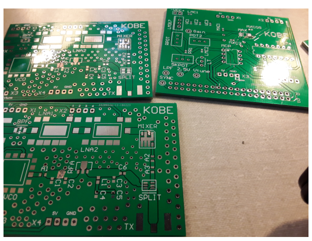
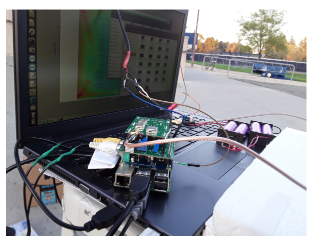
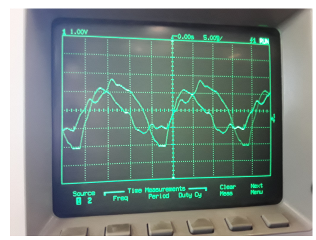
Practical Considerations for a Successful Radar Project







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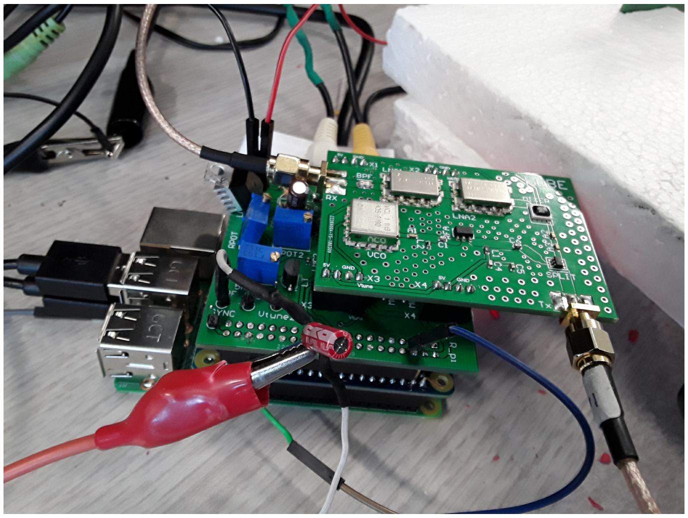
In this application note, I hope to help you obtain better results in your final system by addressing some practical matters that can hold you back. I will show you some typical pitfalls of RF engineering projects with a short turnaround time and tight budget. I will propose how to wire your system to allow more thorough testing and less error in your data. I will show you a typical problem with the modulation source in an FMCW radar system; I will show you how our team optimized our antennas for challenges we had not accounted for; and I will address one or two of the time difficulties you may face in your own project.

Thoroughly testing your system is essential to obtaining good results. When the time came for us to test, we faced some logistical hassles that could have been avoided. We had powered our system from a desktop power supply ever since building the breadboard systems from the first-quarter labs. Since it is impossible to do a realistic test of a radar inside a small laboratory room, your system must be taken outside to an open area, which means you need a portable way to power it. Our solution was to make our own battery pack. We used some lithium cells salvaged from a laptop battery, but you might find a more practical solution like an RC car battery or some 9-volt batteries connected in parallel. The choice of portable power solutions is something you can work on while you are waiting for printed circuit boards to ship, and work seems to be stalled on your project. Whatever you choose, make sure it is easy to move around and easy to connect and disconnect. Remember that if you opt for lithium cells, use of the improper charger can cause heat and explosions!

Most teams had power and signal wires flown haphazardly between circuit boards and/or computers/power supplies on competition day. This made it awkward to set up and use the systems. Most teams (including ours) had breadboard wires to plug in for power, ground, and sync, plus audio and data wiring. Every time we tested the system, we had to deal with this wiring, and one difficulty for us was loose wire connections to the board causing signals to drop out during use. You might waste less time, achieve more in your testing, and run less risk of breaking things during competition, if you create a simple wire harness so that you can plug in and unplug your setup in one step, with all the wires tied together. One good option is Anderson "Power Pole" connectors (http://www.andersonpower.com/us/en/products/powerpole/index.aspx). These are modular and can be easily hooked up together to make one unified wire harness to plug in and unplug. This way, connections to the board are hard-wired and can be soldered in place, reducing the chance of loose connections corrupting your results.

