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Noise source diodes

1.

Noise

1.1 Introduction

All materials generate noise and the noise is proportional to its temperature starting from $0°K$ ($-273°C$). The noise depends on the chaotic movements of the electrons, the thermal noise is known as white noise (from optical physics) as it fills the whole spectrum.

From an electronics point of view the noise causes big limitations to our devices for example amplifiers, instruments, radars, receivers, electro-medical, etc… A very simple example is the sensitivity limitation of receivers caused by the noise.

Although I have said that noise causes problems and limitations, I want to explain how in some cases, if it is artificially generated, it can even improve our electronic devices (see dithering in Table 1) or help to do some tests, a calibrated noise source is a very important tool in our labs.

1.2 Output level

For noise source applications the output level cannot be indicated as for other signal generators. Signal generators, transmitters etc… have the output level indication in mV, dBm, W etc…. If you have a 100 to 200MHz sweep signal generator we say that the output level is, for example -10dBm, the amplitude of -10dBm is swept from 100 to 200MHz but it is not simultaneously in the whole frequency range.

In the case of noise sources the amplitude is simultaneously on the entire frequency range, this means that the amplitude is defined in dBm/Hz power spectral density, or in ENR excess noise ratio. ENR means the ratio in decibel of the output noise between the ON and OFF state of the diode, in the OFF state the diode has only -174dBm/Hz which is the output level generated by a resistor at 290°K.

For example, if you have a power spectral density of -142dBm/Hz it means that (174 - 142 = 32) the ENR is 32 dB. If the bandwidth is 10Hz the noise power is -132dBm/10Hz if the bandwidth is 10KHz the noise power is -102dBm/10KHz.

2.

Noise generator diode

2.1 Diode selection

The first noise generators (in the 1940's) used noble gas such as Argon with

Table 1: Some applications regarding the generation of noise, it can improve electronic devices or help to do some tests on them.

● **Dithering**
In an A/D converter for example digital receivers, the noise injected improves the quantisation error, the sensitivity will be improved (this method is also used in audio and video).

● **Spectrum Analyser Calibration**
With a calibrated noise source devices it is very easy to verify the amplitude calibration of a spectrum analyser, the real advantage is the RF generation simultaneously on all the band.

● **Noise Figure Measurement**
Test instruments for noise figure measurement in low noise amplifiers, converters, receivers, mixers and front-ends.

● **Gain-bandwidth measurements**
A flat noise source can be used as a "tracking generator" combined with a spectrum analyser to ease measurements of gain and bandwidth.

● **Encryption**

● **Audio And Ultrasonic Test**

● **Test On Receiver**
The noise is useful to measure the sensitivity in some complex receivers like radars, base stations, radiometers etc…
A noise source can substitute for a more complex RF generator, moreover it can generate noise in a broad band spectrum simultaneously.

● **NPR** Distortion
This is a complex intermodulation measurement very often made on multichannels FDM, MMDS, CATV, cellular base stations, etc..
Injecting noise and measuring the distortion with special notch filters is used to obtain the measurement.

● **Fading Simulator**
By modulating an RF signal with noise it is possible to simulate a signal affected by fading, this is very useful in mobile radio testing.

● **Radio Astronomy**

● **EMI Testing**

15.3dBENR, Neon with 18.5dBENR, Helium with 21dBENR and were born in order to test the first radar systems.

Another system to generate noise is to use hot and cold resistors, mainly used in research labs with very high precision.

Zener diodes can be used to generate noise but the output level is not constant, not predictable and used only for HF frequencies, even some bipolar transistors like BFR34 have been used in the past for amateur applications using the reverse biased base-emitter diode, the output level is definitely not constant.

For our applications the right selections are:

• NS-301 SMD sod323 case, up to 3.5GHz

• NS-303 ceramic gold plated case, up to 10GHz

Both types are silicon avalanche diodes that provide 30-35dBENR with a broad-band spectrum starting from 10Hz. In this article I will focus on the 3.5GHz type and in a second article I will also describe the 10GHz type which is more complicated.

