Packaging a Low Noise RF Amplifier Module

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1. Introduction

This paper describes the installation of an inexpensive amplifier module in an aluminum enclosure with convenient RF and power connections. I used a specific amplifier but the methods apply to many others. The main reasons for packaging the amplifier as described here are to allow the RF input and output to be connected with type N connectors (the amplifier module uses SMA connectors) and power to be connected with a coaxial power plug and jack.

I have built RF amplifiers using all construction methods including discrete transistors and amplifier integrated circuits on printed circuit boards (PCB) and the so-called “dead bug” and “live bug” construction methods and installing a modular amplifier in a metal enclosure as described here. There are significant advantages to using a modular amplifier:

- Known performance and consistency
- Eliminate flying leads and associated noise pickup and accidental short circuits
- Controlled and simplified RF and power connections
- Allow customization of input voltages
- Extra RF shielding
- Requires little electronic construction experience
- Quicker construction

Arguments for construction from scratch (PCB, “dead bug” or “live bug”) invariably mention cost savings but seldom quantify them. Also, performance measurements often are poorly quantified except for “it works great”. The non-modular types of construction provide no inherent shielding and they must have power filter components and be placed in a metal enclosure anyway. Using amplifier modules, as described here, is much quicker to build and usually is equal or lower cost than other methods. The project discussed in this paper cost < 100 USD and has good RF performance as shown later.

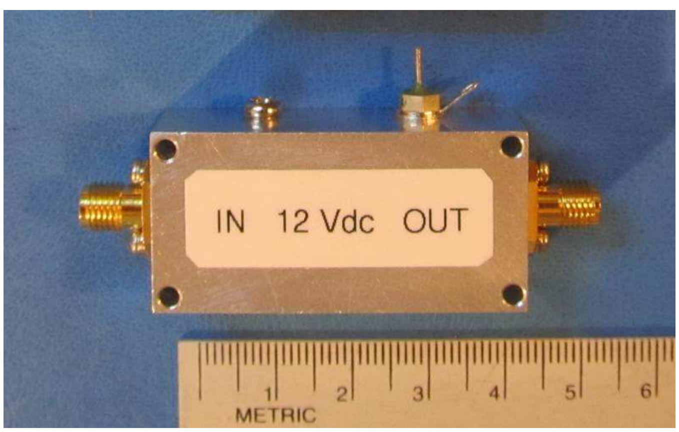

Figure 1 ~ CxLNA amplifier module. The RF input and output connectors on each end are type SMA-F. The 12 Vdc power input connection is via the feed-through capacitor on the side of the amplifier, seen upper-right. Amplifier dimensions (not including connectors) are 45 x 22 x 14 mm, and the case is machined aluminum.

The amplifier is made by a Chinese company called CZH (also called Fmuser) and obtained through eBay for about 60 USD. It has no model number so I call it the CxLNA (figure 1). It is useful in the HF, VHF and UHF frequency bands. As implemented here, the amplifier provides at least 20 dB gain to 700 MHz with reduced gain at higher frequencies, and its noise figure is < 1 dB between 45 and 870 MHz (the limits of my measurements).

The CxLNA module was examined in electrical and mechanical detail in [Reeve13] and is quite impressive given its low cost. A low noise amplifier (LNA) is useful in many lab and field applications such as a preamplifier to increase the sensitivity of a spectrum analyzer or a cheap software defined radio (SDR) receiver, but a description of LNA applications and limitations is beyond the scope of this paper.

2. Amplifier Module RF and Power Interfaces

The CxLNA module has SMA connectors for the RF input and output. I adapted these with type N-F to SMA-F flanged panel-mount adapters, one mounted on each enclosure end panel along with a coupler on the input and coaxial jumper cable on the output. In low noise amplifier applications, the RF input connection should be as short as possible so that the amplifier noise figure is not degraded by input attenuation.

The CxLNA has a feed-through capacitor for the power input and requires 8 to 14 Vdc (nominal 12 V) at 40 mA. This input voltage is compatible with my lab and receiver station power supplies. The 12 V input also is compatible with common lead-acid batteries, making it suitable for portable and field applications.

