Noise figure measurement I5SXN – august 2008

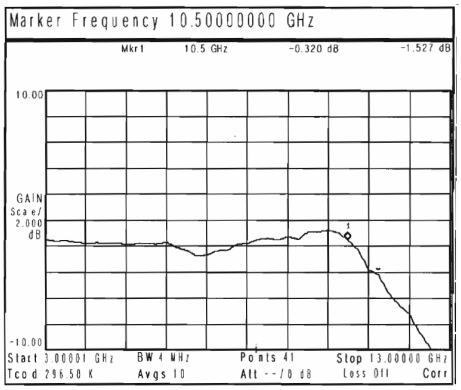
1 – Introduction

Dear friend
As you know this convention is entitled to Piero Moroni I5TDJ. Probably many of you connected him..
For this world EME convention, the tuscan committee decided to realize some noise generator heads from some MHz to more than 10 GHz. Some of this heads will given to some participant.
To realize these heads were engaged myself I5SXN Angiolo Chiti, the friend Roberto Cappadona I5KRD from CNR, Raffaele Tampolli IK5FGJ, Franco Rota I2FHW and the factory Rossbauer.
As you know using a calibrated noise source we can measure the noise figure of a receiver.
The noise head we realized are useful with any automatic system that is able to accept 15 dB ENR plus minus two dB, but can also used in non automatic measurement. The power voltage normally indicated as 28 volt can be not so precise as a current source is included in the circuit.

2 - Noise-figure

The noise figure definition was popular in 1940 when Harold Friis defined it as the signal Si to noise Ni ratio in input of a device respect to signal So to noise No ratio in output.
F = Si/Ni
So/No
The thermal noise is the effect of the electron movement and is defined from the following equation:
Pa = kTB
Were Pa is the power in Joule/s or Watt
K = Boltzmann constant 1,38 x 10^{-23} J/K
T = absolut temperatur in Kelvin degree
B = band pass of the device in test in Hz
At the temperature of 290°K, that is the normal ambient temperature, in one Hertz band the noise power is 4 x 10^{-21} W, that is equal N_{OFF} = -174dBm/Hz, on a fifty ohm resistor.
The Excess Noise Ratio, abbreviate ENR, of the noise generator is the ratio of the noise of the source, when active, and the thermal noise of 50 ohm, generator off., with the ratio N_{ON} respite N_{OFF}

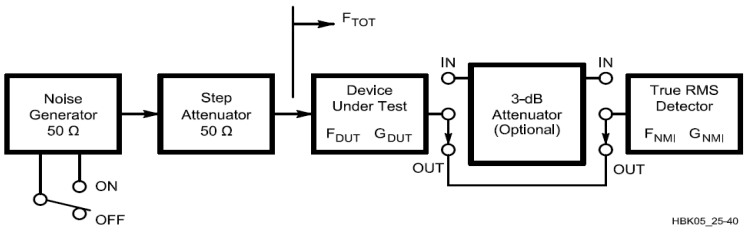
$$\frac{N_{ON}}{N_{OFF}} = \frac{N_{OFF} + N_E}{N_{OFF}} = 1 + \frac{N_E}{N_{OFF}} = 1 + ENR$$



Example of calibration chart of an head.
Each noise head has its own calibration chart.

3 – Noise-figure measurement not utilizing automatic system.

To make the noise figure it is necessary to connect the noise generator as in the following figure. At the output of the system you have to use a true RMS audio voltmeter.



The ENR in dB applied to the Device Under Test è the value ENR of the noise generator indicated in the calibration cart less the attenuation of the Step Attenuator, in dB.

3.1 – The total noise at the output, with the noise generator ON, is $N_{ON(TOT)}$ and when it is OFF the value is $N_{OFF(TOT)}$. The ratio N_{ON} to N_{OFF} give the value Y

$$\frac{N_{ON(TOT)}}{N_{OFF(TOT)}} = 1 + \frac{ENR}{F_{TOT}} = Y$$

If we solve the equation respect to F_{TOT} we obtain

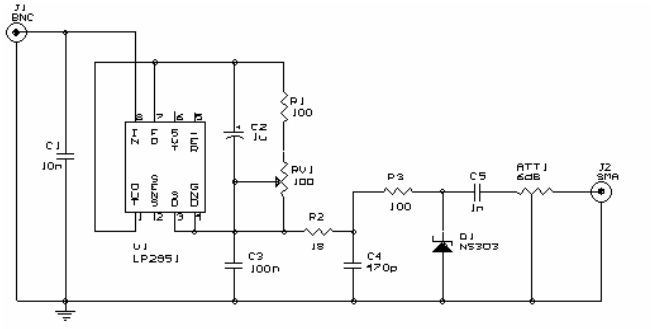
$$F_{TOT} = \frac{ENR}{Y-1}$$

So the Y value is the ratio between the indication of the True RMS detector when the noise generator is ON and when it is OFF.

3.2 - If the output noise is double, that is 3 dB more, when the generator is ON then Y=2 the noise figure is exactly equal to ENR calculated.
If the steps of the STEP ATTENUATOR are not sufficiently small, or if you do not have an attenuator useful in the band you have to measure, you can calculate the noise figure utilising the upper equation.

3.3 – If you have an attenuator with very small steps it is convenient utilize the 3 dB optional attenuator. You have to maintain the noise constant with the generator ON and OFF, in this case the output voltmeter is utilized only as reference. The 3 dB method not necessitate a very precision audio voltmeter.

4 – Draft schematic of the noise generator



5 – Bibliography

In internet you can find a lot of document about the noise, but here I indicated only someone

- ARRL Handbook
- VHF communications N1-2007 – I2FHW - Franco Rota - Noise source diodes
- Friis formula – encyclopaedia Vikipedia
- Agilent - Application Note 57-1- Fundamental of RF and Microwave Noise figure Measurement
- Agilent - Application Note 57-2 - Noise figure Measurement Accuracy
- Agilent - Application Note 57-3 - 10 Hints for making Successful Noise Figure Measurements

First version of the noise generator head

Last version of the noise generator head