Verifying Microwave Receiver Performance using TotalPower by IØNAA

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At microwave frequencies performance is determined by noise figure (NF). Noise figure is measured with a noise figure meter, whose accuracy is determined mainly by the calibration of the noise source. The tinySA Ultra can measure NF, but also requires a calibrated noise source. A more convenient noise source is the Sun – which can measure system noise figure, not just the LNA.

Until recently, measuring sun noise required dedicated equipment. Many EME hams use an old General Radio meter to measure noise at 30 MHz; others have homebrewed a noise meter. A computer program, **TotalPower**[1], developed by Mario Natali, I0NAA, makes it much easier. All that is required is a laptop and a low-cost RTL-SDR dongle. Make sure to buy an official one (https://www.rtl-sdr.com/buy-rtl-sdr-dvb-t-dongles/). The dongle connects to the IF output of a transverter to detect noise and display a plot of the noise level. At 1296 MHz and lower, connecting the RTL-SDR dongle directly to a preamp may be sufficient for antenna tests.

Noise Figure

The noise figure of the receiver alone can be estimated by connecting directly to a small antenna, like a feedhorn, and measuring the ground noise and cold sky. In Figure 1, I have connected my 10 GHz EME preamp directly to a feedhorn through a short waveguide. The wider beamwidth of the feedhorn might pick up some ground noise even when pointed straight up, so it is placed inside a spare dish which shields it from the ground but does not add any gain (W2IMU suggestion). The RF and power cables exit through the hole in the center of the dish. If the hole is big enough, the feed can pass through the hole, like the right-hand photo.

Figure 1 – Measuring sun noise – feedhorn shielded by dish from ground noise

The noise at the IF is plotted by **TotalPower** in Figure 2 – I have added the labels. First the horn is pointed at the sun, then at cold sky, higher than the sun. Finally, it is pointed at the ground to read ground noise. The cold sky has two sections; the second part is with the dish reflector removed. The spike in the middle is me removing the reflector. The cold sky noise level is slightly higher without the shielding effect of the reflector.