This powering scheme is adaptable to other amplifiers. Typical input voltages for commercial modular low noise amplifiers are 3.3 V, 5 V, 9 V, 12 V and 15 V and most use a feed-through capacitor for the power input like the CxLNA. If the amplifier has 12 V input, it can be used without change. However, for voltages other than 12 V, the amplifiers require voltage step-up or step-down to convert the 12 V power supply voltage to the amplifier voltage. For this purpose, I use small encapsulated 5 W dc-dc converters with a 9 to 18 V input range that cost about 8 USD; these are available in a variety of output voltages. I designed a small universal PCB that accommodates both linear voltage regulators and dc-dc converter modules, allowing this powering scheme to be used in many different applications (figure 2).

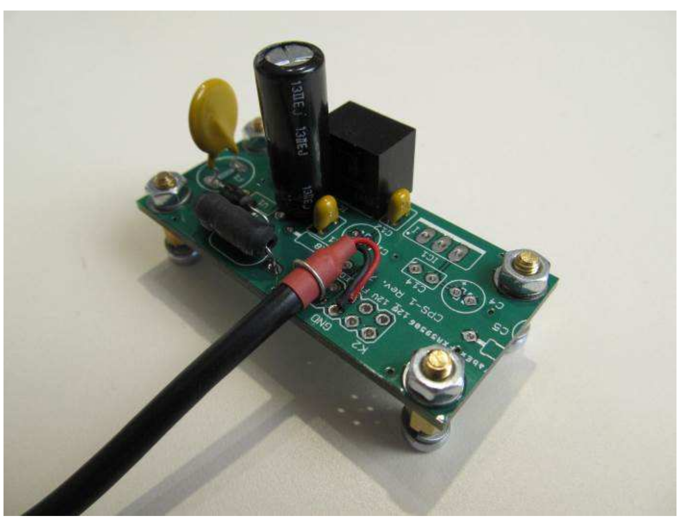

Figure 2 ~ Model CPS-1 power supply PCB that can be used with linear regulators or small encapsulated dc-dc converters. The unit shown here is CPS-1 mod 1 and has a 5 W converter with 5 V output and 9 to 18 V input (black rectangular object to the right of the cylindrical capacitor). This power supply is not used with the CxLNA amplifier but could be used with, for example, the Mini-Circuits ZX60-33LN-S amplifier module, which has performance and cost similar to the CxLNA.

3. Bill of Materials

The total cost of the material (table 1) is < 100 USD with the amplifier ($60) and enclosure ($14.50) representing the majority. The filter capacitors are not critical except that they have a voltage rating compatible with the supply voltage. Similarly, the filter inductor is not critical except that its current rating is compatible with the supply current (about 50 mA for the amplifier and power indicating LED shown). I use a design margin of 2x for both voltage and current, which requires capacitors rated > 30 V and inductor rated > 100 mA.

Table 1 ~ Low noise amplifier material list

Item	Qty	P/N	Mfr or Vendor	Description
1	1	Unknown	CZH	Low noise amplifier module, Fmuser (www.czhfmtransmitter.com)
2	2	Generic	Generic	N-F/SMA-F RF adapter, flanged panel mount or bulkhead mount
3	1	Generic	Generic	SMA-M/SMA-M RF coupler
4	1	Generic	Generic	Coaxial cable, RG-316/U, SMA-M RA/SMA-M, 100~150 mm long
5	1	Generic	Generic	Enclosure, extruded aluminum, 110 x 77 x 47 mm
6	1	317287	Jameco	Toggle switch, miniature, SPST
7	1	151555	Jameco	DC coaxial power jack, 2.1 x 5.5 mm
8	2	545650	Jameco	Capacitor, 10 µF, 35 V, tantalum or electrolytic
9	1	15229	Jameco	Capacitor, 10 nF, 50 V, MLCC
10	1	Generic	Generic	Inductor, 1.5 µH, ferrite core
11	1	637183	Jameco	LED, 12 V, Green, panel mount (with internal dropping resistor)
12	1	1N5819	Generic	Schottky diode, 40 V, 1 A
13	1	WH24-xx	NTE	Hookup wire, stranded 7x32, 24 AWG, 300 V PVC, red and black
14	8	91420A004	McMaster	Machine screw, phillips flat head, M3 x 8 mm (alternate 4-40 x 5/16 in)
15	8	91106A122	McMaster	Washer, internal star, 3 mm (alternate #4)
16	8	90592A085	McMaster	Hex nut, M3 (alternate 4-40)
17	4	Generic	Generic	Rubber bumper feet, self-adhesive, 6 x 2 mm

