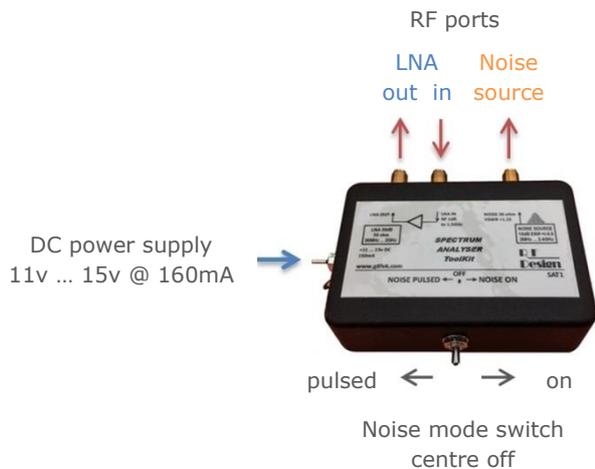


Products: Spectrum Analyser ToolKit SAT1



SAT1 at a glance ...

Calibrated noise source

- 2 MHz ... 2400 MHz
- 10dB ENR +/-0.5dB (-104dBm/MHz)
- PRO option gives 0.1dB resolution calibration
- 50 ohm sma output
- VSWR <1.15:1 noise on or off (RL >23dB)
- Pulse mode frequency 5Hz

Very Low Noise Amplifier

- 30 MHz ... 2 GHz (to 2.5 GHz with reduced gain)
- 32dB gain; <+/-2dB flatness to 2 GHz
- <1dB noise figure to 1500 MHz (<2dB @ 2.5 GHz)

AN-3 is the first of several notes covering the application of SAT1. Others include:

- 2 port testing of active / passive circuits and cables with SAT1
- Using SAT1 VLNA to obtain the optimum low noise floor from your spectrum analyser
- VSWR measurement using an external bridge (not supplied)
- VLNA off air applications for spectrum monitoring
- Educational tutorial applications involving noise figure and noise temperature

First, a few notes on your spectrum analyser

If you have a spectrum analyser (SA) without an internal preamplifier, the noise figure (NF) from HF to around 2.5 GHz is likely to be approximately 25 to 35dB.

Set the SA input attenuation to 0dB if you need to achieve the lowest NF. Input attenuation directly adds to the NF ... so for example 10dB input attenuation produces a 35 to 45dB NF at the typical SA input.

Here are a few instrument sensitivity specifications, Displayed Average Noise Level (DANL) at 1 GHz, input attenuator 0dB, with calculated NF. (To read more about DANL, see the HP app note AN150 2014/16 on our web site, g8fek.com/papers)

HP 141 (1250 MHz plug in) -117dBm in 300 Hz BW;	NF = 32dB
HP 8559A -111dBm in 1 kHz BW;	NF = 33dB
HP 8590A, HP 8591E -115dBm in 1 kHz BW;	NF = 29dB
HP 8593E -112dBm in 1 kHz BW;	NF = 32dB

What if you have an internal preamplifier option inside your SA? The NF is likely to be in the range 10 to 20dB.

For example ...

Rigol DSA815 & DSA710 have a noise floor specification of -155dBm/Hz (typical) with preamplifier enabled, NF = 19dB.

Rigol DSA832 has a noise floor specification of -161dBm/Hz (typical) with preamplifier enabled, NF = 13dB.

Noise figure testing

To make a NF test you will need to measure the difference in noise output from your LNA or transverter, let's call it Equipment Under Test (EUT), with an ENR (Excess Noise Ratio) calibrated noise source connected to the EUT input, noise source switched on and then switched off. The difference figure is commonly referred to as the Y factor (dB). The ENR value quantifies the noise source power with respect to the thermal noise floor. You can find lots of references to ENR, Y factor and NF measurement in general at g8fek.com button 'Papers'.

Note, fitting a 1dB NF preamplifier ahead of your receiver (or SA!) doesn't necessarily provide a system noise figure of 1dB.