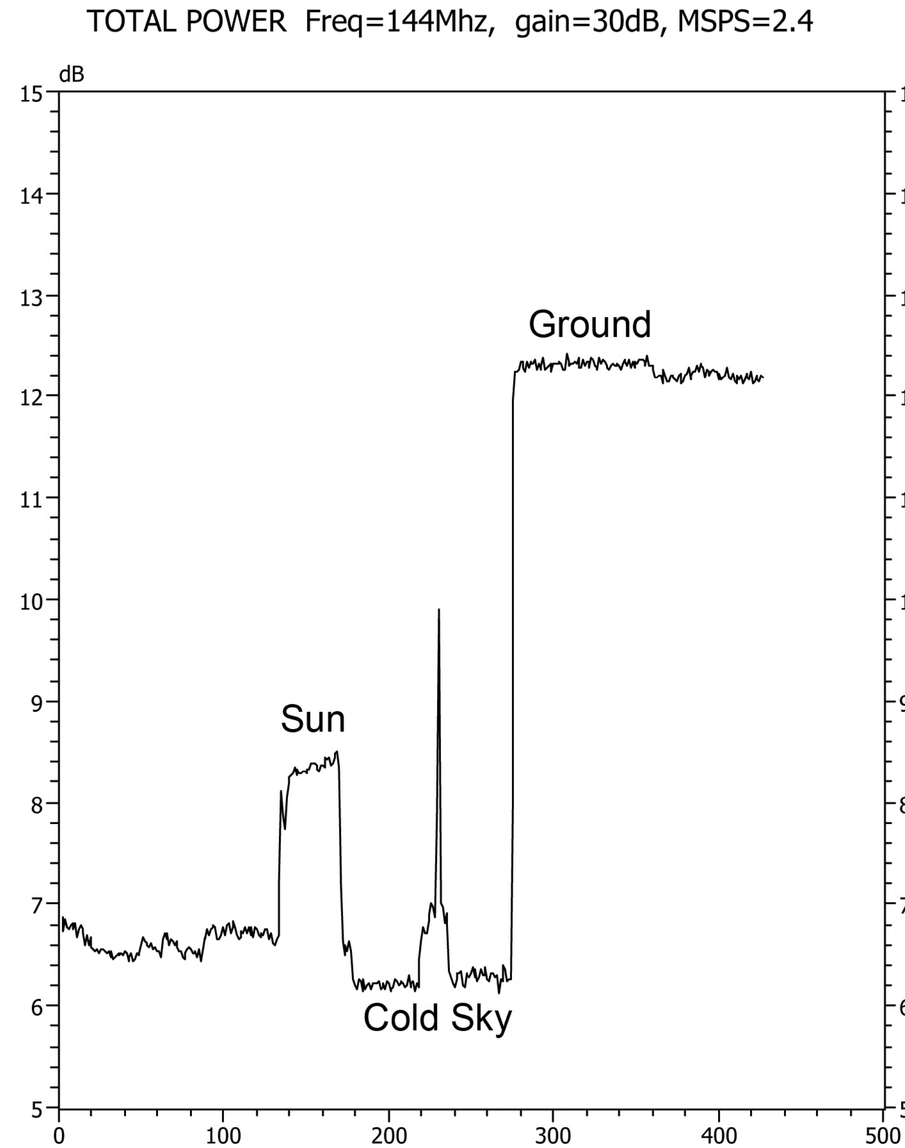

Figure 2 – Noise Plot by TotalPower for Noise Figure Measurement

We measure the difference Y_{db} between ground noise (T_{ground} = 290K) and cold sky (T_{sky} ~30K) to calculate the receiver system noise temperature T_{system}:

$$Y_{dB} = 10\log_{10}\left(\frac{T_{system}+T_{ground}}{T_{system}+T_{sky}}\right)$$

To solve the equation for T_{system} , I used the **nfskydb.xls** calculator spreadsheet[2] by Ed Munn, W6OYJ (SK). In Figure 2, the difference Y_{db} is 6.1 dB; the calculated T_{system} =55K; the calculator also converts to equivalent Noise Figure of 0.75 dB. The rated NF of the preamp is 0.6 dB, so the shallow reflector probably didn't keep out all the ground noise. A larger or deeper dish would do a better job of shielding from ground noise.

System

Figure 3 shows my 10 GHz rover system with an 18-inch dish pointed at the sun. The sun noise is plotted by **TotalPower** in Figure 4, a drift plot for about ½ hour as the earth rotates and moves the sun out of the beam of the dish until only the cold sky is left, which I verified by the moving the dish to point straight up. At the end of the plot, I pointed the dish at the ground to read ground noise, which is greater than the sun noise.