4. Construction

The construction shown here is based on a commercial extruded aluminum enclosure with sheet aluminum front and rear panels. The dimensions given will accommodate many modular amplifiers. I cut all holes after marking the panels with paper templates I prepared in Visio software and printed on a LaserJet printer (figure 3). After the holes were cut, I cleaned the cutting oil and washed the panels, mounted the RF adapters and other panel components, wired the power section (figures 4 and 5) and assembled the enclosure (figure 6).

The amplifier is mounted directly to the RF input adapter with an SMA male coupler (figure 7). A coaxial jumper cable is used from the amplifier to the RF output connector. In the assembly shown here, the amplifier is not mechanically supported except through its RF input connector. It has little mass and will not be a problem in normal use; however, where the amplifier gets knocked around, it should be mounted to the enclosure base and coaxial jumpers used on both input and output. This will slightly degrade the gain and noise figure at UHF. Any two of the four corner mounting holes in the CxLNA can be used.

I usually paint my project enclosures but in this case I left the enclosure in bare aluminum. After finishing the assembly I applied black-on-clear labels to the front and rear panels.

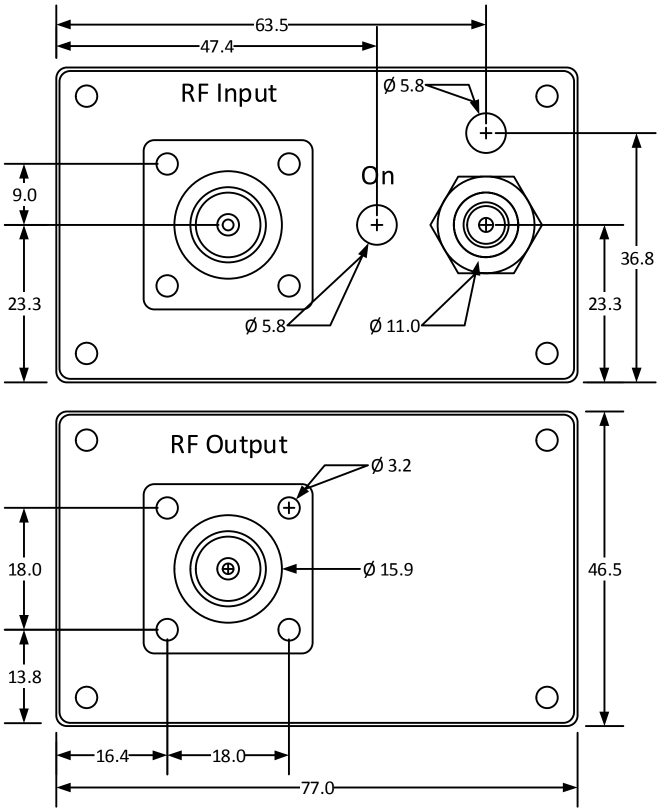

Figure 3 ~ Front (top) and rear panel layouts drawn with Visio software. Dimensions are in mm. The RF connectors are on the left and the on-off switch near the middle. The power connector is middle-right. The hole for the LED above the power connector is shown undersize and will need to be reamed slightly to accommodate the press-fit LED shown in the material list. Flange-mount type N adapters are shown but bulkhead-mount may be used. When the enclosure is assembled, the RF input and output connectors are offset (one on each side when viewed from the font), minimizing the chance of physical interference with the amplifier connectors on the inside.

