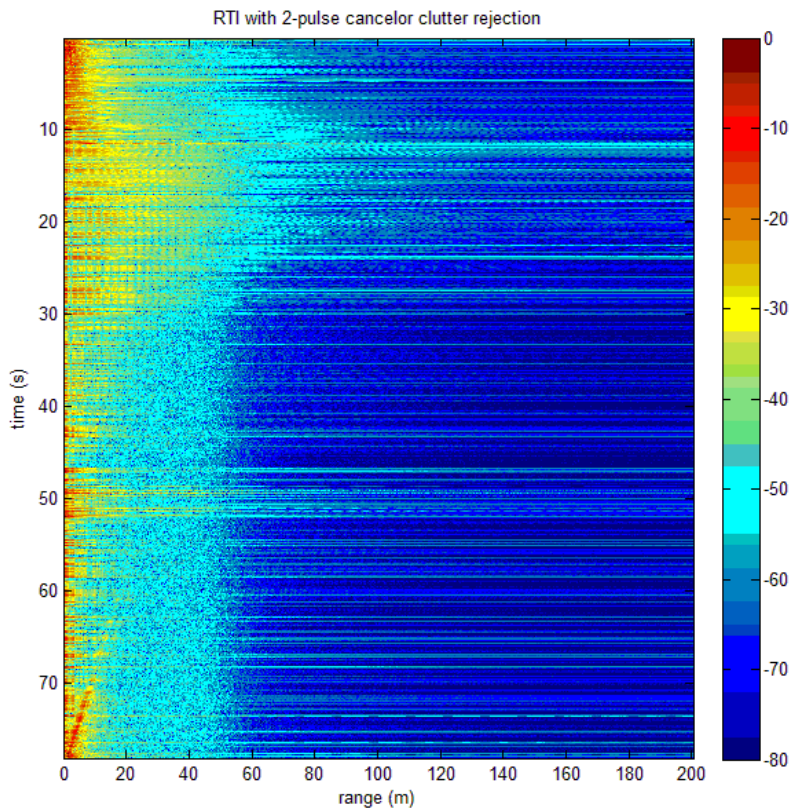


Fig 11: RF board stopped working for no apparent reasons.

2.4 GHz Coffee-Can Radar

02/18/2016: We planned to test our radar from lab 6 as is, to see how much more improvement or work it needs. It showed absolutely no signal. MATLAB figure showed a few fade lines representing noise but no strong or weak signal was being registered, telling us that we needed to do a lot of work (Fig 12)

03/14/2016: We changed the old baseband circuit from Lab 6 with our new baseband with limiter. The results were still not encouraging but it showed some kind of signal at least (Fig 13). There is a lot of noise in the figure and a very faint signal curve which seems to be not following the pattern of our walk with the metal plate but it is a curve nevertheless.

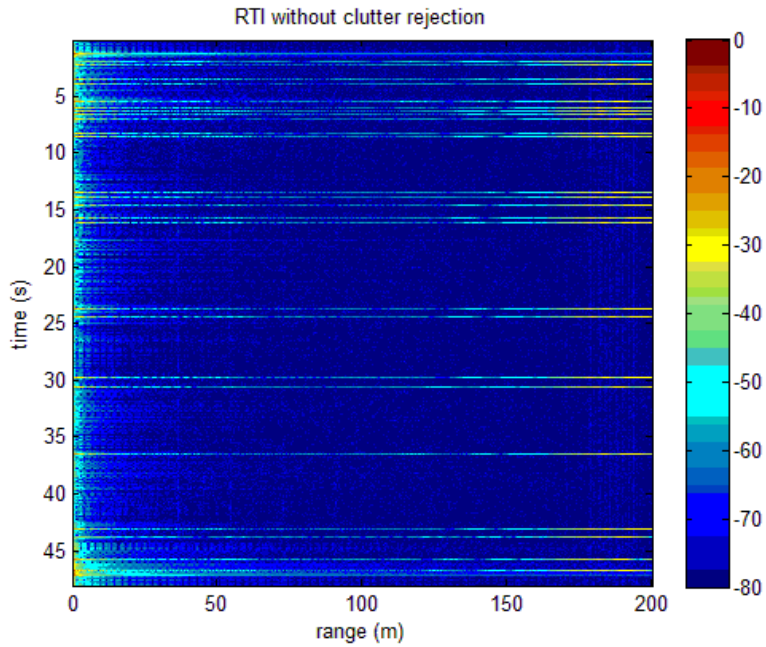


Fig 12: Coffee-Can radar showing no registered signal.

