

Noise Figure Measurements of the Callisto

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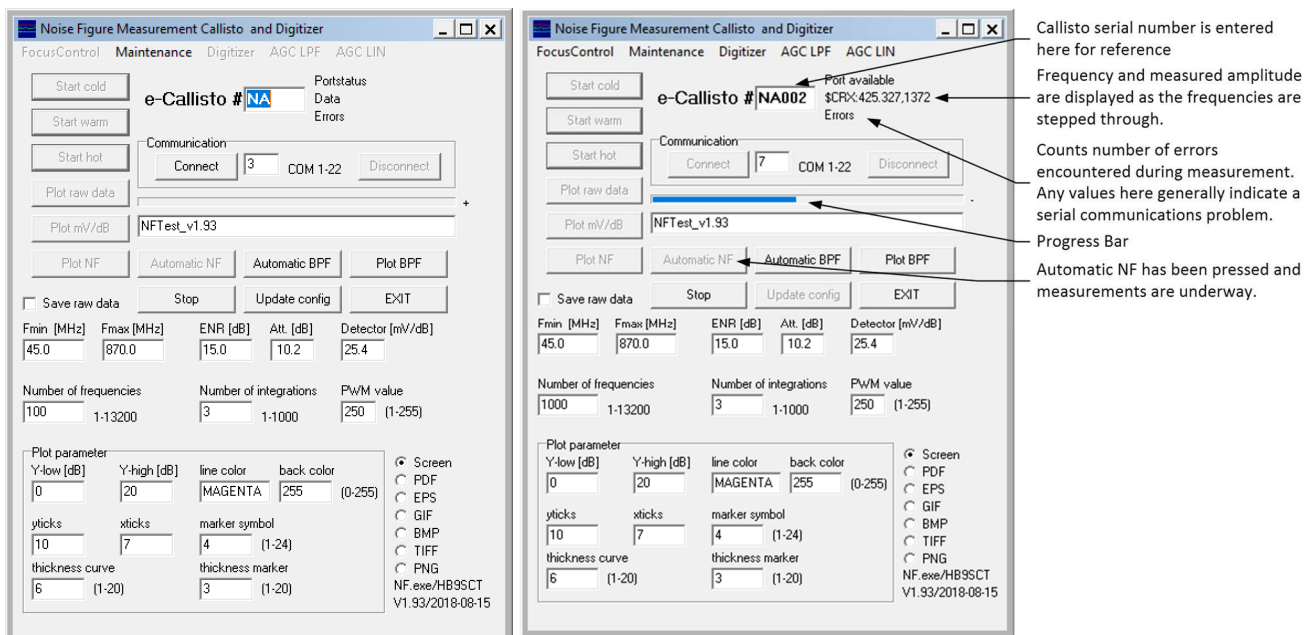
1. Introduction

Callisto is the instrument used in the e-CALLISTO solar radio spectrometer network. The noise figure in the Callisto's native frequency range (45 to 870 MHz) is typically between 7 and 8 dB with a maximum of 10 dB. The noise figure and system sensitivity can be improved by adding an external low noise preamplifier {[Preamp](#)}. NF Test is a standalone software tool developed by co-author Monstein that can be used to measure the noise figure of the Callisto with or without a low noise preamplifier.

NF Test was originally developed as a Callisto production test tool with many features and capabilities, but this article focuses only on its noise figure measurements feature. NF Test uses the *Y-factor* method (for example, see {[R&S-YFactor](#)}). A future article will discuss the other features.

2. NF Test Executable

The NF Test tool is in a Zip file under the Software tab at {[e-CALLISTO](#)} or it may be downloaded directly at {[NFTest](#)}. After the files have been extracted to a convenient folder, for example, c:\Callisto\Tools\NF Test, the executable file, NF.exe, may be opened. When the files are extracted, many header files and other files used to compile NF Test are placed in the same folder. Most files are not needed for NF Test operation and may be deleted; however, the following files must be retained: disbcc.lib, nf.cfg, NF.exe, Symbol1.ico, wsc.dll, and wsc32bcb.lib. The installation does not change the Windows registry, and the tool may be uninstalled simply by deleting it. Generally, a shortcut to the file is placed on the Desktop. When NF Test is run, a main window opens (figure 1).



pressing Connect, it is necessary to change the COM port to match the serial port to be used. Right: The image shows a successful connection to a Callisto on COM port 7, and the *Portstatus* label has changed to *Port available*. The *Data* label indicates the Callisto command, frequency and raw data as the Callisto is swept through the frequencies. The *Error* label indicates any communication errors on the serial port, which usually result from a bad cable or out-of-date driver on the PC serial port. Some of the parameters used in noise figure measurements are annotated.

