Subject:	Three LNA4ALL + Two Minicircuits ZX60-P103LN+ Amp Configuration
Memo:	9, Revision 3
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Date:	2016 March 4-22

This note describes additional test measurements of a variety of radio frequency horns configured with amplifiers powered via Bias-Tees. The project has goal is designing a prototype system for astronomical observations that has high sensitivity (low sensitivity and large aperture) and wide frequency

The horns tested are the same as those measured in Memos 4 and 8. It appears that earlier hight system temperature test results in Memo 8 were partially due to insufficient gain. The SDR dongles appear to have very high noise figure when operating act high gain (> 40 dB). A number of different small test results are reported. The current best system temperature, 270 K, is still significantly higher than the target of 90 K.

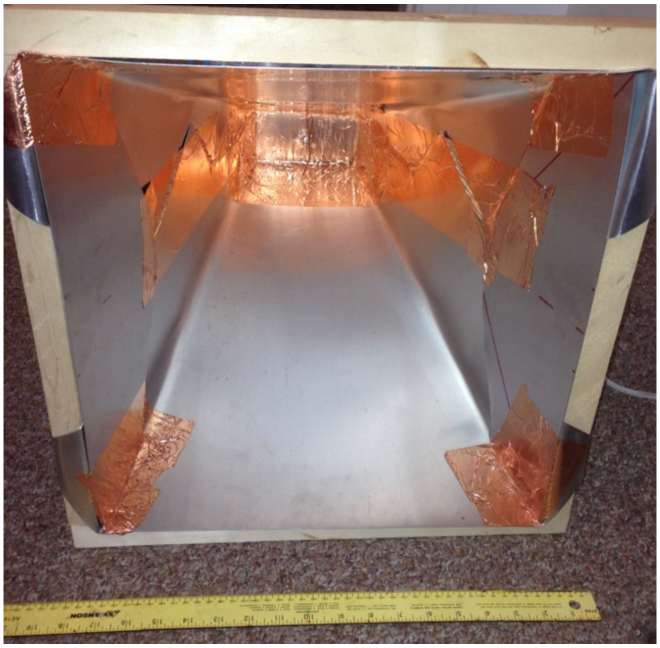
My current guess as to why the target system temperature has not been achieved is that out of band noise is being folded into the observing range, increasing the apparent system temperature. This would explain the similarity of results for all wide-band systems and the best results for the horn with integrated band pass filter. The development of this system has been hampered by the large parameter search made in the initial tests. Further progress requires help from other parties interested in contributing to the goal of putting radio telescopes in the hands of enthusiastic citizen scientists.

Hardware

A variety of tests of different system designs have been tried over the last few months. The initial goal of simplifying the electrical design through use of bias-Ts to power the low noise amplifiers has been successful. There have been no amplifier failures since the ground has been shared with all amplifiers. I believe the earlier failures were due to powering the different amplifier stages with different power supplies with different ground level voltages, so that it was possible to reverse-power different amplifier stages, resulting in amplifier damage.

Horn and Magnetic field Probe

The measurements were carried out on the weekends of February 27,28 and March 3,4,5, 2016 under snowy weather conditions. The February 27,28 tests were made with a “magnetic field” feed port and yielded similar results to results in memo 8, system temperature of roughly 1200K. The horn is constructed from one 24”x48” aluminum sheet, cut and folded into the required shape, and secured with metal screws onto a 16”x16” inner-diameter wooden frame around the outer edge of the horn. The inner parts of the horn are covered with copper tape. The side pieces of the horn are cut from the same sheet and secured with copper tape. The horn and amplifier hardware configuration is shown in figure 1. The details of the construction will be described elsewhere (once the performance reaches the design level).



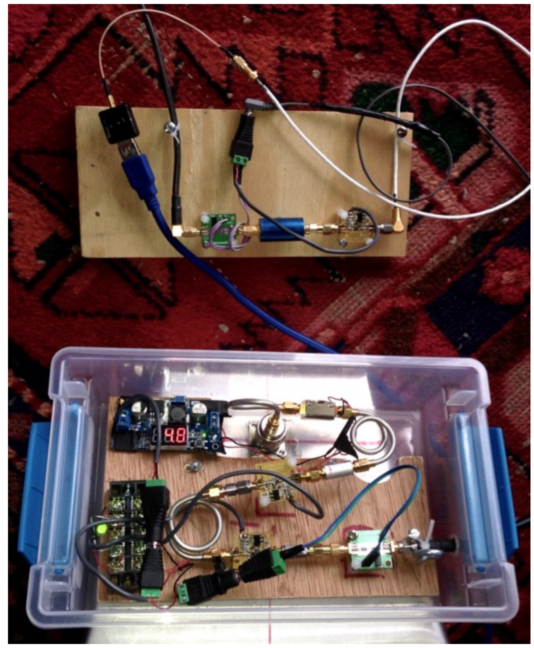


Figure 1: Aluminum horn with 16"x16" aperture (left). At the right are the electronics box at rear of horn, (bottom) and power supply end of the rf feed (top right). Bias Tees are at the input of the feedbox and output of the power supply. The small NooElec SDR dongle is in the upper right of the image.