The overall system noise figure you enjoy depends on the NF of the, lets call it 2nd stage (your RX or SA) and the gain and NF of the preamplifier ahead of it. A good way to get a feel for this is by experimenting with different values in a cascaded noise figure calculator, you can find several linked at g8fek.com/papers, the page is linked on the button 'Papers' on our index web page at the top.

A typical commercial transceiver at VHF / UHF is likely to have a NF of around 6 or 7dB. When using the calculators don't worry about the GAIN value for the 2nd stage, enter any value and this has no impact on the system noise figure.

Notice that you need a minimum amount of gain in the preamplifier to achieve a system noise figure (preamp plus RX or SA) that is close to the preamplifier's own NF specification. This is important when making NF measurements with your spectrum analyser with say 30dB NF, since a lot of gain is required ahead of the SA to measure anything close to the EUT real NF.

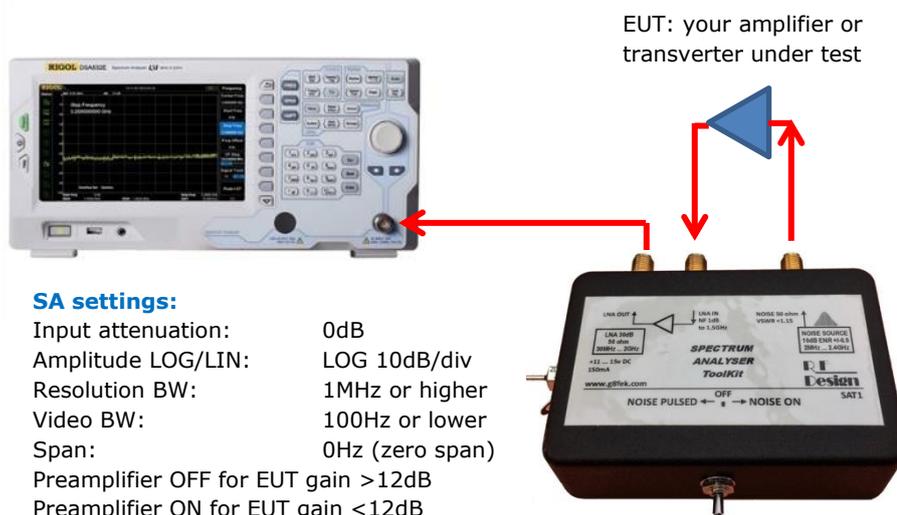
Which brings us nicely around to one use for the high gain very low noise amplifier (VLNA) in SAT1.

Measuring noise figure with your spectrum analyser and SAT1

For quick look see NF testing, the SAT1 VLNA connected in front of your SA (even without an internal preamp option) provides a sufficiently low NF to reduce the impact of the 2nd stage NF (that of the SA) to a low level. This is particularly the case if your EUT gain is >12dB.

(For precise NF measurements we can use software that compensates for the 2nd stage NF, but more on that later.)

Here is an example NF measurement setup:



With the SA internal preamplifier turned off and 0dB input attenuation, the NF at the input to the SAT1 VLNA input will be around 2dB and with the SA preamplifier enabled, it will be around 1dB.

Procedure

- 1) Connect as shown in the diagram above, apply 12v to the SAT1 and power to your EUT. Keep the connection from the noise source to the EUT short and low loss, an adapter straight into the EUT (no cable) is preferred for accurate NF results. Loss in the other cables is not critical. Your EUT preferably needs to be screened and filtered.
- 2) If your EUT has a gain >30dB, place a 10 or 20dB attenuator (pad) at the EUT output, feeding the SAT1 VLNA input.
- 3) Adjust the SA settings as shown.
- 4) Select noise 'OFF' on the SAT1 mode switch and adjust the SA amplitude REF level to set the noise trace near the middle of the SA display screen. Take a power reading, units are dBm.
- 5) Select noise 'ON' on the SAT1 and take a power reading in dBm.
- 6) The Y factor dB value is the difference between the dBm values in steps 4) and 5). Use the marker and delta marker functions on your SA if these are available on your instrument to give a direct readout of the Y value.
- 7) Use the graph supplied with your SAT1 to determine the NF for a given Y value. If you are using the SAT1 PRO cal table, use the appropriate curve for the noise source ENR at your frequency of interest.