3. NF Test Configuration

NF Test uses a configuration file *nf.cfg* that defines its default parameters. The configuration file is located in the same folder as the executable and is shown below. When first installed, *nf.cfg* is populated with a complete set of default values, which must be edited to comply with the user's specific setup. The configuration file may be accessed by navigating to the installation folder or by clicking on the Maintenance menu of the NF Test window. If changes are made to *nf.cfg* after NF Test is opened, the Update Config button must be pressed before any measurement.

Most configuration file parameter names are identical to the field labels in the NF Test window. The configuration file includes comments denoted by *//* characters. The comments define the range of variables that may be used and in many cases a suggested default or nominal value. The comments may be edited in any ASCII text editor but their length must be no more than 120 characters.

```
// Measurement Parameter
[rxcomport]=3           // 1 .... ?? RS-232

[maintitle]=NA           // any text without space, use underscore or - instead, like 00...99
[sstitle]=NFTest_v1.93  // any text without space, use underscore or - instead

[fmin]=45.0             // lowest frequency (45.0...870.0), nominal 45.0
[fnom]=408.0            // nominal frequency (45.0...870.0) for digitizer/scope
[fmax]=870.0            // highest frequency (45.0...870.0), nominal 870.0

[enr]=15.0              // ENR nominal 15.0 dB .... 35 dB, 5.0 dB with an LNA
[detector]=25.4         // conversion AD8307 nominal 25.4mV/dB
[channels]=200          // number of channels to measure (1...13200), nominal 200
[integrations]=3        // the more the better the resolution, (1...10'000), nominal 16
[pwm]=250               // receiver gain control (1...255), nominal 100...250

// Plott Parameter
[xleft]=600             // position left corner of window, default 300
[ytop]=100              // position top edge of window, default 100
[xsize]=424             // width of the window, default 848
[ysize]=300             // height of the window, default 600 (golden cut)

[ylow]=0                // yrange -100...100, nominal 0
[yhigh]=20              // yrange -100...100, nominal 20

[yticks]=10             // number of ticks in y-axis, nominal 10
[xticks]=7              // number of ticks in x-axis, nominal 7 or 8

[linecolor]=MAGENTA     // BLACK, RED, GREEN, BLUE, CYAN, YELLOW, ORANGE, MAGENTA, WHITE
[backcolor]=255         // 0=black, 255=white background, inbetween some colors, I like 230

[marker]=4              // marker symbol (1..24), nominal 4

[thickcurve]=6          // tickness of plot (1..20), nominal 8
[thickmarker]=3         // thicknes of marker (1..20), nominal 6
```

```
// Switching parameter for static relays in test fixture with focus code control
[cold]=00,S           // cold noise source focus code
[warm]=03,S           // focus code later used for determining detector coefficient
[hot]=01,S            // hot noise source focus code to determine noise figure

[att]=10.2            // attenuator value to produce 'warm' out of hot

// digitizer/scope parameter
[focus]=00           // focuscode for digitizer/scope
[sampling]=200         // digitizer/scope sampling time [ms] 50...
[logpath]=C:\Temp\    // data path for light curve file
[ending]=csv           // data file ending (txt, prn, dat, lst, csv)
[delimiter]=;          // column-delimiter = TAB or , or ;
```

Below is additional information concerning some of the parameters in nf.cfg that apply to noise figure measurements:

COM port [rxcomport] parameter: The example above shows port 3 but it may be changed to any appropriate value to match the PC serial port or USB-Serial Converter.

