Outfitting an RF/Microwave Lab on a Budget

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Modern RF and microwave test equipment is awesome. It can provide accurate measurements to 20 GHz and above in small, lightweight packages with bright color screens and many time-saving data-reduction options. But it is also extremely expensive. The photo at left is an HP8753E we bought from the refurbished market. Newer models sell for $50K to $100K depending on frequency range!

For those of us who must live within reasonable means, such instruments are usually outside our reach. However, there *are* ways to continue working in this business - if we are willing to give up on some of the fancy looks and features. Fortunately, this does NOT include giving up on basic performance (much). The picture at right is a 20 GHz network analyzer assembled from pieces bought for less than $2K total, after scouting Ebay and used-line.com. Admittedly this is a rather old system to provide an extreme example. Most of our equipment here at K-State is nicer than this. But we, like many of you, cannot always afford to buy the latest and greatest.

This page provides an overview of what we have learned over the years in moving our lab capabilities from VHF into the microwave arena on a budget. I hope you find it useful.

Purchasing Options

Some good ways to save money include the following: (listed from highest cost to lowest)

- Buy economy models or refurbished equipment from a manufacturer or their one of their representatives. Economy spectrum analyzers from folks such as Agilent and Advantest now run below $10K and refurb units have discounts on top of that. Often refurbs are demo units and are in very good to perfect condition. Savings range from 10 to 50%. (and if you're a school, you might get more)
- Buy through one of the many after-market equipment vendors. These vendors buy equipment from government and business surplus, clean it up nice (usually), check it out, and sell it at good discounts (relative to comparable performing newer generation models).
- Browse the Test Equipment section of Ebay. Here you will sometimes find the after-market vendors selling for less than on their own sites, as well as many smaller operators. Of course you take more of a gamble, but if the feedback is above 99.5% on at least several hundred sales, this is their line of business, and they clearly state it has been checked out, the risk is much reduced. But it does take time to find and land a good deal.

Examples of Equipment Deals

UHF signal generator. Shown here is an HP8656A which runs $500 to $1K. The newer HP8656B has a prettier display and the more desirable "soft-keys" (if you get the right year), but is otherwise the same. Models HP8657A and B with the nice display and keys can also be had for around $1K to $3K and cover to 1 GHz and 2 GHz respectively .	

RF vector signal generator and vector modulation analyzer. The sig-gen is an HP8780A which is good through 3 GHz and supports I/Q inputs as well as digital bits which it formats into BPSK, QPSK, QAM, etc. It also has wideband FM capability.

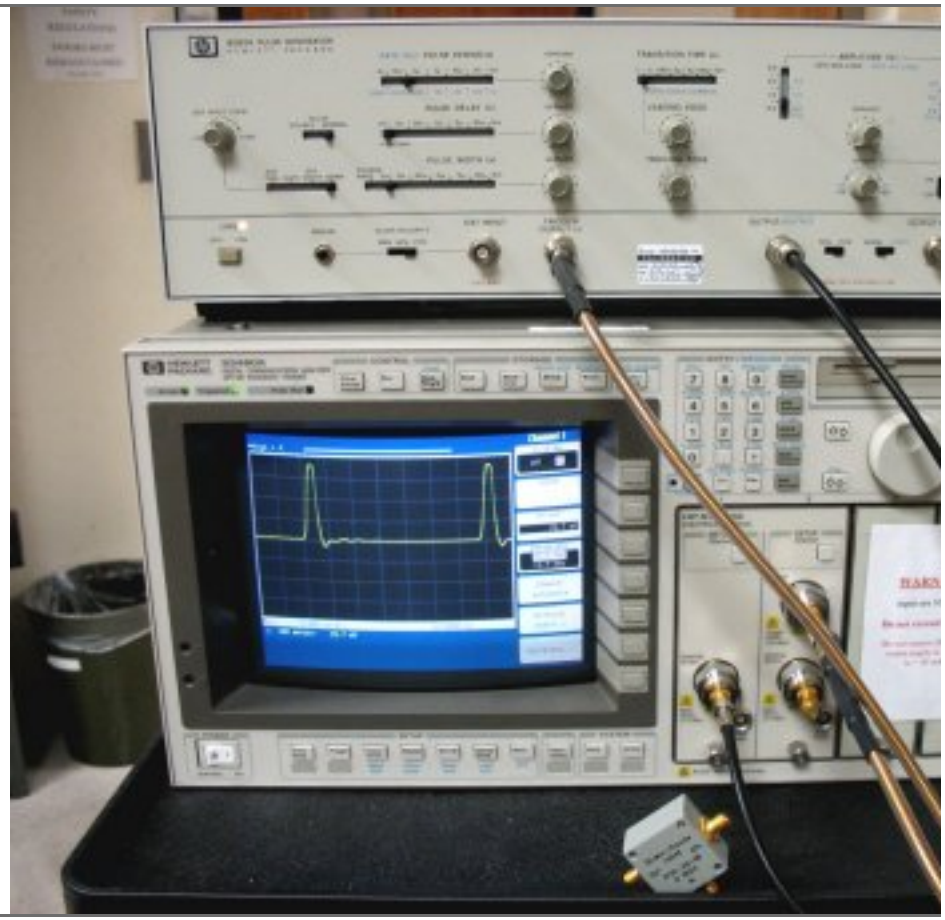
The modulation analyzer is an HP8981A which looks at I/Q on a vector display. Baseband inputs are on the front, and RF on the back. The RF input only works up to a few hundred MHz (and needs an unmodulated coherent reference signal alongside the RF), so you need to downconvert if you're looking at a transmitter output, but that's easy.

