Spectrum analyzer and sweep generator on a budget

Dennis Farr

Introduction

Data obtained in radio work is only as good as the instruments gathering it. Having worked for many years in radio/radar communications, I have used premium top of the line spectrum analyzers and sweep generators. Now that I am retired, access to that level of equipment is no longer available to me.

When I started in amateur radio and radio astronomy, the desire to have accurate readings was instilled in me by my training and education. Checking on the prices of even modest spectrum analyzers quickly convinced me that they were pretty much out of my league.

My interest in radio astronomy started when I read an article about the RTL-SDR dongle radio. For about $20 it seemed like I could at least get started for a very low cost. After putting together an LNA using amps and filters from Mini-Circuits, I wanted a way to determine the overall gain and bandwidth of the system. Another search on eBay turned up the TPI calibrated signal generator.

This paper is about using these two pieces of hardware to enhance my radio astronomy experience.

The RTL-SDR receiver

These are pretty common and well documented. The challenge I had was to find software that would provide what I wanted for use at 21cm.

I started with SDR# software. It has some nice features, but also some draw backs.

First of all, it has a nice spectral display. When I saw that I recognized its value as a spectrum analyzer. The output readings are in db, so easy to see those values.

The big draw back for my use was that it doesn't record information regarding the level of signals being processed. The recording feature is for audio, essentially to record modulation in the carrier.

Further research led me to Radio-SkyPipe and RTL Bridge. This seemed to be a good solution that recorded like a strip chart recorder. However, at this time, I am unable to get a stable reading from a signal source.

I then was directed to rtlsdr-scanner software from eartoearoak.com This seems to have all the features I wanted. It is written in Python so it runs across many platforms.

Finally, I found an Android app that runs on my Motorola smart phone.

TPI Synthesizer

The synthesizer has an internal crystal controlled 10Mhz reference oscillator. It can also be synched to an external 10MHz reference. The frequency output range is from 35MHz to 4400MHz and the output is variable from +10dBm to -55dBm is one dB steps. It is controlled by a PC with a USB interface. The Synthesizer can be set to scan both frequency and power at variable rates. It has many other features that are not relevant to my needs.

The model I have, which has been discontinued, is the Version 4.9. The replacement is the model 1001 which is slightly more expensive but has more features.