[Fmin] and [Fmax] frequency parameters: The maximum resolution of the Calisto tuner is 62.5 kHz. When measurements are underway, the frequency steps are rounded to the nearest multiple of 62.5 kHz. There are 13 200 possible frequencies (or [Channels]) in the Callisto's native frequency range of 45 to 870 MHz. The [Fmin] and [Fmax] frequencies can be set to any practical value in that range and divided into any practical number of [Channels], but the frequency resolution is limited to 62.5 kHz and the maximum number of [Channels] is limited to 13 200. For reference, noise figure measurements that use the full range of 13 200 [Channels] and 3 integrations require about 45 minutes. If the [Channels] parameter is set to 100 with 3 integrations, the time to complete a noise figure measurement is about 37 seconds and for 1000 with 3 integrations is about 5 minutes 20 seconds. Spurious signals will sometimes be observed in high-resolution measurements.

Noise Source [ENR] parameter: The ENR of most noise sources varies a small amount with frequency, but the configuration file parameter allows only one value. The value typically is an average over the measurement frequency range or it may be the value for a specific frequency. The ENR value entered here should take into account any coaxial cable loss between the noise source and Callisto RF Input. Since cable losses vary with frequency, a single mid-range value normally is used in the correction. Most often, the noise source is connected directly to the RF Input and no cable is used. The ENR value generally will be lower for measurements with a low noise amplifier because a higher value may drive the LNA out of its linear operating region. The following guidelines may be used to choose the noise source ENR:

1. Callisto only:

$$ENR_{dB} > NF_{dB}^{Callisto} + 5 \text{ dB}$$

2. Callisto with low noise amplifier: If $NF_{dB}^{LNA} + Gain_{dB}^{LNA} > NF_{dB}^{Callisto} + 1 \text{ dB}$, then

$$ENR_{dB} > NF_{dB}^{LNA} + 5 \text{ dB}$$

Guideline 1 results in an ENR of 15 dB, and, in most cases, Guideline 2 results in an ENR of 5 to 7 dB. For both situations, the [ENR] parameter setting must be corrected (reduced) for cable losses and attenuator, if used.

AD8307 log [Detector] slope parameter: The default value of 25.4 mV/dB is based on many measurements and should not be changed without justification.

[PWM] gain parameter: The gain parameter normally is set to a high value (for example, 250) for noise figure measurements of a standalone Callisto because its measured noise figure worsens at lower gain settings. However, when a low noise preamplifier is to be used, the [PWM] setting must be reduced to prevent overload (saturation) of the Callisto during measurements and operation. Generally, the [PWM] setting must be determined experimentally by repeatedly measuring the noise figure with different settings until a setting is found that provides the best noise figure. This setting would then be used when the Callisto/LNA combination is placed into service. A *getting started* estimate is to use a [PWM] setting of about 130 when the external LNA has a gain of 20 dB.

[Cold] and [Hot] relay control parameters: The default focus codes 00 and 01 correspond to the bits (or pins) set on the Callisto FPU connector and used by the Callisto Test Fixture designed by co-author Reeve. These values may be changed to suit user requirements but are needed only when NF Test is used in the automatic mode with a Callisto Test Fixture. These values are ignored in manual mode measurements. Note: The Callisto Test Fixture takes advantage of all NF Test capabilities and is designed to be used with 28 Vdc noise sources.

4. NF Test Modes

NF Test may be used in an automatic or manual mode. In the automatic mode, the Automatic NF button on the NF Test window sends specific focus codes over the serial port to the Callisto instrument, which then sets the associated pins on its Focal Plane Unit (FPU) connector. The Callisto FPU connector in-turn controls a relay in the Callisto Test Fixture that removes Noise Source power for Cold measurements and applies it for Hot measurements. In the manual mode, two buttons, Start Cold and Start Hot, on NF Test control the Callisto frequency sweep while the user manually controls the (Cold) or (Hot) power to the noise source through a switch. The next section provides basic measurement procedures.