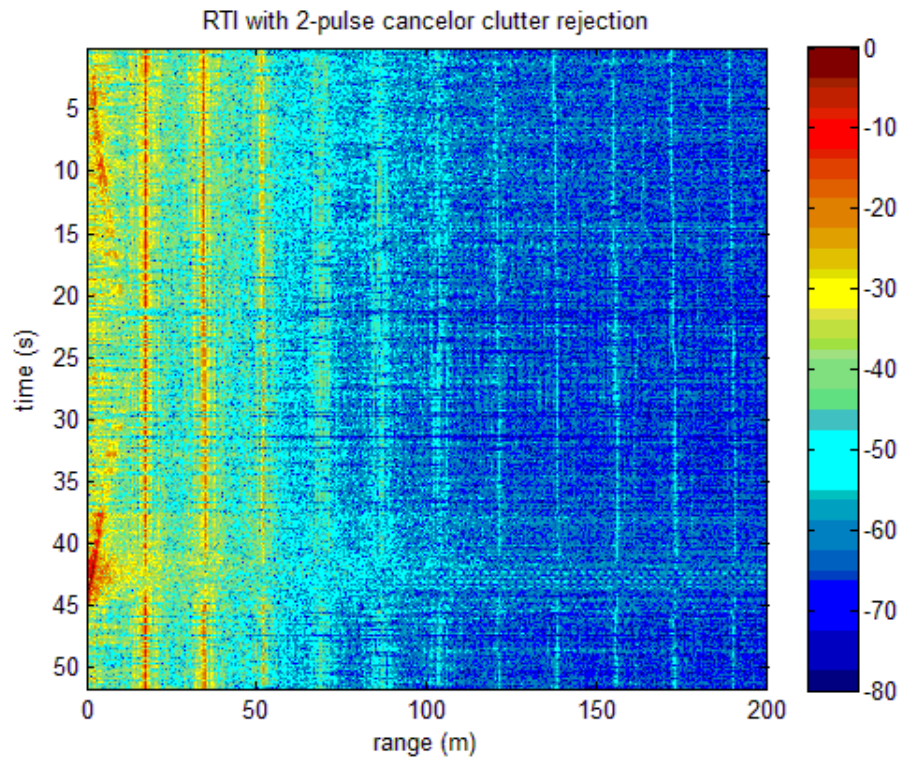


Fig 13: A faint signal and a lot of noise with old assembly and a new baseband

03/27/2016: Next we thought about limiting our sync signal instead of the signal coming out of the Low-Pass filter. Our main purpose to do this to suppress all the noise coming out of it while retaining our high frequency. This was a very successful step because it not only reduced noise drastically but also gave a very visible curve which was corresponding perfectly to our movement (Fig 14). The field testing process is shown in Fig 15. It shows how we were using a table to keep our radar still to avoid any extra discrepancies or noises introduced in the circuit

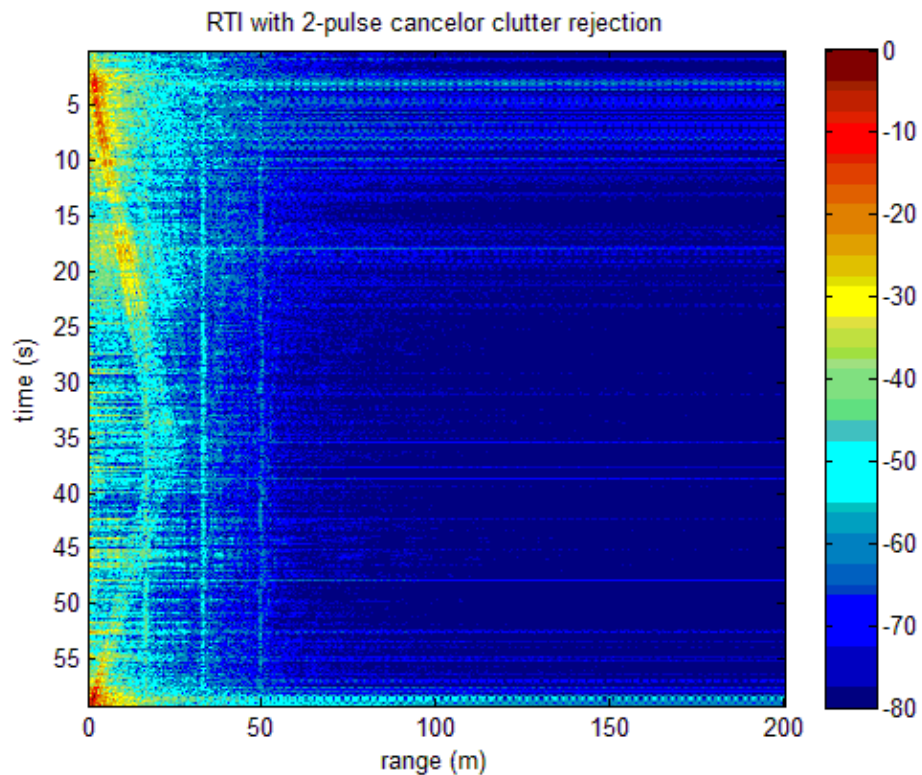


Fig 14: MATLAB figure showing a working radar with a very visible and accurate waveform.