At the beginning I tested the glass case type but this case was not suitable because the maximum frequency can be around 1.5 - 2GHz, for the same price we can have 3.5GHz with a flatter output
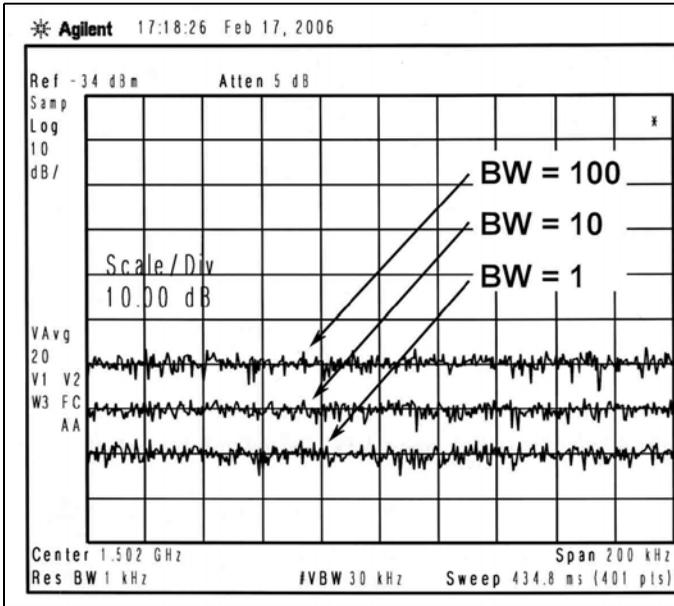
Fig 1: The same noise level related to 3 different bandwidths.

level.

The SMD sod323 case has a very low series inductance typically 1 - 1.5nH which is reasonable for a 3GHz application. Fig 2 shows the SMD case sod323, the body is about 1.9mm long, it is useful for many applications in the lower microwave frequency range.

2.2 Schematic diagram

Fig 3 shows the circuit diagram of a NS-301 noise source diode up to 3.5 GHz.

C1 – dc blocking capacitor

The selection of this capacitor is extremely important to flatten the output level. I spent much time testing several
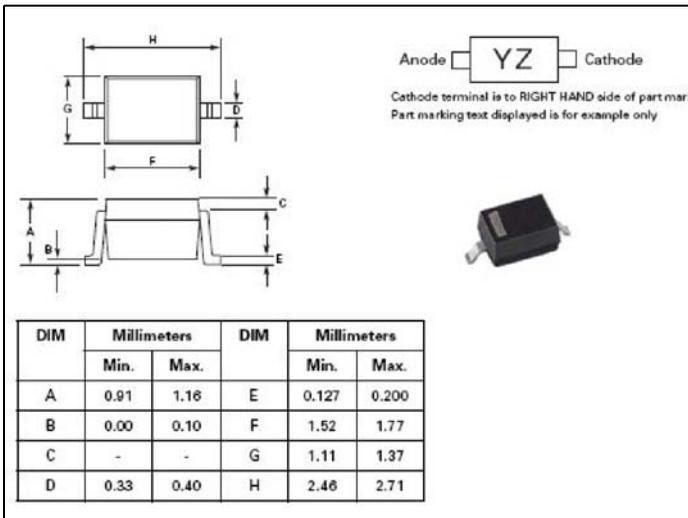

Fig 2 : The SMD SOD323 case.

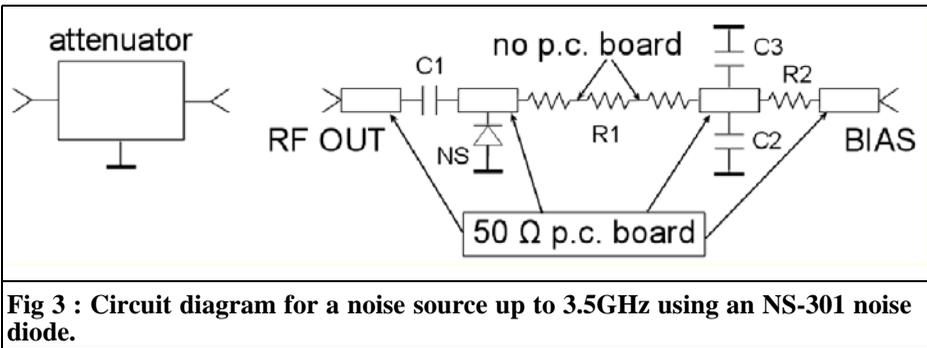| DIM	Millimeters		DIM	Millimeters	
	Min.	Max.		Min.	Max.
A	0.91	1.16	E	0.127	0.200
B	0.00	0.10	F	1.52	1.77
C	-	-	G	1.11	1.37
D	0.33	0.40	H	2.46	2.71