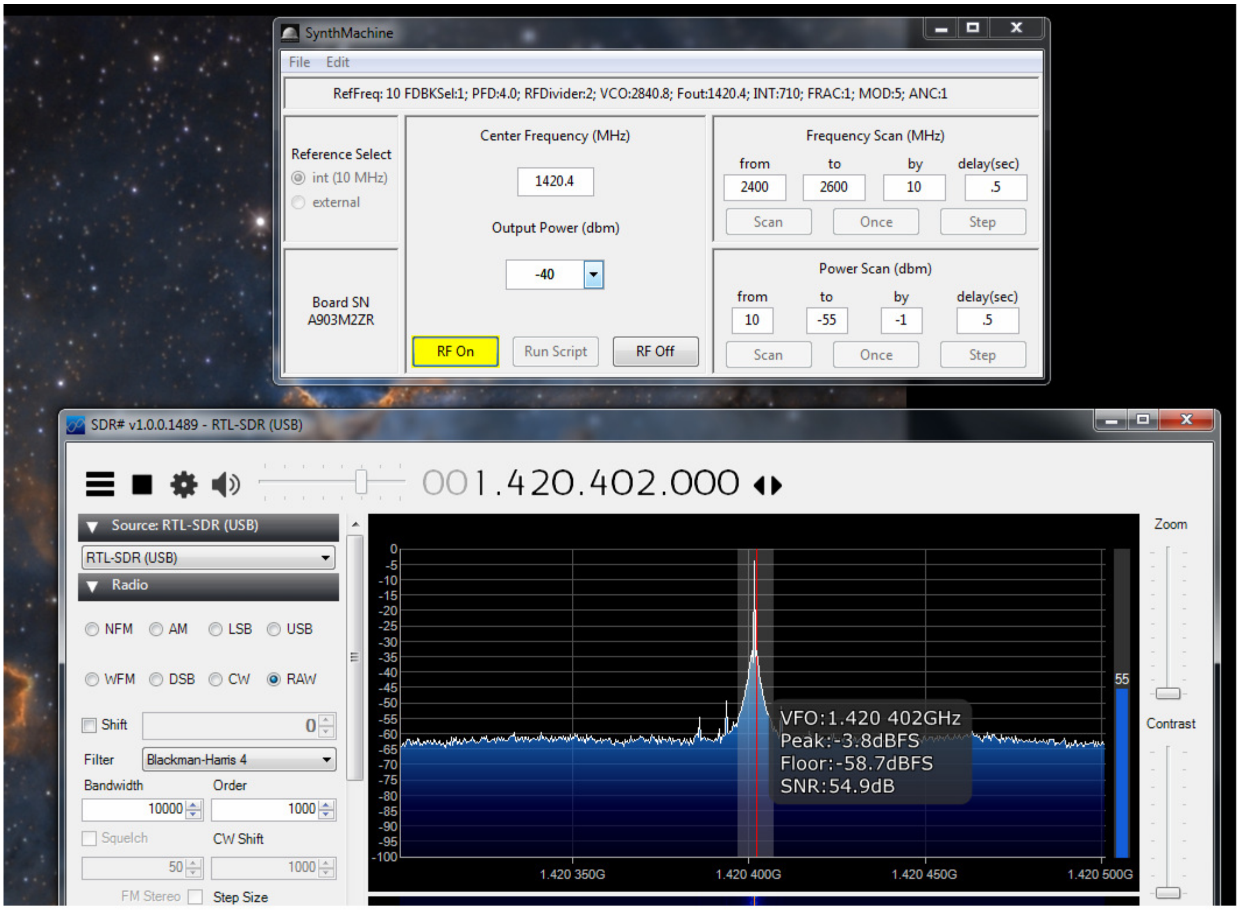
Initial tests

Before any testing could be done, the operation and use of the two pieces of equipment needed to be checked.

The output of the TPI was connected directly to the input of the RTL-SDR dongle. Both could be controlled from the same PC, which made it convenient to use.

Initial tests were run at 1420.4 Mhz at an output level of -40dBm. Base line data was determined by taking readings every .5MHz from 900MHz to 1750MHz.

The screen shot of the test:



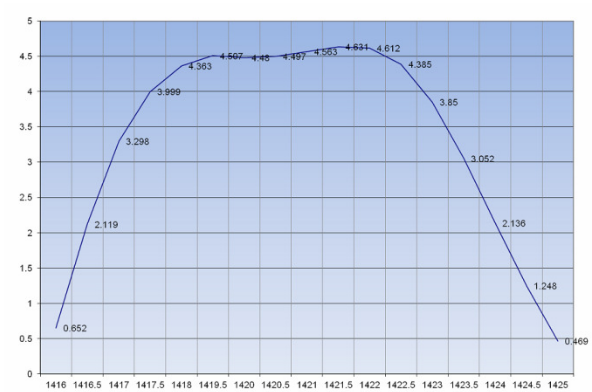
On the top is the window that runs the generator, set to 1420.2MHz with an output level of -40dbm below the SDR# software showing the peak output at -3.8dBFS which indicates that the receiver has a gain of 36.2dB. This of course is for a single frequency. If you need to plot data for a range of frequencies, or a spectrum, measure multiple data points and record in a program such as Microsoft Excel, then graph the data.

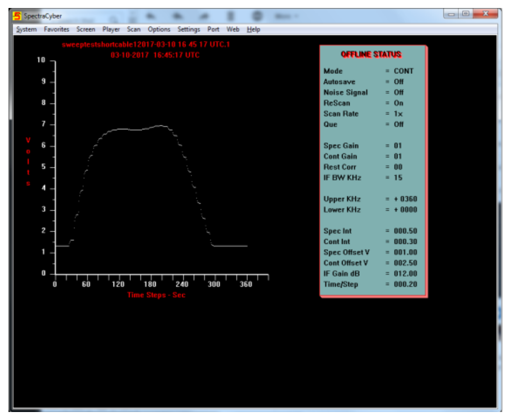
Real world testing

SpectraCyber receiver

The TPI Synthesizer was connected to the input of a SpectraCyber receiver. The TPI output was set to -75dbm and the frequency changed in increments of .5MHz from 1416MHz to 1425MHz. The readings were entered into Excel. The spread sheet graph is the result.