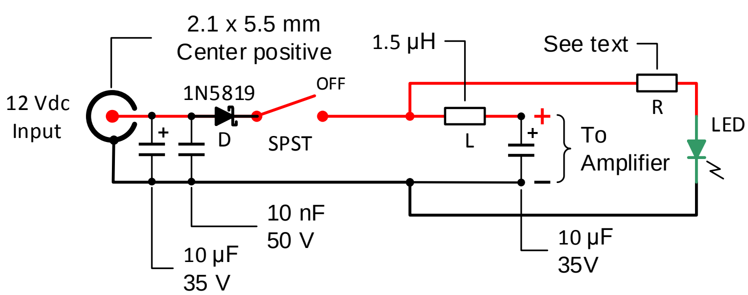

Figure 4 ~ Power wiring schematic with the center-positive coaxial power jack on the far left. The current limiting resistor, R, is not required if the specified LED is used. Although tantalum capacitors were used in this project, I recommend electrolytic capacitors instead (tantalum capacitors really stink when they fail and burn). The power section connects to the amplifier module's feed-through capacitor.

Figure 5 ~ Close-up of the inside front panel showing the input filter capacitors soldered directly to the coaxial dc power jack on the left, polarity-guard diode and switch. The filter inductor from the power switch to the amplifier module is in lower-center and secured with a cable tie to the amplifier ground lead.