5. Measurements

The following are required:

- 1) Callisto
- 2) EIA/RS-232 serial cable with DB-9M to DB-9F connectors (straight-thru wiring)
- 3) 12 Vdc, 300 mA power supply with 2.1 x 5.5 mm coaxial power plug for Callisto
- 4) Noise source with nominal 15 dB ENR (notes 1, 2)
- 5) Power supply to match noise source
- 6) Optional low noise preamplifier, nominal 15 to 20 dB gain
- 7) Power supply to match low noise amplifier
- 8) Optional 10 dB attenuator (note 2)
- 9) Windows PC (XP through 11) with a native serial port or USB port for instrument control
- 10) USB-Serial Converter if a USB port is to be used for instrument control (note 3)
- 11) Callisto Test Fixture (not required for manual noise figure measurements)

Notes:

1. A suitable low cost noise source is available at <https://e-callisto.org/Products/Products.html> (figure 2). This noise source requires a power supply rated 15 Vdc and at least 7 mA. The noise source should be connected to the power supply through an On/Off switch for operational convenience of setting its Cold and Hot states.
2. For noise figure measurements of the Callisto by itself, a 15 dB ENR noise source is recommended. For measurements of the Callisto with a low noise preamplifier, a 5 dB ENR noise source is recommended. A 15 dB ENR noise source may be used for the latter measurements by reducing its ENR with a 10 dB attenuator. The attenuator also improves the impedance matching and reduces the measurement uncertainty due to mismatch losses. See also Section 3.
3. The USB-Serial Converter and its drivers must be compatible with the Windows operating system to be used.

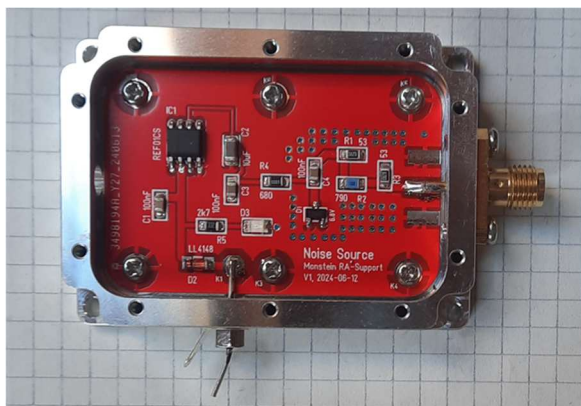


Figure 2 ~ Low cost Noise Source produced by Monstein Radio Astronomy Support with cover removed. The noise output connector is on the right and the power supply inlet feed-through capacitor is on the bottom left-of-center. Delivery is with aluminum cover. See {MRAS}

Frequency range: 10 MHz ... ~900 MHz

ENR: 14 ... 17 dB

Supply voltage: 15 Vdc at ~7 mA.

Enclosure size with SMA-connector and with feed-through capacitor: 65 x 50 x 12 mm

Net weight: 54 g

Typical setups are shown in figure 3.

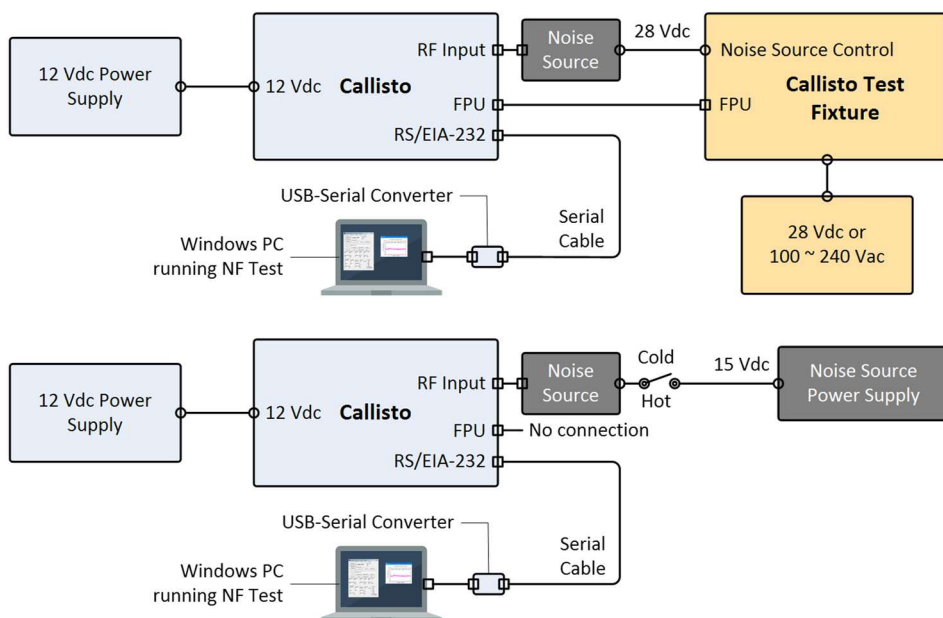


Figure 3.a ~ Callisto noise figure measurements with NF Test, automatically controlled Callisto Test Fixture and 28 Vdc Noise Source.