After that, the TPI was set to scan in frequency 1416MHz to 1425Mhz with the same level output. Screen shot of SpectraCyber on the right.



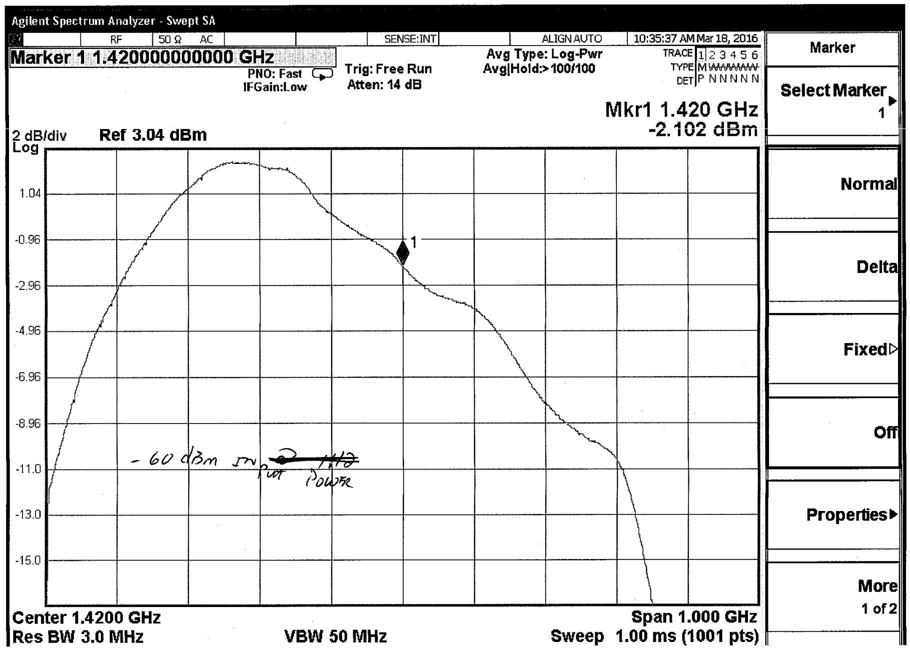


First LNA and band pass filter

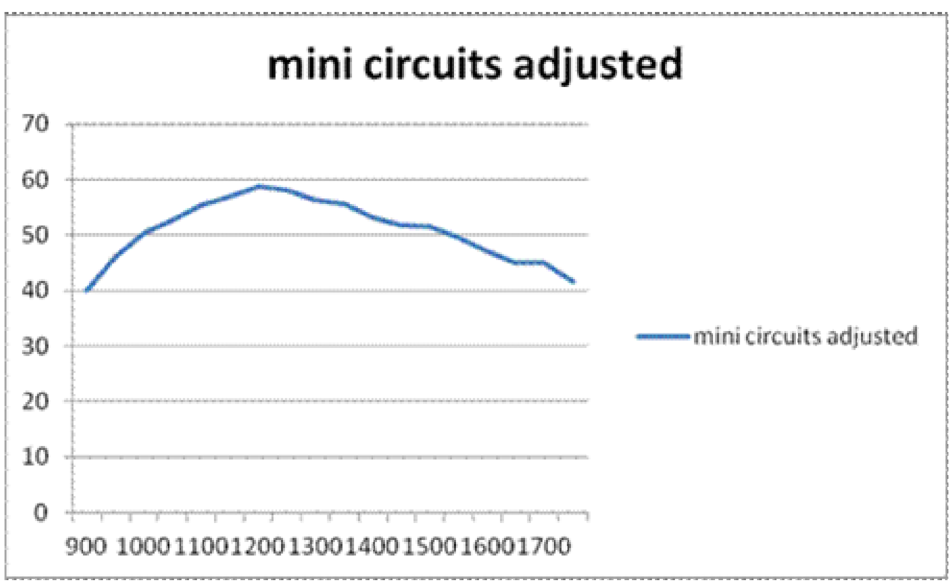
The first attempt at building and LNA used amplifiers and a filter from Mini-Circuits.

