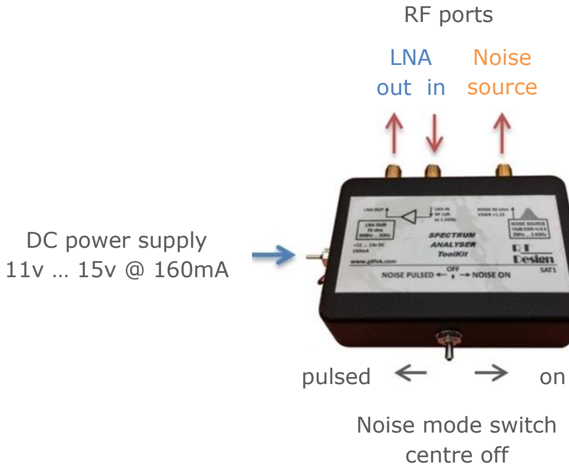
Products: Spectrum Analyser ToolKit SAT1



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 (VLNA)

- 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)

Searching out and measuring low-level signals

From HP an150 .. 'One of the primary ways engineers use spectrum analysers (SA) is for searching out and measuring low-level signals. The limitation in these measurements is the noise generated within the SA itself. This noise, generated by the random electron motion in various circuit elements, is amplified by multiple gain stages in the analyser and appears on the display as a noise signal. On a SA, this noise is commonly referred to as the Displayed Average Noise Level or DANL'.

DANL is commonly normalised to a 1Hz bandwidth. Noise power increases with bandwidth according to 10log(BW2/BW1), that's 10dB per decade of bandwidth. So for example -111dBm in a 1kHz bandwidth scales to -141dBm/Hz. Noise marker features on SA apply this arithmetic (and other important corrections as described later on) when measuring RMS noise levels in larger resolution bandwidths.

At room temperature the noise power contribution of passive components is approximately -174dBm/Hz (see references to kTB in HP an150). This is the absolute minimum noise power level present at room temperature.

Your spectrum analyser DANL (Displayed Average Noise Level)

Here are a few instrument Displayed Average Noise Level (DANL) specifications at 1 GHz, input attenuator 0dB.

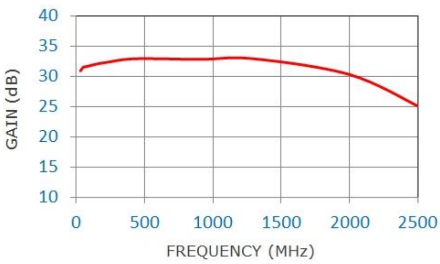
HP 8559A	-141dBm/1 Hz BW
HP 8590A, HP 8591E	-145dBm/1 Hz BW
Rigol DSA815 & DSA710	-155dBm/1 Hz BW
Rigol DSA832	-161dBm/1 Hz BW

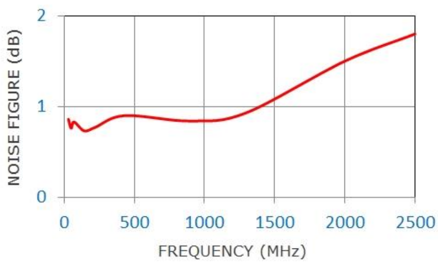
Notice how all of these DANL specifications fall well short of the ambient noise level of -174dBm/Hz.
With SAT1, the DANL of most general purpose SA can be reduced to <-170dBm/Hz from 30 MHz to 2 GHz.

SAT1 VLNA characteristics

Third order output intercept is >+20dBm. The saturated output is limited to <+12dBm for safety.

Gain is very flat from 30 MHz through 1.5 GHz with a noise figure of 1dB.





SA settings for best DANL

SA amplitude offset

SAT1 VLNA gain is typically 32dB from 30 MHz to 1.5 GHz. If your SA has an amplitude offset feature, enter +32dB to read corrected amplitude levels directly from your instrument.

SA input attenuator setting

To achieve the lowest noise floor, check your SA safe input level is at least +12dBm and set input attenuation to 0dB.

SA resolution bandwidth (RBW) and video bandwidth (VBW)

RBW setting is usually kept wide during wide spans to increase the permissible sweep time and maintain amplitude accuracy. If you wish to decrease DANL and can tolerate a longer sweep time, then each decrease of RBW by a factor of 10, from 1 MHz to 100 kHz for example, reduces the DANL by 10dB. Use a lower video bandwidth setting to smooth the noise trace.

SA preamplifier

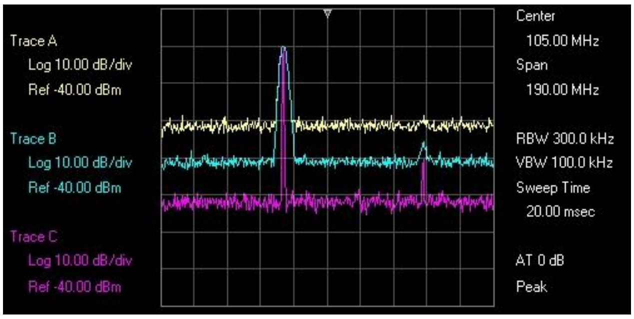
With the internal preamplifier switched off and 0dB input attenuation, SAT1 will reduce the input noise figure of your instrument to approximately 2dB. The DANL will be typically -172dBm/Hz.