Figure 3.b ~ Callisto noise figure measurements with NF Test, manual controls, and 15 Vdc Noise Source.

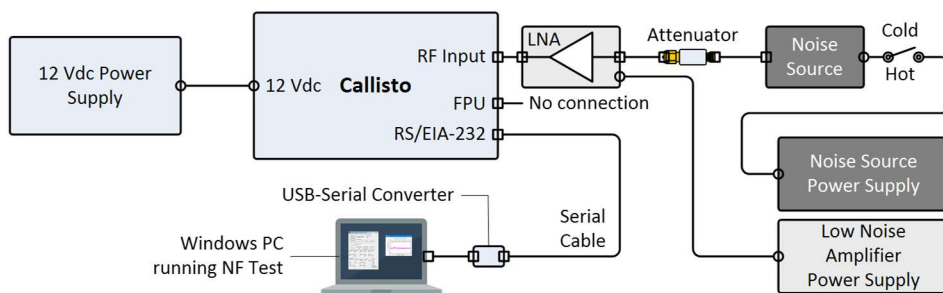


Figure 3.c ~ Combination of Callisto and low noise amplifier noise figure measurements with NF Test, and manual controls. The attenuator reduces the Noise Source ENR for use with the LNA. Another attenuator may be needed on the LNA output. See text.

After all connections are made and all parameters are set, a noise figure measurement may be started. When the Callisto Test Fixture is used under control of the Callisto focus codes, it is only necessary to press the Automatic NF button. NF Test commands the Test Fixture to place the Noise Source in the Cold state by turning Off its power. The Callisto is then commanded to step through the specified frequencies. When finished, a window pops up showing the Raw Data for the Cold state (figure 4.a). In a couple seconds, NF Test then commands the Test Fixture to place the Noise Source in the Hot state by turning On its power. The Callisto is again commanded by NF Test to step through the specified frequencies. When finished, the pop-up window is replaced with the measured Noise Figure vs frequency (figure 4.b).

The plots will often show small steps near 175 and 450 MHz in the noise figure, which are normal and the result of band switching in the Callisto's internal tuner. In addition to the noise figure plot, the window shows reference information, the average noise figure across the entire frequency range and the standard deviation (sigma) of the noise figure measurements in that frequency range.