I called in a favor from a friend at the last place I worked. He used laboratory grade equipment to run a curve on the amplifier.

dennis.png



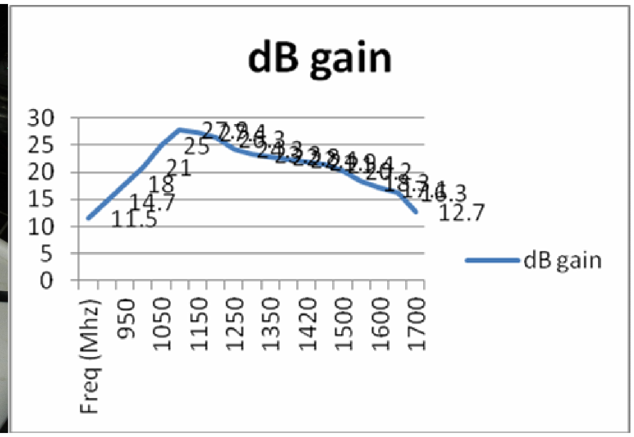
Running the same test using the SDR-RTL with SDR# software and the TPI synthesizer, I got this graph.



To run the test, first the TPI was connected directly to the RTL-SDR and a reading was taken every .5 Mhz from 900MHz to 1750MHz (the limit of the RTL-SDR) and recoded on a spread sheet. Then the same readings were taken through the amplifier/filter chain. The difference in the readings for each point were then plotted to determine the gain and bandwidth of the chain.

Second LNA and band pass filter

I read about some inexpensive amplifiers on the SARA list. I bought two and another band pass filter from mini circuits. I built this to donate to a school that wanted to put in a 3 meter dish up for their STEM classes.

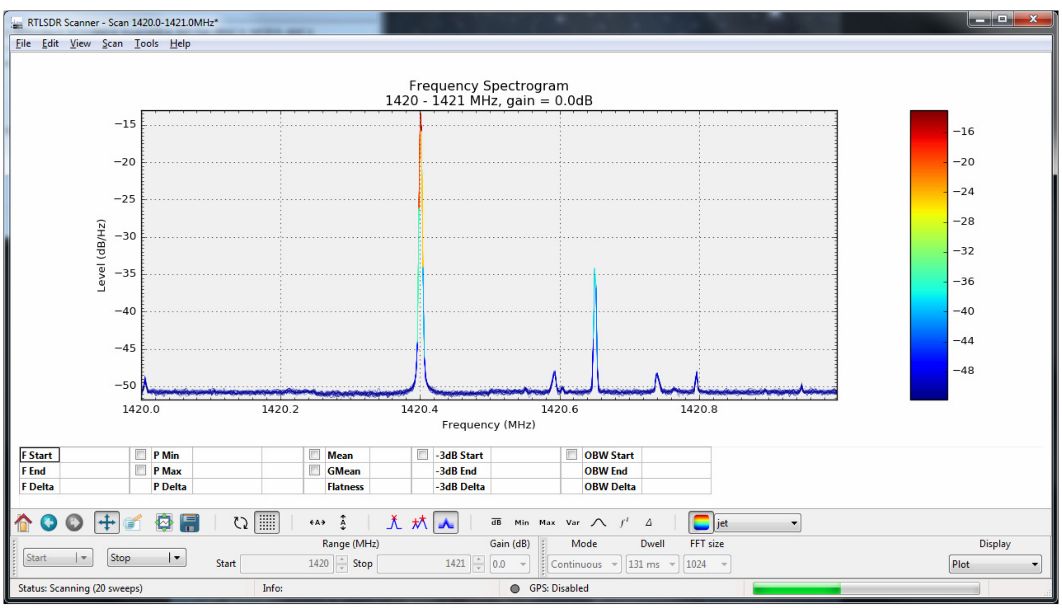


Other Software

Other software I have tried and found useful.