Fig 3 : Circuit diagram for a noise source up to 3.5GHz using an NS-301 noise diode.

types of capacitors, ATC porcelain capacitors have less insertion loss at microwave frequencies but they can't be used because their Q increase the self resonance dip.

For this purpose I selected a special capacitor case, 0805 COG, which can be used up to 12GHz (about 1.5nF), with this capacitor the minimum frequency is about 10MHz.

In the next article about the 10GHz noise source diode I will describe these capacitors in more details.

For 3GHz application the C1 capacitor isn't a crucial component, case 0805 or 0603 and values form 1nF to 10nF are good anyway.

C2, C3 – bypass capacitors

These capacitors are not critical; they can be 1nF and 10nF.

R1 - RF load resistors

This resistor is the sum of 3 resistors in series in order to keep the stray capacity as low as possible, the total value can be around 30 to 40Ω

The manufacturer of noise diodes says that the diode impedance is about 20 to 40Ω, I noticed that by assigning to R1 a lower resistance (20Ω), the output noise level is flatter, on the contrary with an increased resistance (40Ω) the output noise level is a little higher.

If possible, it is better to solder the resistors without using copper track on the PCB.

R2 - bias resistor

For the noise diode NS-301 at about 5mA, +8/+12 V, the correct value is 3.3KΩ if you use the diode for noise figure measurements with a classic +28V pulse available from all the noise figure meters. If the diode is used as a general purpose noise generator to test a filter, for example with a spectrum analyser, you can connect directly to a +8/+12Vdc without the R2 resistor.

NS - Noise diode

As described above the NS-301 sod323 diode is a good selection for the 3GHz frequency range, it is important to remember to keep the pins as short as possible! The diode must be mounted very close to the output connector.

P.C. board

The FR4 fibreglass p.c. board is ok, the insertion loss is so little that it isnn't worth a teflon laminate, vice versa it is very important the noise diode ground connection that has to be as short as possible (see the above explanation).

I tested several noise source diodes in my lab with sod323 case, Fig 4 shows the best and the worst result, in the frequency range 10MHz to 3GHz with 2dB/step and 300MHz/step, the centre reference level is 15dBENR and the noise source diode is connected with a 16dB pad attenuator.
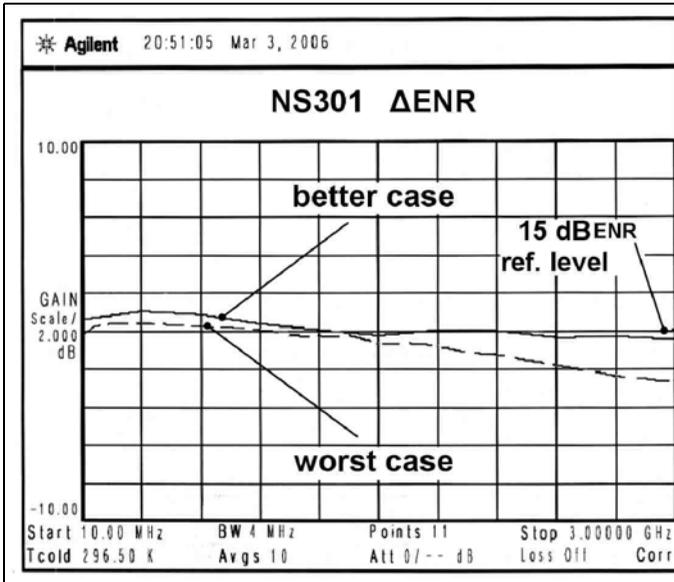
Fig 4 : The best and the worst test results on different noise source diodes.