Measurements

The feed probe was reconfigured for electric field connection and additional gain was added before the SDR dongle. Adding one ZX60-P103LN+ (#17 in my inventory) reduced the system temperature to roughly 800 K. Next an additional LNA4ALL was added (#10 in my inventory). This amplifier had no gain, so must have been damaged in tests. Finally I added a second ZX60-P103LN+ (#18).

Before the hot-cold load tests, measurements showed roughly 21 dB gain with two amplifiers, while measurement of the gain of the individual amplifiers showed +14 dB gain. In retrospect, am worried that there is significant gain compression at these power levels somewhere in the system. The total gain of the system is now roughly +63 dB, or a factor of 2 million.

Another test was performed on the loss due to the cable from the feed port to the SDR dongle. Measurements of a 75 ohm (white) cable showed loss of roughly 4 dB. Replaced this cable with better quality, and shorter, 50 ohm black coaxial cable. Measured slightly less than 4 dB of loss, but comparison suggests that either cable is acceptable for this use (or neither).

Lastly additional hot-cold load measurements of system temperature were performed using two SDR dongles, one from NooElec, the smallest on the market and the second an "improved dongle" with better timing accuracy. The improved dongle was from RTL-SDR.com. The input power levels were -54dB for the NooElec and -50 dB for the RTL-SDR.com dongle. The gain levels, internal to the dongles, were both set to +15 dB..

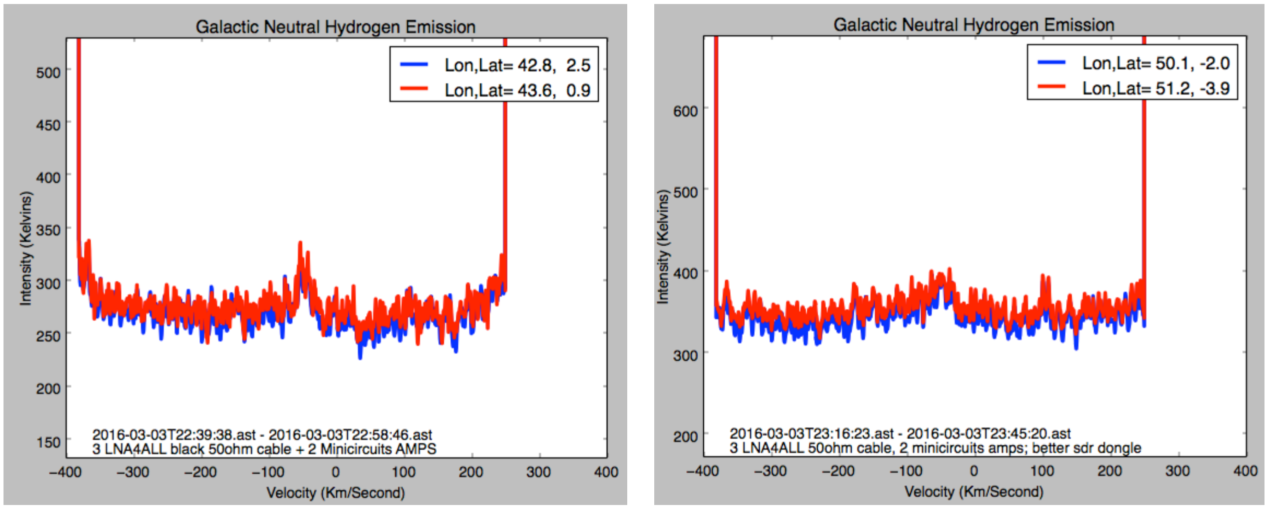


Figure 2: Two plots of system temperature versus velocity, from measurements with the feed horn described above. Measurements of the System temperature (K) are based on HOT-COLD load measurements, while the horn was pointed at 50 degrees elevation.,and at the ground (elevation = -90). The results using the NooElec dongle are at left and have 280K system temperature, while the “improved” dongle is at right and has system temperature of roughly 360K. The galactic neutral hydrogen emission is seen as the peak near -60 km/sec.

Two system temperature versus velocity plots are shown in Figure 2, using the methodology described in Light Work Memo 4.

SDR Linearity

While writing these test results I realized it would be relatively easy to measure the linearity of the SDR dongles. I ran two tests of the NooElec dongle, with input gain of +3 and +15 dB. Figure 3 shows the intensity (counts) versus attenuation for (Off) lowest, 30 dB, 20 db, 10 dB and 0 attention from lowest to highest curves. The linearity is fairly good. There seems to be some significant gain compression above the -45 dB level. The previous tests were well below that level so should not be adversely impacted by SDR linearity.