The HP8981A was bought on Ebay for < $1K. The HP8780A was also bought through Ebay, but cost a bit more (about 4 to 5K). Both are Big and Heavy. Hence, the large rolly cart was purchased for a few hundred bucks to hold all this good stuff.

Spectrum Analyzer. This one is a 22 GHz unit we bought new, but now sells for maybe $8 to 10K. You can also get 859X series models with lower frequency range such as 1.5 GHz for less than 1K, or, if you need the microwave spectrum on a budget, an 8565A with 0.01 to 22 GHz capability can be had on Ebay for around $2.5K (or less).	

2 - 20 GHz vector network analyzer assembled from parts bought through Used-Line and Ebay. A modern VNA includes a sweep generator, a sampler and display, and an S-parameter test set in one box. Here the sweeper is an (unsynthesized) HP8350B with 86290B plugin ($1K to $1.5K). The sampler is an HP8411 (a few hundred bucks). The display is an 8410B with 8412B plugin (another few hundred bucks). Note that the 8412 can be swapped for an 8414 polar display for Smith Chart format) and full SOL calibration can be added with an external computer using our nifty software. The test-set is an 8743B (also a few hundred bucks - although the nice cosmetic condition one here was bought through used-line for about $1K).	

High speed pulse generator (HP8082) and sampling oscilloscope (HP83480A). The former has edge speeds of less than 1ns. The latter can observe signals with frequency content to 20 GHz or more depending on plugin (limit of triggering is 12 GHz (or less if option 100 is not included).
The pulse gen was bought through Used-Line for < $1K and the scope with plugin was bought through Ebay for about $4500.
Comparable performance new equipment would be > $20K for each unit.



Getting Publishable Output

Newer equipment supports dumping screen shots and data to a floppy, or to a USB memory stick. Unfortunately, older equipment was designed for use with GPIB and/or plotters, which have

become all but obsolete. Never fear though. There are software packages on the web that emulate a printer or plotter (instrument outputs to PC GPIB port or serial port and things it's talking to the plotter or printer). A really nice freeware package is 7470 from KE5FX. This is part of the KE5FX GPIB Toolkit that also includes many other cool applications. A good low-cost commercial software is PrintCapture. Some research and understanding of your setup is required to get these to work, but its not hard, and the software can be dowloaded before you commit to anything :-)

So What's the Catch ?

As you can see, it is possible to put together RF and microwave equipment for 10 cents or less on the dollar relative to new equipment cost. So what's the catch? What do you lose compared to new $100K equipment. Here are some general comments. I will try to provide more quantitative info in the future as this page expands.

- Its bigger, heavier, and somewhat noisier. Some instruments will weight upwards of 50 to 90 pounds and can be as deep as 24 inches or more. Get an old HP catalog if such physical size issues are a concern. You can find the dimensions in there - as well as most of the instrument specs.
- You'll get little or no warranty - and on Ebay, you could get stung. However, a) old HP gear is pretty reliable (except for a few units like 8660's, etc.), b) I've never been stung on Ebay for bigger items - perhaps because I am very careful (see above), and c) At these prices you can afford to insure yourself. For example I keep some money in reserve in case something breaks and I sometimes buy more than one unit of a given model.
- Performance is not quite as good. This is, of course, a difficult issue to comment on in

general. The best advice is to get old HP catalogs, or search on the web for specs and user/service manuals and judge for yourself. For some products like HP8657B units, the performance is about as good as new models, if you can live with the 2 GHz upper limit. For others, such as the 8350 microwave sweeper, its not synthesized, and RF attenuators are optional on the RF plugins - so it may not suit your needs. Just be careful and do your homework :-)