An alternative to using the supplied graph is to download the Excel spreadsheet from the SAT1 product web page. This provides both single stage and two stage measurement results.

Enter the noise source ENR value, top right. For SAT1 enter 10.0, for SAT1 PRO, the calibration value from the table.

Use the 'Instrument only calibration' column to input your two power values for noise on and noise off.

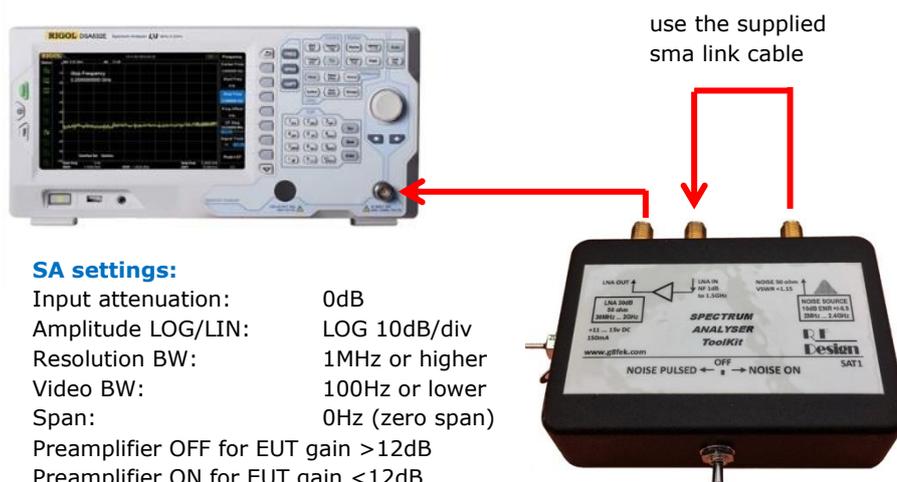
The single stage measurement box at the bottom displays the Y value and the calculated NF.

The 2.77dB NF result was obtained using an HP 8590 series SA testing a broadband amplifier at 1 GHz.

Spectrum Analyser ToolKit SAT1 noise figure calculator with 2nd stage correction ©2017 Continental Compliance Ltd			
GREEN TEXT = REQUIRED USER INPUT	INSTRUMENT ONLY CALIBRATION or single stage measurement	EUT* IN CIRCUIT	SOURCE ENR (dB) 9.90
Noise source off (dBm)	-53.50		EUT RESULT
Noise source on (dBm)	-45.60		#DIV/0! dB NF
			#NUM! dB Gain
Single stage measurement result		* Equipment Under Test V1.1	
Y factor (dB) 7.90			
Noise Figure (dB) 2.77			

Procedure for two stage measurement, compensating for 2nd stage NF

For increased accuracy we need to carry out the maths to resolve the impact of the measurement system noise figure. In our case that is the combined system noise figure of the SAT1 VLNA and your SA.



The two stage measurement just requires two more power measurements to be taken for the Y factor without the EUT in circuit ...

- 1) Connect as shown in the diagram above, apply 12v to the SAT1.
- 2) Select noise 'OFF' on the SAT1 mode switch and adjust the SA amplitude REF level to set the noise trace near the middle of the SA display screen. Take a power reading, units are dBm. Enter into cell 'A' on the spreadsheet. (see spreadsheet picture on the next page).
- 3) Select noise 'ON' on the SAT1 and take a power reading in dBm. Enter into cell 'B' on the spreadsheet.
- 4) The single stage measurement box at the bottom displays the Y value and the calculated NF for the SAT1 VLNA plus your SA.
- 5) To measure your EUT, now carry out the procedure on page 2 with the sma link removed and your EUT connected.
- 6) The two power results are input to cells 'C' (noise off) and 'D' (noise on). See spreadsheet picture on the next page.
- 7) Your EUT and gain are displayed in the 'EUT Result' cells. Remember to enter the source ENR value.