If your SA has an internal preamplifier feature, the available noise figure will typically reduce to 1dB and DANL to -173dBm/Hz. In most instances it's probably not worth using your internal preamplifier when using SAT1 since the extra 1dB improvement in DANL comes at the expense of a considerable dynamic range reduction.

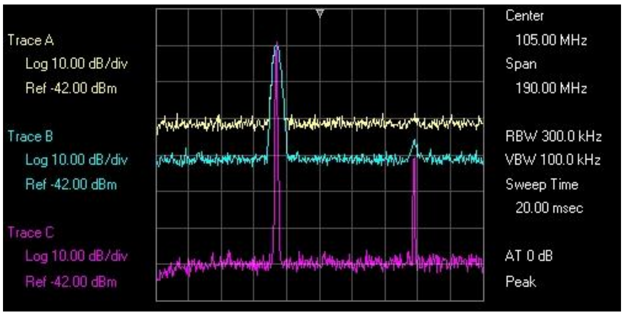
Plots showing DANL improvements

Plots show an 80 MHz signal generator at -50dBm and second harmonic at -30dBC observed on HP 8596E SA.

Plot 1 barefoot SA



Plot 2 SAT1



(Please disregard the RBW and Attenuator settings to the right of the plots. These were altered for each trace sweep)

Plot 1 shows the DANL improvements possible using your SA settings, without the benefit of a preamp or your SAT1.
The top trace (yellow) is with 10dB input attenuation and 3MHz RBW. Note the second harmonic is only just visible.

The middle trace (blue) is with the input attenuator set to 0dB. The harmonic is now visible, although the level is exaggerated because of the proximity to the noise floor.

The bottom trace (violet) is with 0dB attenuation and the RBW set to 300 kHz, providing a 10dB DANL improvement. The harmonic is now >10dB above the noise floor and an accurate measurement is possible.

Plot 2 reruns the last settings (violet trace) but now with SAT1 in circuit. Notice the noise floor reduction of approximately 18dB, allowing observation of much lower level signals during measurement.

So for best DANL set your RBW to the minimum available and your input attenuator to 0dB, although this may come at the cost of a reduced span and sweep settings.

When using input attenuation set to 0dB, always ensure the SA specified maximum permissible input power is observed.

Measuring DANL

The normal convention for DANL specification involves terminating the SA (or preamplifier) with a resistive load, value to match the instrument input impedance, so typically 50 ohms.

Noise power measurement using a SA is not as straight forward as may at first be imagined. SA LOG IF amplifier and detector stage responses require weighting factors when measuring Gaussian noise to present a corrected RMS power measurement. Additionally, the shape factor of analogue IF filters used for RBW settings require compensation to adjust to the actual noise bandwidth.

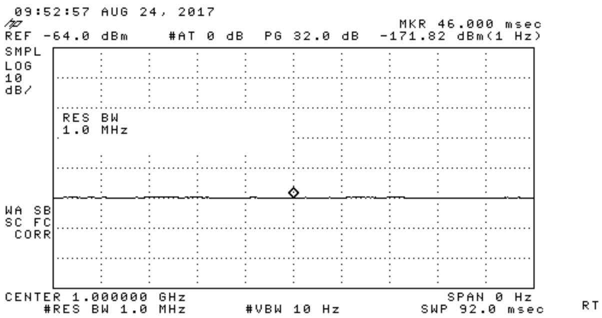
The corrections typically used are +2.5dB for the LOG amp and detector and -0.3dB for the RBW filters

SA with noise markers displaying dBm/Hz will automatically apply the required corrections. If you don't have a noise marker function then adjust your peak detector / LOG amp derived measurement result by 2dB.

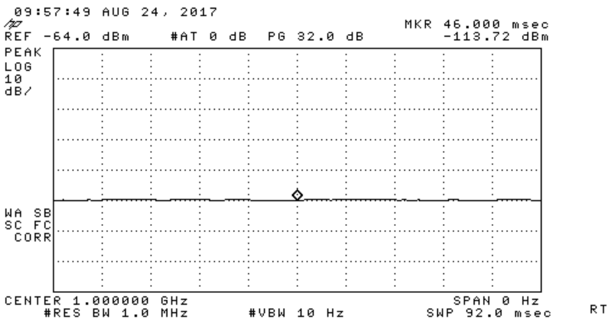
E.g. a screen result of -143dBm in 1kHz RBW would be -173dBm/Hz +2dB = -171dBm/Hz DANL. Remember to terminate your input in 50 ohms.

Because the SAT1 NF is so low, you may notice that leaving the input unterminated reduces the noise floor even further. If you have an antenna with sufficiently low noise temperature, you can use your SAT1 and your SA to observe ground noise against a lower cold sky noise. For example, a 1420 MHz cantenna offers 4.2dB warm earth to cold sky noise with SAT1 using an HP 8596E. Much more detail on that in a future SAT1 app note.

Plot 1 noise marker



Plot 2 standard marker



Here are two plots using HP 8596E with SAT1. Plot 1 noise marker indicates -171.8dBm, Plot 2 marker -113.7dBm/1MHz.

Notice the wide RBW setting to get minimise sweep time and the narrow VBW setting to smooth the noise.

The standard marker result of -113.7dBm/MHz with RBW translation equals -173.7dBm/Hz (10dB per decade of BW) and then with +2dB correction equals -171.7dBm/Hz DANL.

We hope you have found this note useful.