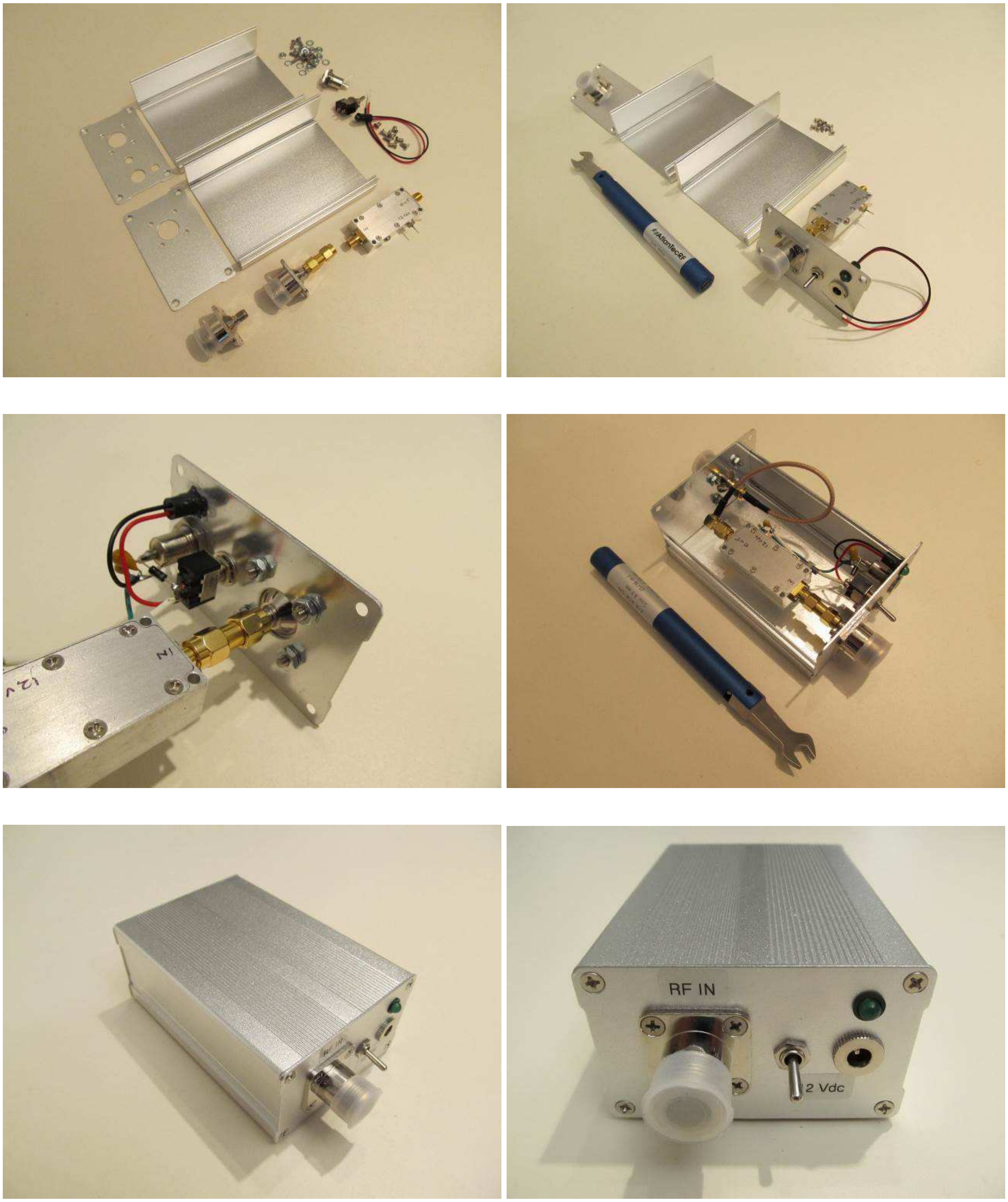

Figure 6 ~ Six pictures showing basic sequence of construction from a “pile of parts” to finished unit. The wrench seen in some of the images is an 8 mm (5/16 in) torque wrench for the SMA connectors.

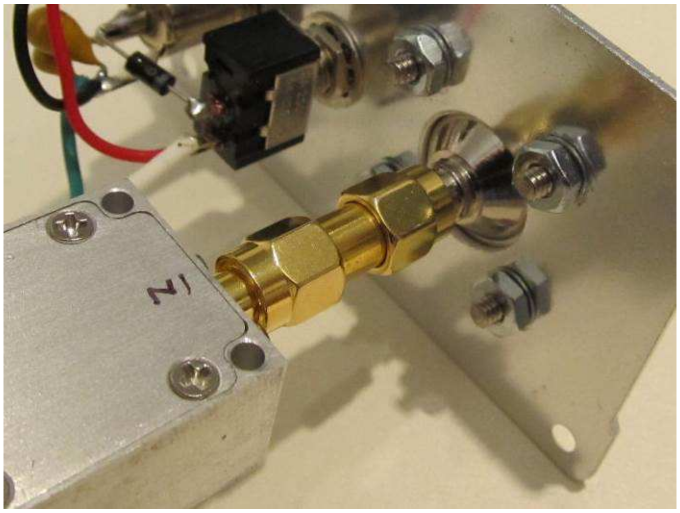

Figure 7 ~ An SMA-M coupler connects the amplifier RF input to the front panel RF adapter and supports the amplifier. All connectors are brass and are torqued to 0.34 to 0.56 N-m (3 to 5 lb-in).

5. Measurements

I measured the input reflection coefficient and forward gain of the completed amplifier to verify operation (figure 8). The unit has at least 20 dB gain to around 700 MHz with decreasing gain as the frequency increases. The reflection coefficient is better than 10 dB at all frequencies above about 50 MHz with worsening reflection coefficient below 50 MHz. The amplifier assembly including the power indicating LED draws about 48 mA at 12 Vdc input. I also measured the noise figure from 45 to 870 MHz (figure 9 and 10) using a Callisto instrument and NF software developed by Christian Monstein. Test conditions were

- Callisto s/n: NA008
- Frequency minimum to maximum: 45 to 870 MHz
- Number frequencies: 100
- PWM (Callisto gain setting): 150
- Noise source ENR: 5.0
- Integrations: 3

The measured noise figure is for the cascade consisting of the amplifier and Callisto. The contribution of each to the total is

$$NF = NF1 + \frac{NF2 - 1}{G1}$$

where

NF noise figure of cascade
NF1 noise figure of the amplifier
NF2 noise figure of Callisto instrument (7.5 dB, 5.62)
G1 gain of amplifier (20 dB, 100)

The measured average cascade noise figure is 0.8 dB. Solving for NF1 gives the noise figure of the amplifier by itself as 0.75 dB (the reduction is buried by the measurement uncertainty). In this case, the gain of the amplifier is high enough so that its noise figure dominates the measurement.

Figure 8 ~ S11 and S21 scattering parameters from 2 to 1500 MHz. S11 (yellow trace) indicates the degree of impedance matching (reflection coefficient) and S21 (blue trace) indicates the forward gain. The more negative the reflection coefficient, the better, and the more positive the gain, the better. Measurements were made with an Agilent N9923A vector network analyzer. See [Reeve13] for additional s-parameter measurements of the amplifier module.