2.3 Output attenuator

The purpose of this attenuator is two fold, the first one is to obtain the

Fig 5 : A simple explanation of the mismatch due to the noise figure measurement.

15dBENR which is the right noise level accepted by a lot on noise figure meters. The output noise of the NS-301 diode is about 30-35dBENR this means that with a 16dB attenuator you can have about 15dBENR. Any other attenuation values can be used to get other ENR values.

The second and most important purpose of this attenuator is to match the output impedance to 50Ω. In noise source devices used for noise figure measurement, one of the most important condition is to match the output impedance as near as possible the 50Ω resistive load, the easiest way is to insert an attenuator to the output connector.

Normally the ultra low noise GaAsFet preamplifiers have a very bad input return loss, typically a VSWR from 20 to 2 (return loss from 1 to 9.5dB), so if we test this kind of preamplifier with a noise source with an high return loss the total error is unacceptable.

Fig 5 shows a simple explanation of the mismatch due to the noise figure measurement, we can assume that the preamplifier input return loss is 3.5dB, SWR = 5 (it can seem too high but it is a realistic
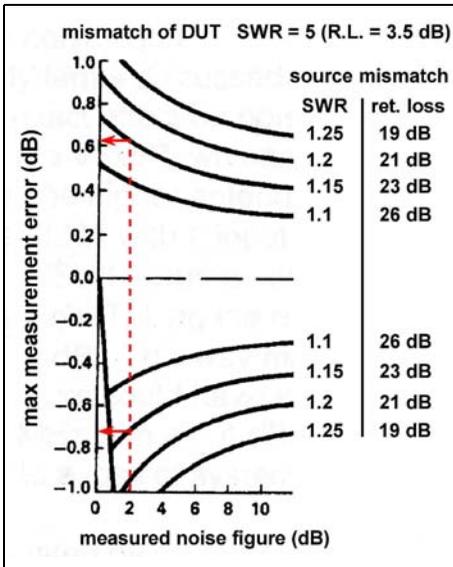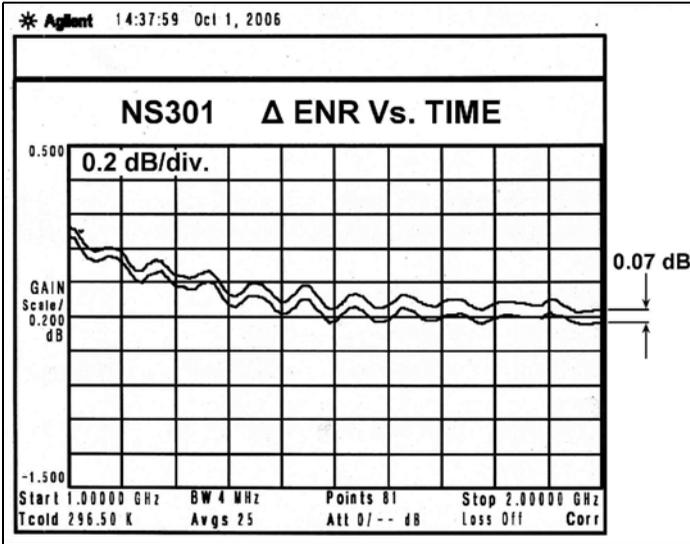
Fig 6 : Instability of noise source diode output.

value).

If our noise figure meter measures 2dBNF and we assume also that the noise source output return loss is 23dB (SWR 1.15), the true noise figure can be between +0.63dB/ - 0.7dB for a 2dB measured value.

In conclusion we should keep the SWR of a noise source as low as possible in order to do more accurate noise figure measurements.