Figure 3 – Measuring sun noise of 10 GHz rover system

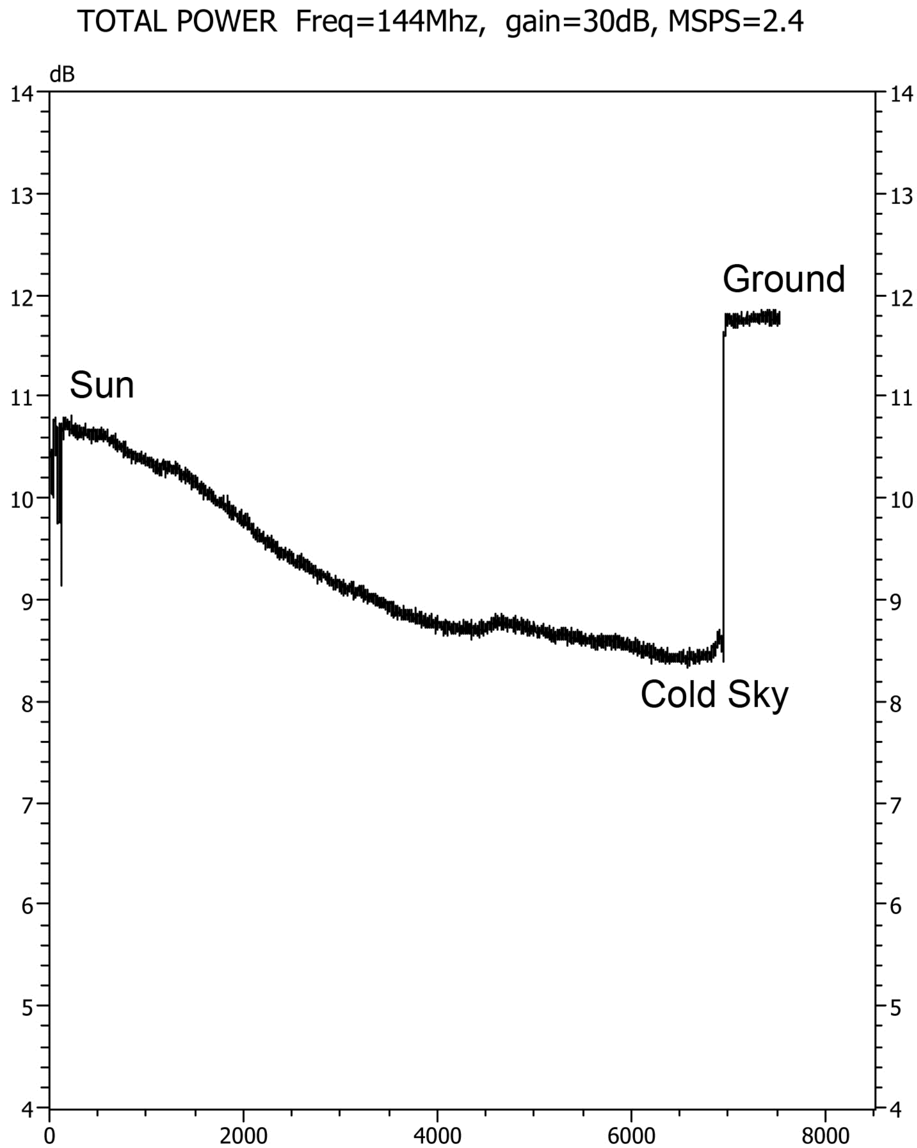

Figure 4 – Sun noise plot for 10 GHz rover system as earth rotates

The difference between sun noise and cold sky in Figure 4 is about 2.3 dB. The sun temperature is roughly 6000K, but the small dish only receives a small part of that, since the sun (~0.5 degrees diameter) fills only a small part of the beam diameter (~4 degrees). For this small dish, the received sun noise is less than the ground noise. A large dish with a 0.5 degree beam would see the full sun temperature, perhaps 20 dB greater than the cold sky. Some EME stations do have large enough dishes to see this much sun noise.

The difference between cold sky and ground is about 3.4 dB, so T_{system} calculates to about 189K (NF = 2.2 dB), for the transverter plus coax relay and cables – small losses add up.

Indoor Verification

The first time I measured sun noise on the rover system, the difference between cold sky and ground was smaller, with a calculated NF of about 3.5 dB. This is far worse than expected. To troubleshoot the problem, I put it on the workbench and connected a noise source to a spare feedhorn and held it in front of the system feedhorn, as shown in Figure 5. The noise figure meter showed the high number. A few substitutions isolated the problem to a short flexible coax cable that I added while making the measurements in Figure 1. A very short piece of semi-rigid coax reduced the noise figure to the lower number in Figure 4.

