

## Suggestions for RF Projects & Self-Study for Students and Non-Traditional Students

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Jan 28, 2023

This is for students of electrical engineering at any level who are interested in RF, and would like to do a practical RF project or self-study. Reasons for doing this might be any of the following:

- You are interested in RF and feel the urge to build something and see it work.
- You've taken one or more RF-relevant courses, but want to learn more via self-study, hands-on, learning-by-doing, etc.
- You're seeking a job in RF engineering and you want something in your portfolio to show potential employers.
- You get a thrill from DIY-ing things that normal people would not attempt without expensive professional equipment.
- You are a radio hobbyist – perhaps an amateur radio operator (a “ham”) – and you want to build or modify your own gear. I have more to say about this at the end of this document.

If this is you, here are some ideas:

**Build a kit.** *Warning:* Many commonly-available radio electronics kits are not very useful for actually learning RF. Below are a few suggestions for kits which I think have some *bona fide* value for education and facilitate subsequent hacking. Most of these are marketed to radio hobbyists, however this does not limit their suitability for purpose.

- Down East Microwave (<https://www.downeastmicrowave.com>), especially their low-noise amplifier kits. Their web site contains lots of useful technical information. Impress your friends or future employers by modifying the design for even better sensitivity or linearity, implementing pre- or post-filtering, reducing power consumption, etc.
- Vectronics VEC-131K aviation band receiver (<https://mfjenterprises.com/products/vec-131k>). Hams might be interested in some of the other Vectronics kits.
- Elecraft K2 (<https://elecraft.com/products/k2-the-classic-hf-transceiver-full-kit>). This is an expensive amateur radio transceiver kit, but the design is relatively modern and quite good. An aspiring RF engineer can learn a lot by building one of these and then figuring out what makes it good.
- QRPme (<http://www.QRPme.com>) is another amateur radio company. Their “Rockmite” kits are inexpensive and can provide a decent learning experience.

***The Electronics of Radio*** by CalTech professor David B. Rutledge is a pretty good book for undergraduate-level RF self-study. The receiver kit described in book is no longer available but that shouldn't get in the way of doing most or all of the activities – just buy the parts you need. Fair warning: The NE/SA602 IC is becoming hard to get. If you can't find one, that's also no problem – develop a work-around as part of your project/self-study.

**Reproduce, implement, or hack designs from your classes.** Usually instructors and textbooks will analyze or design circuits, and occasionally they are demonstrated in simulation, but only rarely are they demonstrated in hardware. You can learn a lot by trying to make something discussed in class or in a book work on the bench, or in the field. Also look for designs and project ideas that instructors of other courses and other experts have made available on the web. Here are some video segments that show some class projects that I've supervised: <https://youtu.be/o0614nb2jdU?t=410>, <https://youtu.be/11RBnPF4uO8> (See video description for details)

**More interested in the systems and applications?** Here are some ideas:

**Satellite communication** has become relatively easy in recent years. Here are some fun examples:

- LoRa/TinyGS: <https://youtu.be/ltJQjqm5bKA>, <https://youtu.be/Z83ihDBL1M8>
- LEO weather satellites: <https://youtu.be/cjClTnZ4Xh4>
- GEO weather satellites: <https://www.rtl-sdr.com/rtl-sdr-com-goes-16-17-and-gk-2a-weather-satellite-reception-comprehensive-tutorial/>

**Radar:** Again, easier than you might think, and lots of opportunities for learning and hacking.

Examples:

- “Coffee can” radar: <https://spectrum.ieee.org/video-build-a-coffeecan-radar>
- Passive radar: <https://spectrum.ieee.org/passive-radar-with-sdr>.

**Wireless Networking:** There are many things you can do to improve the performance of off-the-shelf telemetry and WiFi equipment, like increasing power, improving filtering, improving antennas, and so on. Just be careful to stay legal. Also, here are a few ham radio projects in that vein:

- “NPR-70 IPv4 Radio Modem” <https://youtu.be/104mm0lRsGs>
- Automatic Packet Reporting System (APRS). Cannot be described in a few words -- Google it.

**Radio Astronomy:** Yes, you can. Here are some possible entry points:

- “Alex Pettit: Galactic Hydrogen 1.42 GHz RF Emission Radio Astronomy for \$300” (<https://youtu.be/C6NCefVxNL8>). Turned off by the size of the antenna? Check this out: “21cm neutral hydrogen receiver with no dish and no LNA” (<http://parac.eu/projectmk9.htm>).
- Radio Jove: <https://radiojove.gsfc.nasa.gov/>

**Software defined radio (SDR)** USB dongles are inexpensive and have all kinds of applications in projects (some already appearing above). They’re cheap, so there’s no reason not to crack open the case, poke around, and change things up. Browse <http://rtl-sdr.com> for ideas.

**Ham radio:** I have no way to know what the actual numbers are, but a large fraction of RF engineers are also licensed hams, including me (AK4WY). Part of that has to do with needing more of the visceral thrill of doing difficult hands-on things. It’s not for everybody, but many hams would say they learn useful skills and insights via ham radio that they would not have learned otherwise.