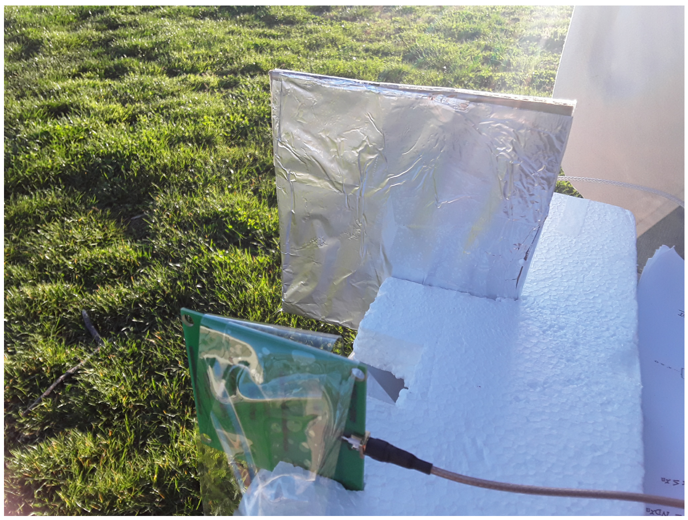


Typical wiring for a college engineering project (our own). Sync wire (lower left, middle board) broke off the PCB during competition and had to be probed.

Anderson connectors. Wires solder into the metal lugs, which insert into the plastic sockets. Sockets slide together to make a harness.

Given that we are working within the quarter system, you will probably find that time is more important than any other consideration in designing and testing your radar system. It is most likely that you will only have time to order and assemble one PCB design, plus one bugfix or modification to that design. In our case, we had some traces on our circuit board that should have passed through a component hole, to the other side of the board, but did not. We almost had to use a board we had drilled through, with wire connecting both ends of the hole, but we managed to get a redesigned version of the board shipped to us just in time. It might be in your best interest to find a supplier faster than the default one used by the class. In some cases, PCBs can arrive more quickly from overseas than from locally. It is worthwhile to find such a supplier because almost every printed circuit board design will have some kind of problem in its first iteration.

While you may be able to predict the behavior of your system using some careful hand calculations, its actual performance will be affected by factors you had not thought of or included in your mathematical model. Our design used Yagi-Uda antennas for both the transmitting and receiving end, but some factors in their implementation had to be obtained experimentally. We did not predict an optimal spacing between the two antennas, their optimal orientation (vertical, horizontal, sideways, etc.) or the effect of ambient noise, reflections, and crosstalk between the antennas. We dealt with all these factors experimentally. Crosstalk was the most important unforseen variable for us. While testing in the lab, we viewed the received waveform on an oscilloscope and saw a very noticeable change in the waveform whenever we inserted a metal plate between the transmitting and receiving antennas. Our final solution looked goofy, but it was lightweight and effective: we placed tinfoil-wrapped cardboard vertically between our antennas to stop crosstalk between them. We could have fabricated something out of a steel or aluminum plate, but the change in system weight would be significant, and the only other gain would be aesthetic.



Silly-looking but effective antenna crosstalk eliminator. Other antenna is behind foil plate.

Finally, we also improved our results by working on the triangle wave we used for modulation. We had started with a simple, commonly-used Python script, and we did get usable results with it, but when we viewed the wave on an oscilloscope, it was clear we could do better. The waveform was "stair-stepped", meaning it only made use of a small number of bits for vertical resolution. Ultimately, we generated a better wave with our Raspberry Pi, and the higher resolution meant that our VTune was moving smoothly between a large number of values, instead of stepping the VCO abruptly from one frequency to another. This greater number of different VCO frequencies as a function of time allows your code on the receiving end to better discern the exact distance from the target; this is because each frequency corresponds to a different time of transmission for a continuously-modulated wave. Make sure you look at your triangle wave on an oscilloscope to see if you are getting a smooth waveform; if you are not, either you need a DAC with a higher bit depth, or you need to adjust the maximum and minimum values in your code to make full use of whatever bit depth you have.

Low-resolution triangle wave showing "stair-stepping" effect from low bit depth. Avoid this by using a good enough DAC and optimizing your code for as much amplitude as possible.

Remember that not every result or technical difficulty can be predicted on paper. Get something done fast, then get out and test it! The best systems are the ones that have been burned in and shaken down before the time comes to present your work. This is true in industry as well! Good luck with your projects!