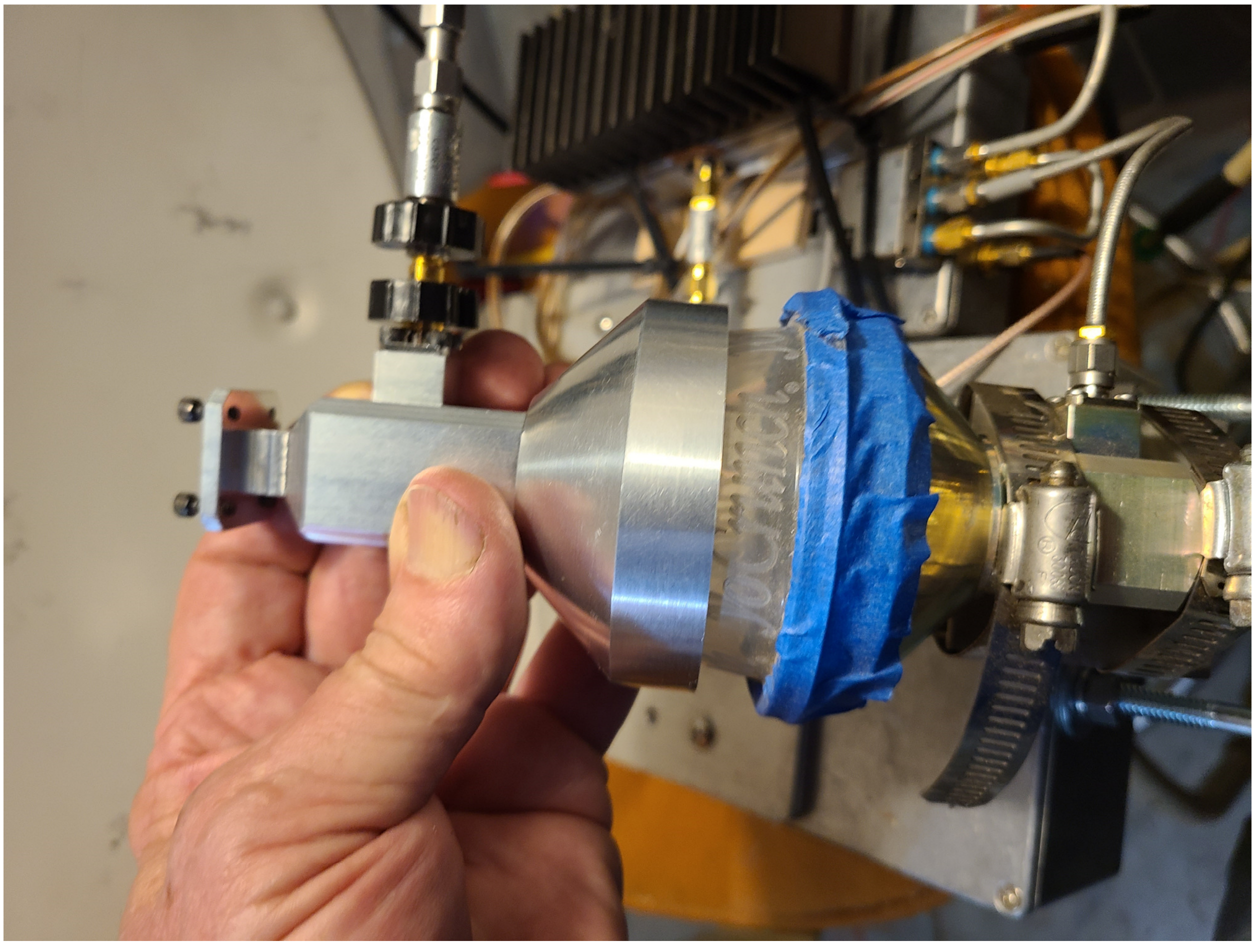

Figure 5 – System testing on the workbench with spare feedhorn

I often use the spare feedhorn trick for system checks, of both receive noise figure and output power. The loss between similar feedhorns is less than one dB so it is reasonable check. It works with the radome, as shown, or without, with horns butted together. If you don’t have two identical horns, any similar sized one should give reasonable results.

Using the TotalPower program by I0NAA

All you need to make noise measurements with the TotalPower program is an RTL-SDR dongle and a computer running Windows 10 or later – a modest laptop will suffice.

Here are some hints for using TotalPower, after you have read the manual. The manual is found by downloading (https://i0naa.altervista.org/index.php/downloads) and installing the program. The Help button allows printing the manual.

After installing the RTL-SDR ((https://www.rtl-sdr.com), start TotalPower. The main screen in Figure 6 should appear.