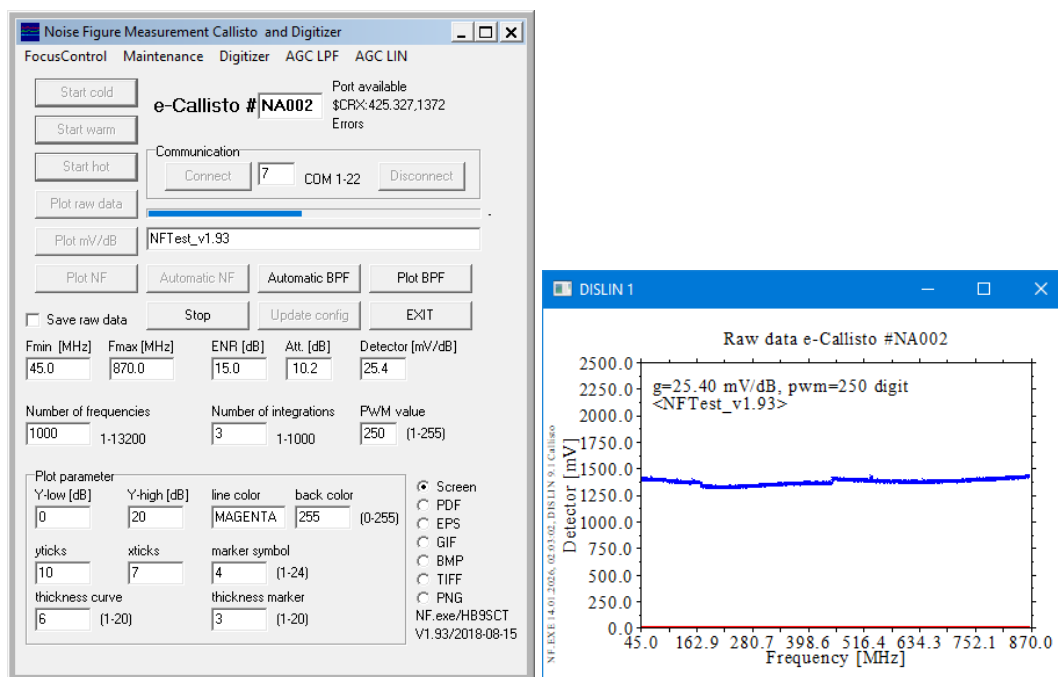


Figure 4.a ~ The Automatic NF button has been pressed. NF Test commands the Noise Source to the Cold state and then commands the Callisto to step through the frequencies. The window on the right shows the Raw Data for the Cold state. In this example, the Noise Source ENR is 15.0 dB and the frequency range is 45 to 870 MHz in 1000 steps.

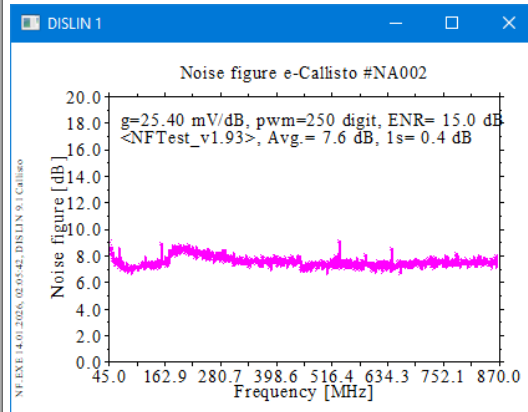
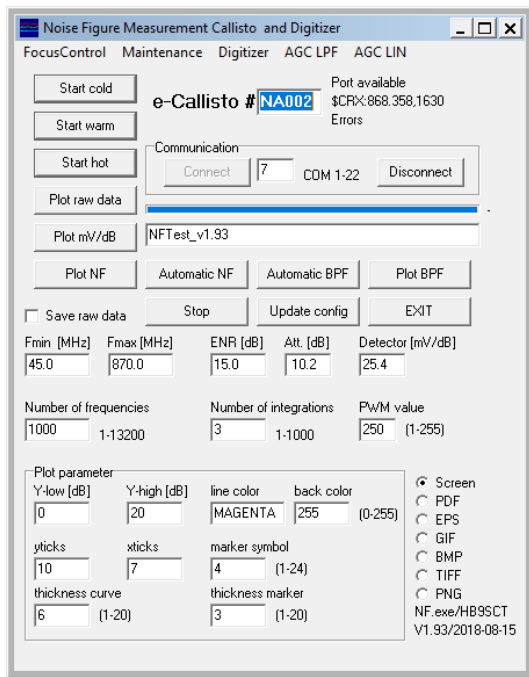


Figure 4.b ~ After the Cold measurements, NF Test commands the Noise Source to the Hot state and then commands the Callisto to step through the frequencies again. The window on the right shows the completed noise figure measurements.

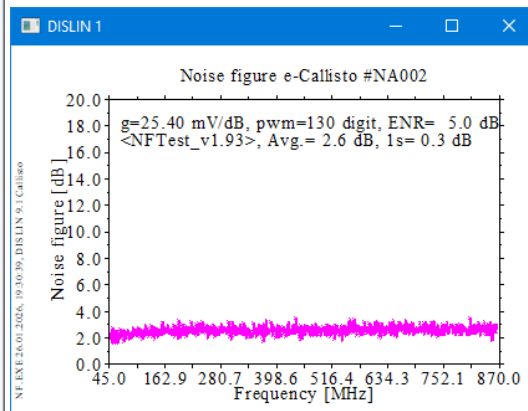
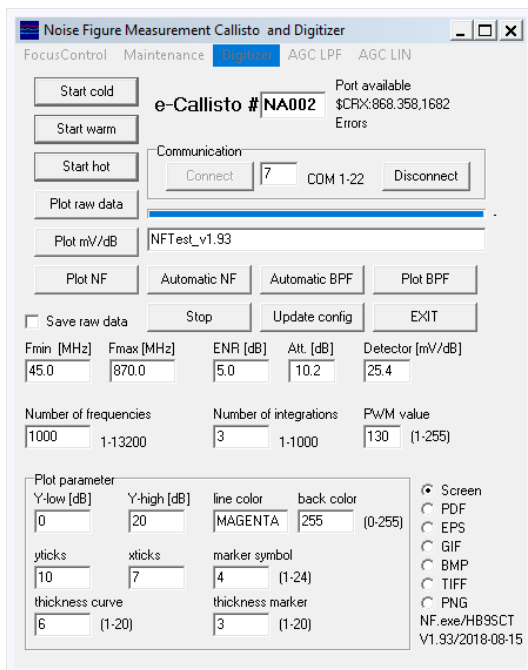