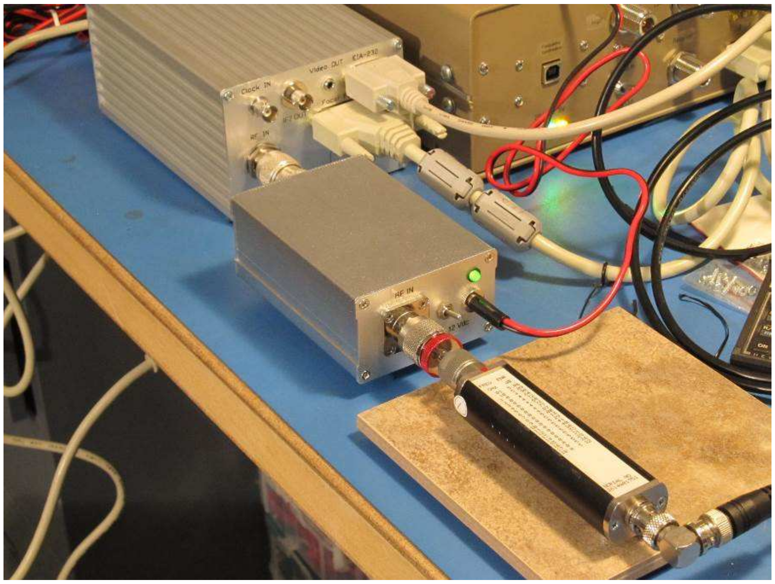

Figure 9 ~ Noise figure measurement setup includes an HP 346A noise source (5 dB ENR, foreground right), low noise amplifier assembly (center), Callisto instrument (background left) and test fixture used to control the noise source (background right). In this setup, the Callisto frequency and its measurements are controlled by the NF software on a PC. The Callisto in-turn controls the test fixture, which controls the noise source. The noise source is turned on and off to obtain the Y-factor from which the noise figure is calculated.

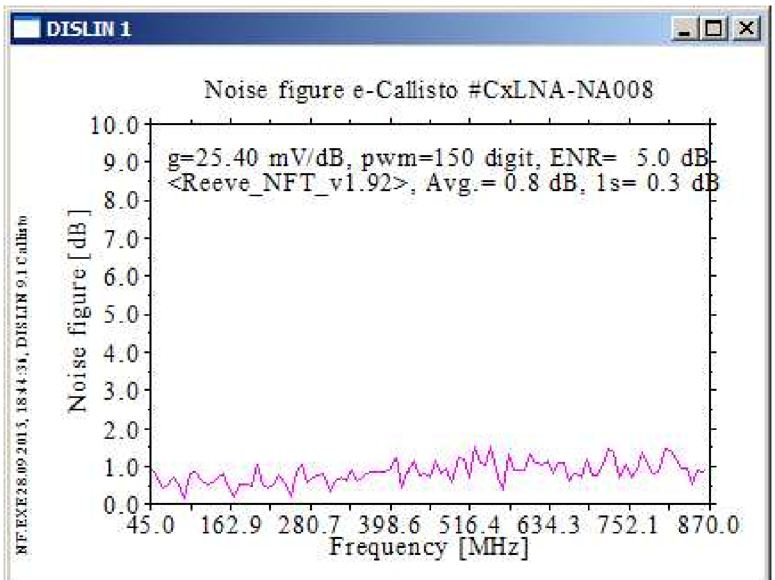

Figure 10 ~ Measurements from 45 to 870 MHz show an average noise figure of 0.8 dB with standard deviation of 0.3 dB. The measurements include the cascade effect of the Callisto instrument (7.5 dB noise figure), so the noise figure of the amplifier itself is slightly lower than shown.

6. References

[Reeve13] Reeve, W. and Monstein, C., Preamplifiers for Callisto Solar Radio Spectrometer, Society of Amateur Radio Astronomers, July-August 2013 (paper available at: http://www.reeve.com/Documents/CALLISTO/Reeve-Monstein_PreampComparison.pdf

Document information

Author: Whitham D. Reeve

Revision: 0.0 (Original draft started, 27 Sep 2015)
0.1 (Added noise figure measurements and embedded figures in table, 29 Sep 2015)
0.2 (Minor edits, 30 Sep 2015)
0.3 (Add'l edits, 01 Oct 2015)
0.4 (Final edits prior to distribution, 04 Oct 2015)
1.0 (Distribution, 06 Oct 2015)

Word count: 2216
File size: 1355264