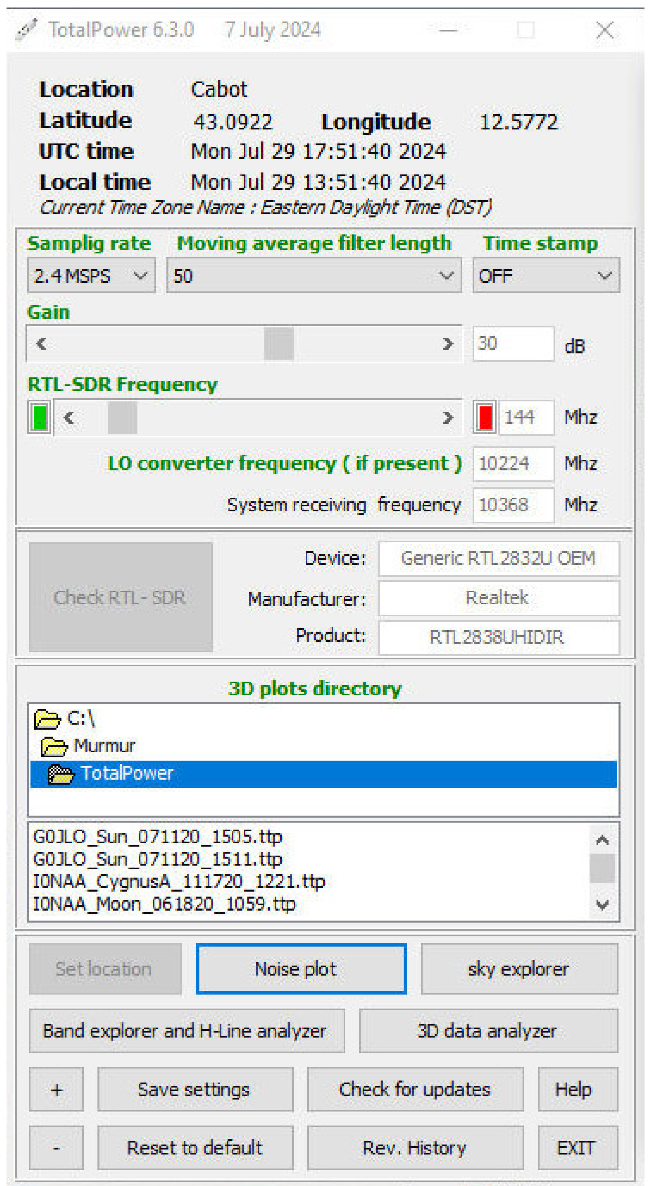

Figure 6 – TotalPower main screen

If the RTL-SDR has been installed correctly, it will show near the "Check RTL-SDR" button; otherwise, you will probably get an error. You can enter your location, but obviously I still have Mario's latitude and longitude listed. Use the slider to enter the RTL-SDR frequency, usually the IF frequency, and the LO frequency if using a transverter (the LO frequency only changes the frequency shown on plots).

The "Noise plot" button will bring up the plot screen, shown in Figure 7. This is a drift plot of sun noise on a larger dish. At startup, the noise trace will start at the left side of the plot window. Do something to change the noise level, like putting your hand in front of the feedhorn, and look for a change. If it changes, you are measuring noise.