RTLDSR Scanner

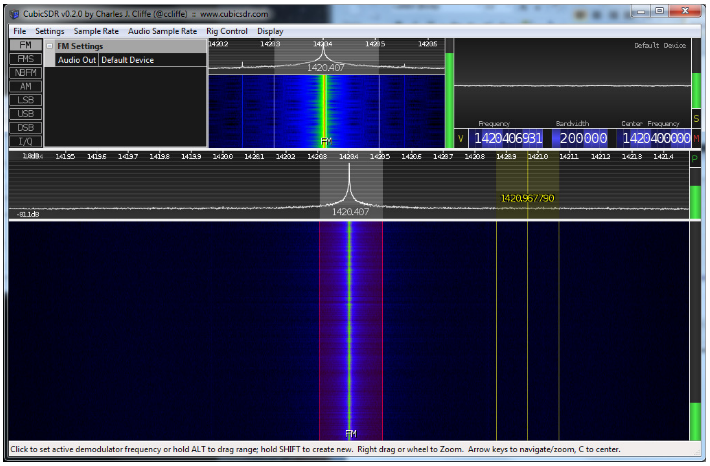
Written in Python, it can be used on many platforms.



This seems to be the best display I have found so far.

CubicSDR

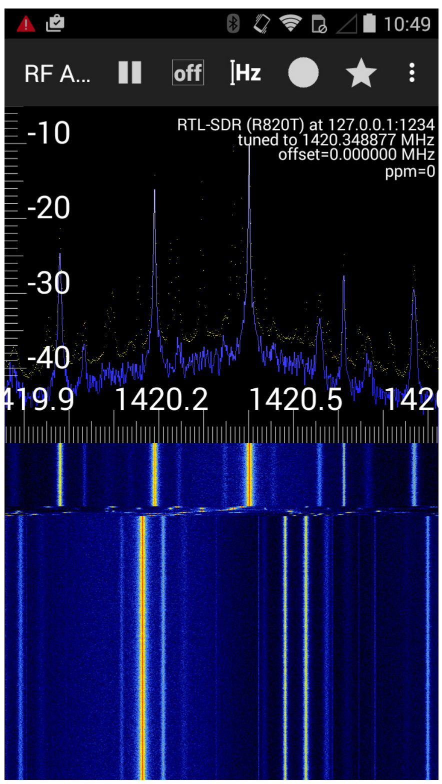
Another free program that has multiple screens.



Android app

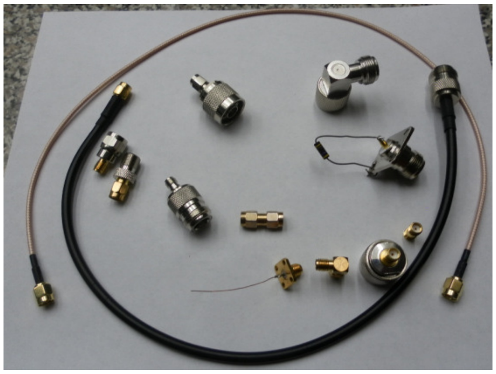
There's an app for that!

Could be the most portable radio telescope of all, if you don't count the antenna.



Ancillary equipment

My life working on the test bench taught me that you can't have too many adapters to connect equipment properly. The TPI and the RTL-SDI both use SMA connectors, but some of the equipment I need to test had type N connectors and I even got some adapters for type F connectors. I also got a 20dB pad to decrease the output of the TPI to as low as -75dBm.



Summation

The ability to measure signal strength at a specific frequency is vital to many forms of communications. The availability of free software coupled with the RTL-SDR dongle has given amateurs the ability to perform measurement tasks that enhances their hobby experience.

The TPI synthesizer although not inexpensive, is a cost effective device that enables the testing of amplifiers, antennas, and filters which is extremely helpful.