Fig 6 shows the instability that it is quite good for amateur applications, for 8 hours of continuous operation it is only 0.07dB of output level but there is also a 0.03dB of testing instrument instability to consider.
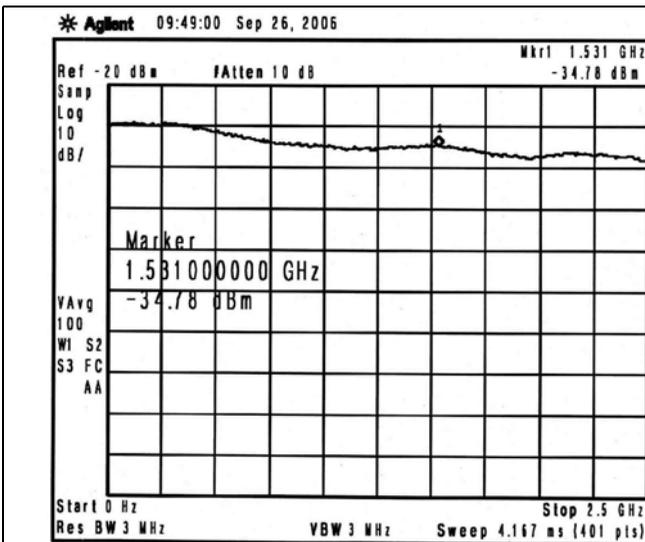

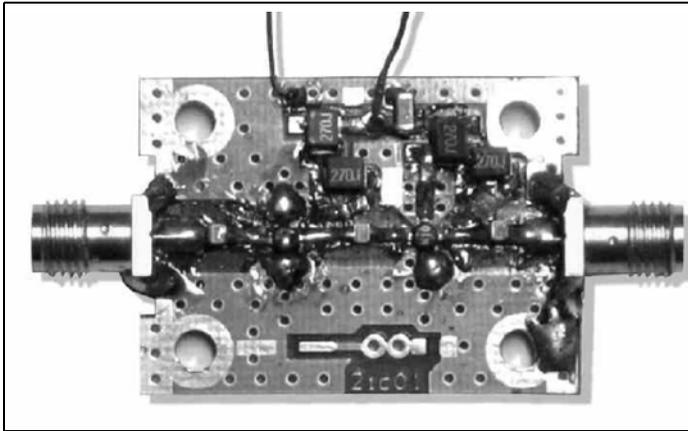**Fig 7 : Response with a 45dB amplifier.**

Fig 8 : Picture of the broadband amplifier.

3.

General purpose noise generator

As shown in Table 1 a diode noise source can be used successfully in a broadband noise generator combined with a spectrum analyser like a "tracking generator". This is not a true tracking generator because it works in a different way. As I said above the tracking generator is like a sweep generator so its frequency moves from start to end but it is not simultaneous in all the frequency range.

If we combine a broadband noise generator with a spectrum analyser we can do a measurement of band pass filters, return loss etc. The signal coming from the noise generator diode is very low so we need at least 45dB of amplification, however 65dB is better. The real difficulty is to obtain a reasonable flat amplifier response. For this purpose I made an amplifier using INA03184 and INA10386 MMICs, the result is shown in Fig 7 and the total response is given by the noise source diode combined with the 45dB amplifier.

Figs 8 and 9 show the 45dB broadband amplifier from few MHz to 2.5GHz used as noise amplifier in order to test the 2GHz band pass filter. This circuit is not difficult to build and it can be used in any lab as general purpose broadband amplifier.
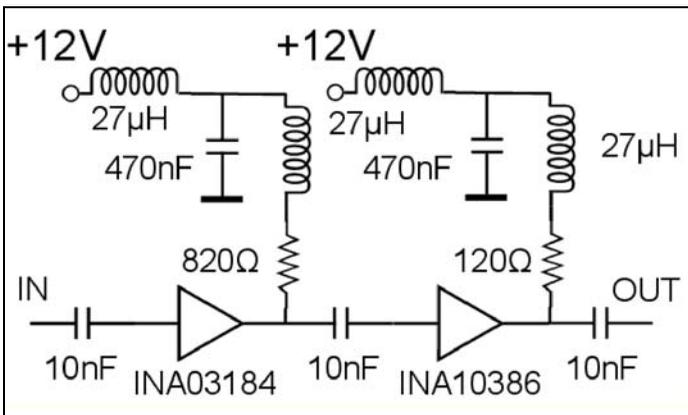