Spectrum Analyser ToolKit SAT1 noise figure calculator with 2nd stage correction ©2017 Continental Compliance Ltd			
GREEN TEXT = REQUIRED USER INPUT	INSTRUMENT ONLY CALIBRATION or single stage measurement	EUT* IN CIRCUIT	SOURCE ENR (dB) 9.90
Noise source off (dBm)	-77.40	-53.50	EUT RESULT 2.76 dB NF 22.62 dB Gain
Noise source on (dBm)	-68.40	-45.60	
Single stage measurement result			
Y factor (dB) 9.00			
Noise Figure (dB) 1.48			

* Equipment Under Test V1.1

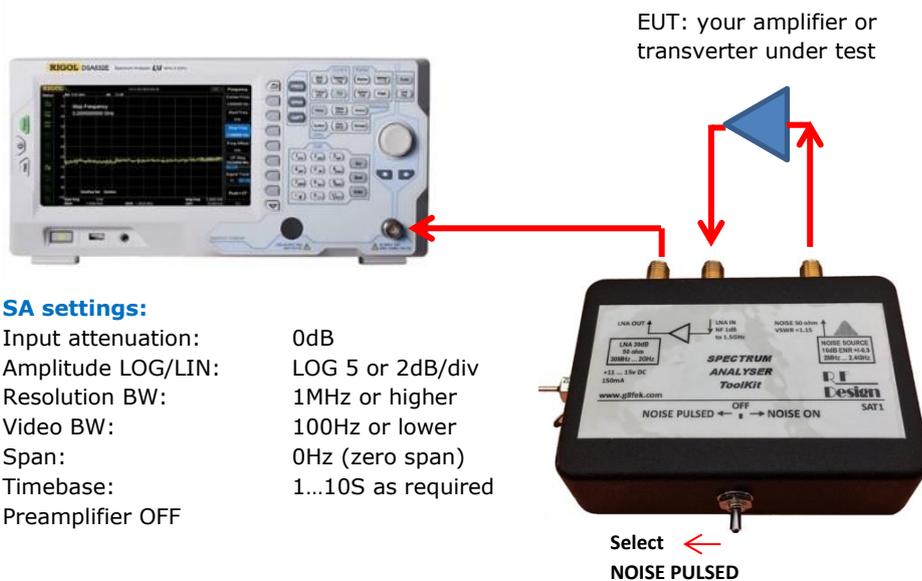


Peaking EUT noise figure with your spectrum analyser and SAT1

Solutions for tuning a circuit for optimum noise figure and measuring absolute NF accurately, has been met with a variety of low cost 'noise figure meter' and NF tuner designs over the decades. These offer varying degrees of effectiveness but many suffer lack of repeatability, stability and in some cases limited frequency agility. What is preferred is stability and day to day repeatability to progress your experiments and make performance improvements.

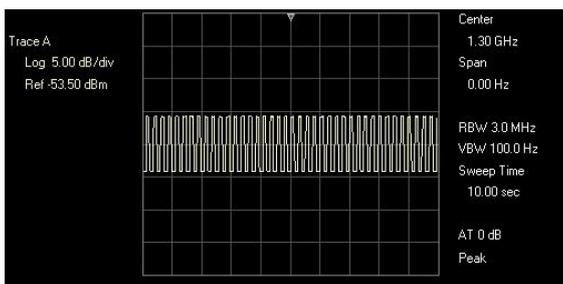
Armed with a sensitive broadband spectrum analyser (almost any SA is very sensitive with the SAT1 VLNA in front!) and a low VSWR pulsed noise source, you have the tools to carry out real time NF adjustments that are both stable and repeatable. With SAT1 and your spectrum analyser frequency range permitting, testing from HF through to 13cm is possible.

Here is the NF peaking test configuration ...