I intended to tabulate gain corrections as a function of power level, but below -45 dB these corrections are smaller than I could measure with my step attenuator. These values could be tabulated and applied to the counts before computation of the hot-cold load tests. If the power is kept in this range, the gain linearity of the SDR dongle is not a limiting factor in the system temperature measurements. Figure 3 shows the results with the 3 dB internal gain of the NooElec. The 15 dB setting allowed better tests of gain compression. About a signal level of -45 dB, the gain was clearly compressed, only gaining a few dB more intensity when increasing the power level by 10 dB.

My impression is that the dongles are more linear at lower power levels. May first retry measurements with input powers set to -65 dB on input. This is somewhat close to the noise floor of the dongles at -75 dB.

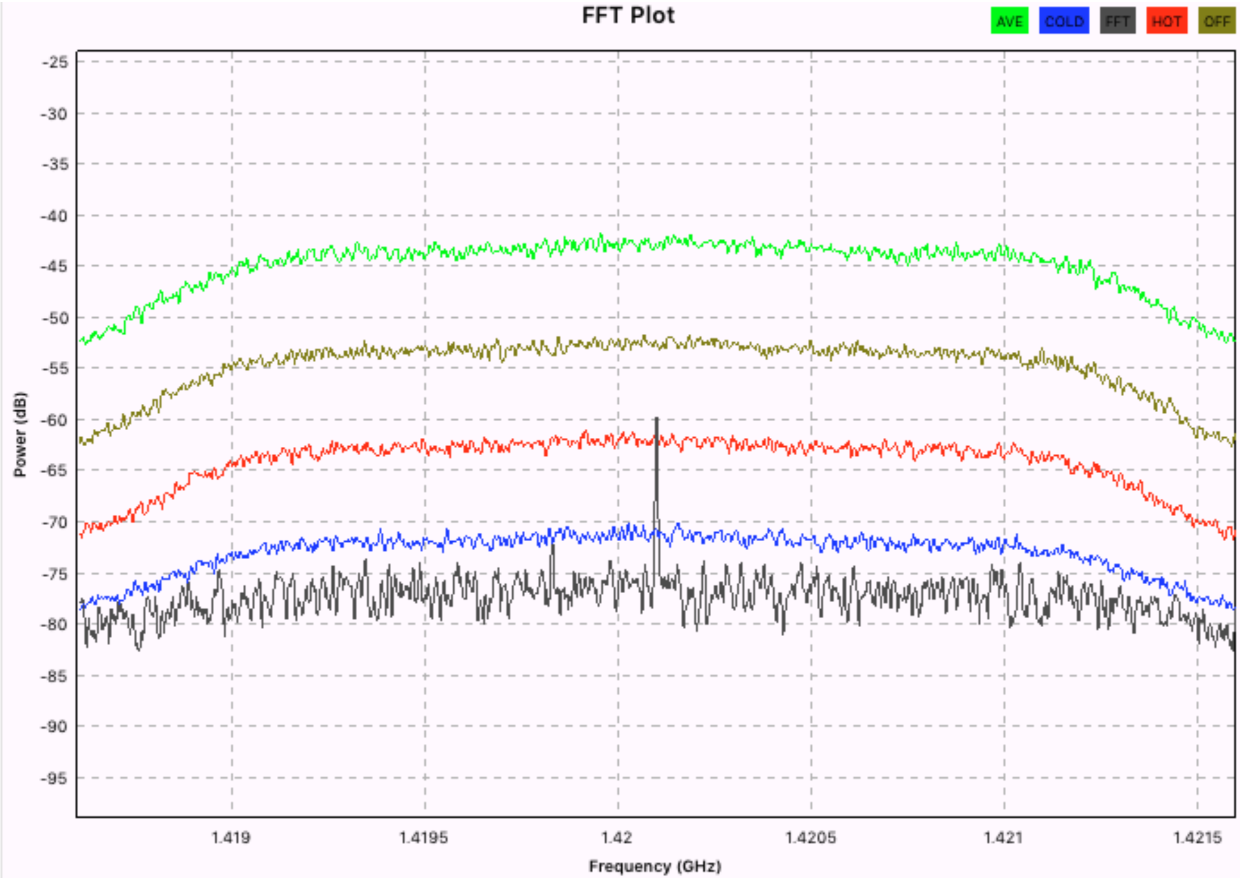


Figure 3: Noise source intensity versus frequency for 4 attenuation levels and with the noise source off. The lowest curve is with the noise source off, so is the internal minimum detectable signal from the NooElec SDR dongle. The blue curve is the noise source with 30 dB attenuation. The red curve shows 20 dB attenuation, grey 10 dB attenuation and green shows signal level with 0 dB attenuation. Gain is roughly linear in the power range of -67 to -45 dB, sufficient for astronomical observations.

Conclusion

The Bias T system works with the three LNA4ALL amplifiers and two ZX60-P103LN+ amplifiers, has better gain and shows improved measurements of the system temperature. The new layout has improved convenience and robustness. The improved system works better, but still has worse effective temperature than is desired.

The linearity of the low cost Nooelec dongle is sufficient for astronomical observations if the input power level is kept between -50 and -65 dBm.

NOTE added after later tests: The gain of the system was not sufficient and lead to the higher measured system temperatures.