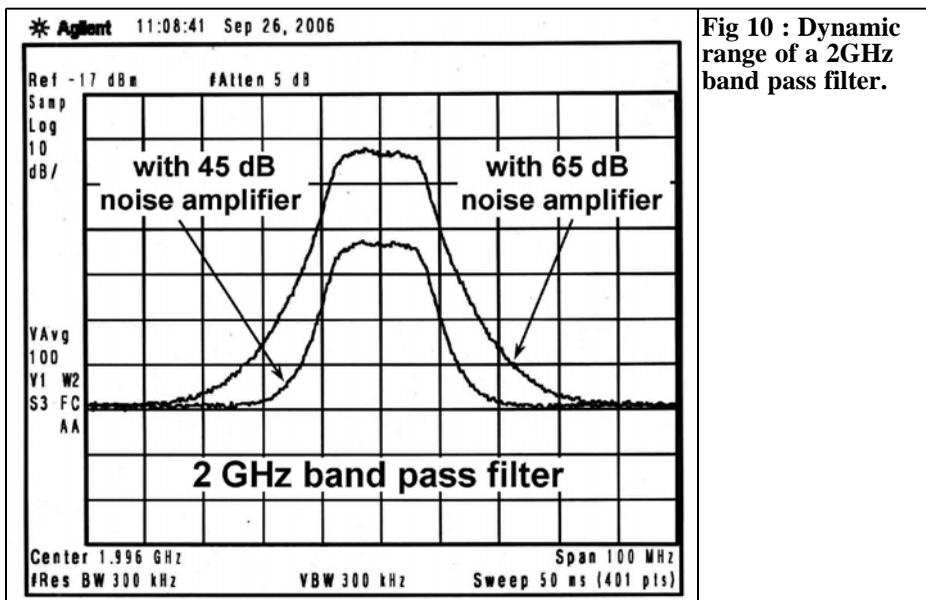**Fig 9 : Circuit diagram of the broadband amplifier.**

Fig 10 : Dynamic range of a 2GHz band pass filter.

Fig 10 shows the dynamic range of a typical 2GHz band pass filter with a noise amplification of 45 dB and 65dB. The dynamic range improves with more amplification, but it is more difficult to achieve a flat output level.

Fig 11 shows the equipment setup used for the filter measurement.

It is demonstrated that with a simple noise generator and a good amplifier it is possible to build an instrument very close to a tracking generator to use with any kind of spectrum analyser. It means that we can "upgrade" an old spectrum ana-lyser, typically the HP 141 series or any other type, with an option that works like a tracking generator.

NS301 noise source specifications are:

Frequency range: 10Hz - 3.5GHz

Output level: 30/35dBENR (-144/-139dBm/Hz)

Bias: +8/+12V, 5mA

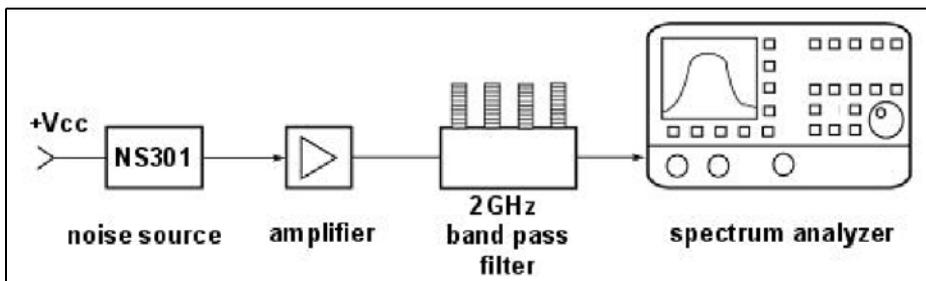It is available from R F Elettronica - www.rfmicrowave.it

Fig 11 : Equipment setup used for the filter measurement.