Fig 15: Testing process

04/11/2016: Just to make sure that our radar was almost ready for the competition, we went to the field testing arranged by Hao. We preferred to use our own computer since we wanted to see the results right away. The radar worked and it worked even better for the 50m walk since the thick waveform is replaced by the thin curve which goes very accurately to exactly 50m (Fig 16)

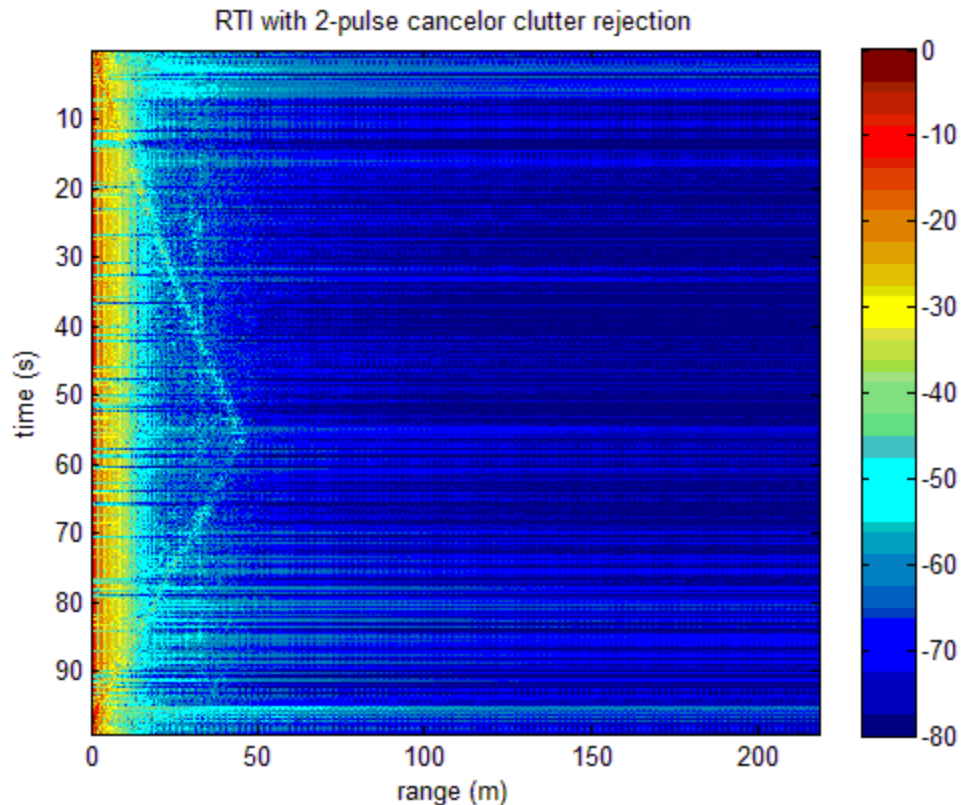


Fig 16: More precise waveform during the field testing process.

Conclusion

In conclusion, I want to shed some light on the issues which can be proven useful for the future EEC134 students. First thing is, if unsure, build the circuit on the breadboard first to see the precision of the circuit. Second, the 20 dB LNAs from Mini-circuits are not a good option for the RF circuit. In any of our RF boards, when we tried to use that LNA, we got a short in the circuit. There was no way to check the connection of the LNA with the board either, since the pins are under the LNA and there is no way we would see the connection once the part was soldered. Thirdly, even if you are told something is not available in the market, don't give up and try to find it anyways or may be try for an after-market alternative. We were told the XR2206 function generator was

not available in the market. We did a little bit of research and in the end we were able to find an after-market version from china which worked just as great and saved us all the headache of working with Teensy and trying to produce the same exact results which we produced with a smaller component and a potentiometer. Fourth, RF results are lot better during a sunny day compared to a cloudy day and even worse for night. So, plan to do your testing on a good sunny day. Fifth, as I mentioned before, one gain stage for the baseband will work just as great as two gain stages and with lot less noise. You can always try to build it on the breadboard first if you want to test the accuracy of my statement. Sixth, for the limiter, it is best to use Zener diodes (consult Professor Momeni for more information on how these work to make a limiter). Seventh, do not but do not make 90 degree angles on transmission lines, since it will bring up the issue with return ratio and return loss. Lastly, always have a lot of test points, especially on the baseband board and especially after the gain stages, LPF, sync signal and limiter signal. It always helps you to find the problem at the most important parts of the circuit and helps you to take care of those problems without affecting any other part of circuit in any way.