Figure 5 ~ Measurement of Callisto with 20dB gain LNA. All settings are the same as previous except for lower [ENR] and [PWM] settings. Note that the resulting noise figure is for the Callisto and LNA cascade and not the LNA by itself. The LNA in this example has a noise figure of 2.5 dB.

Manual measurements follow the same sequence as the automatic measurements described above except the Noise Source is manually turned Off and then On before the Callisto is stepped through its frequency list. First, the noise source power is turned OFF, then the Start Cold button is pressed. After the progress bar indicates a completed frequency sweep and the Raw Data window appears, the noise source power is manually turned ON followed by the Start Hot button. NF Test then commands the Callisto to step through the frequencies again. Upon completion, the Raw Data window changes to the Noise Figure window as described above.

The Automatic NF button also may be used for manual measurements. In this case, the Noise Source is manually placed in the Cold state and then the Automatic NF button is pressed. The progress bar shows the status of the measurements and the Raw Data window pops up when the Cold state measurements are completed. There is a 2 second delay between the end of Cold state measurements and the start of the Hot state measurements, and the Noise Source must be placed in the Hot state during this interval. When the Hot state measurements are completed, the pop-up window changes to the Noise Figure window as above.

An example measurement of a Callisto with LNA uses the same procedures and setup as above except that the [ENR] and [PWM] parameters are adjusted (figure 5). In this example, the LNA has a nominal gain of 30 dB and noise figure of 2.5 dB. A 10 dB attenuator was placed on the LNA output to reduce its gain to 20 dB. It was found experimentally that the lowest noise figure of the cascade occurred with the [PWM] setting in the range 125 to 130. In the example shown, the Y-high Plot parameter could have been set to 10 dB (or even 5 dB). The setting may be changed and then replotted by pressing the Plot NF button.

The raw noise figure measurement data can be saved as a text file by checking the box on the left side of the main window labeled *Save raw data*. The data files contains frequencies and digitizer values measured at the output of the log detector. The data are saved in the file location specified in the [logpath] parameter in nf.cfg (in the above example, C:\TEMP\) with the filename formats RAW_yyyymmdd_hhmmss_cold.txt and RAW_yyyymmdd_hhmmss_hot.txt.

6. References

- {[e-CALLISTO](https://e-callisto.org/index.html)} e-CALLISTO Solar Radio Astronomy Network: <https://e-callisto.org/index.html>
- {[MRAS](https://e-callisto.org/Products/Products.html)} Monstein Radio Astronomy Support, Products: <https://e-callisto.org/Products/Products.html>
- {[NFTest](https://e-callisto.org/Software/NoiseFigurePlotterV193.zip)} NF Test software tool, available at: <https://e-callisto.org/Software/NoiseFigurePlotterV193.zip>
- {[Preamp](https://www.reeve.com/Documents/CALLISTO/ToPreamplifyorNot.pdf)} Reeve, W., Monstein, W., To Preamplify or Not, available at: <https://www.reeve.com/Documents/CALLISTO/ToPreamplifyorNot.pdf>
- {[R&S-YFactor](https://www.rohde-schwarz.com/us/applications/the-y-factor-technique-for-noise-figure-measurements-application-note_56280-15484.html)} The Y Factor Technique for Noise Figure Measurements, available at: https://www.rohde-schwarz.com/us/applications/the-y-factor-technique-for-noise-figure-measurements-application-note_56280-15484.html

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