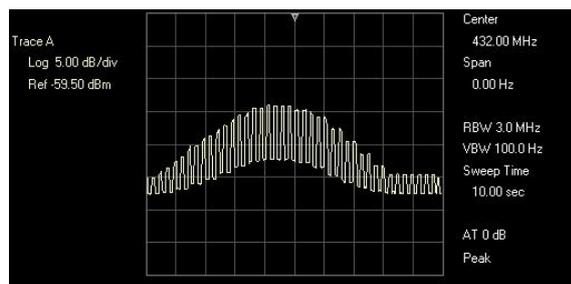


Using the SA settings above, adjust the SA reference level to centre the pulsed display as shown in the first plot below. The peak to peak value is a direct measure of the Y value, so a larger peak to peak reading correlates directly to lower NF.

As you tune the EUT, the gain will change and the displayed trace will move on the amplitude axis. If your tuning is introducing large gain changes, for example at the very beginning of the tuning process, adjust your SA amplitude reference level to establish the trace in the centre. Use the SAT1 Y factor NF graph to estimate roughly the absolute NF value from the peak to peak excursion of the trace. Some SA pk-pk marker features may be useful for this.



The first trace here shows an aligned 23cm EUT



The second trace shows a 70cm front end being tuned

FAQ's

Q My test results are bad and inconsistent, it may be off air transmissions or incidental radiation from my PC?

A Off air transmissions (ambients) can cause problems when making high sensitivity measurements. If you have a problem with a known ambient, moving your test frequency may help. Because we normally recommend a >1MHz resolution bandwidth (RBW) setting, you would need to move several MHz or reduce the RBW setting. Alternatively take greater measures to screen and filter your equipment under test (EUT). The SAT1 enclosure is fully screened and the DC input is fitted with a high performance filter.

Q What NF measurement accuracy can I expect?

A Because your SA is making relative measurements to determine Y factor, the absolute noise power value isn't important in the NF calculation. The most significant uncertainty in most tests will be the noise source ENR value. The SAT1 10dB ENR +/- 0.5 dB specification translates into +/-0.5dB NF result plus other uncertainties in the Y measurement. A typical NF result will be within +/-0.5dB for SAT1 and +/-0.2dB for SAT1 PRO.

Q How does ambient temperature influence the noise source performance?

A The ENR value has a temperature coefficient of -0.03dB / °C. This translates in to a 0.3dB change in ENR for a 10°C temperature change. If you use SAT1 PRO at a variety of temperatures, factoring in this characteristic to your calibration table values will improve measurement accuracy.

Q How good is the noise source output impedance match?

A The SAT1 output VSWR specification is <1.15:1, that's >23dB return loss. If the input VSWR of your equipment under test is say 2:1 there is the potential for a modest mismatch error of up to 0.1dB.

If you measure an amplifier with very poor input match, 5:1 or greater is typical of older generation VLNA for example, significant errors can be introduced. The noise source output match can be improved with an external attenuator. A good quality 6dB attenuator brings the SAT1 return loss to over 30dB. The attenuator needs to be calibrated at your frequency of interest and the dB value subtracted from the ENR calibration. The ENR will now be approximately 4dB.

Adding even an uncalibrated attenuator yields benefits for NF optimisation tuning when you are just looking for the maximum Y factor and not seeking an accurate absolute calibrated NF value.

Q What is the SAT1 VLNA maximum output power and is this a safe level for my instrument?

A The VLNA saturated output is <+13dBm at any frequency. This was part of the SAT1 VLNA target specification to provide a good margin to damage levels typically found in spectrum analyser specifications. Please check your instrument specification to ensure +13dBm is a safe level.

Other resources useful for SAT1 owners ...

It's worth a mention that Owen Duffy VK1OD has produced a wealth of reference information, calculators and software applications, including some for noise in RF circuits. Please see the software page at <http://owenduffy.net/software/index.htm>

Owen has a terrific shareware 2 stage Noise Figure Meter NFM at <http://owenduffy.net/software/nfm/index.htm> This uses a PC soundcard interface to measure noise on the line input to the PC. However, NFM can also be used to manually input noise values and calculate NF and gain. NFM offers similar math manipulation as the spreadsheet we introduced earlier in this note but with additional features. It's worthwhile working through the use of NFM, as a tutorial and as an alternative to the spreadsheet if you don't have MS Excel to hand.