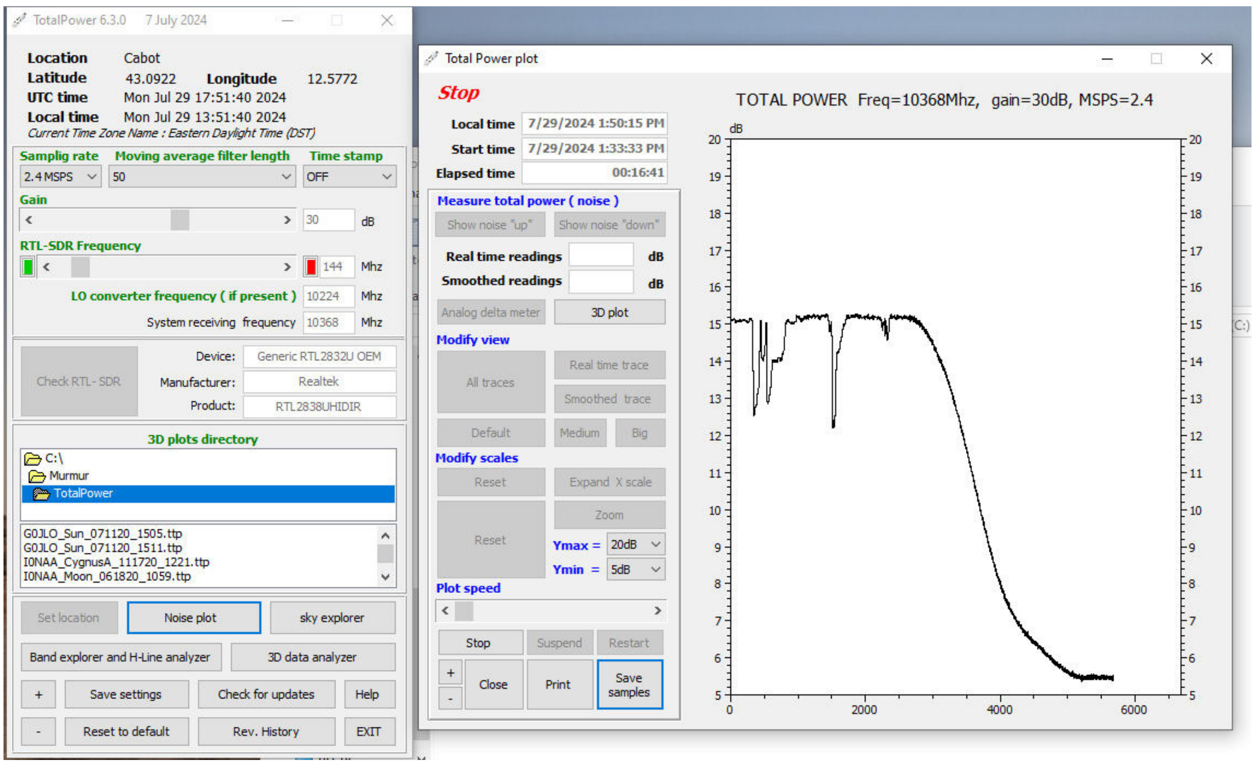

Figure 7 – TotalPower plot screen on right

The plot vertical scale can be adjusted with the "Ymax" and "Ymin' buttons to better show the noise line, and the "Expand X scale" button can keep a long plot from running off the screen.

When the plot is finished, the "Print" button will print the plot – I usually print to a .pdf file. And the "Save samples" button makes a .csv file of all measurement points for further processing.

I put a step attenuator in the IF line and use it to make sure that the lowest noise level, like cold sky, is several dB above the noise floor, and that there is at least 10 dB of headroom above the maximum expected level to prevent compression by noise peaks. Random noise has unlimited noise peaks, but peaks more than 10 dB have low enough probability that they may be ignored.

The noise plotted in Figure 7 has ups and downs where I was fine-tuning the dish position to peak the sun before starting the drift plot where the rotation of the earth moves the sun out of the beam. I usually move the "Plot speed" slider to a faster setting while peaking the dish, then move the slider to the slowest speed for the drift plot. An idiosyncrasy of the program is that changing the speed doesn't affect the plotting, so the up and down time is far less than the drift time.

The "Smoothed trace" button makes the plot a pretty line, but I prefer to see the actual points and uncertainty, in case of something unexpected. During one plot, the line suddenly dropped 2 dB – just before I felt raindrops.

Summary

For most of us with modest antennas, sun noise is good indicator of decent system performance and useful for comparisons, especially for system changes and improvements. The big guns can measure moon noise. The **TotalPower** program makes this much easier – you can't hear these small differences. A future release of the program will include sun noise prediction, to see if your gear is working as expected.

Even without the sun, a quick check of system performance with **TotalPower** is to simply put your hand over the feedhorn and look for an increase in noise.

Notes

1. https://i0naa.altervista.org/index.php/downloads
2. http://www.ham-radio.com/sbms/sd/swindex.htm