MEASURING NOISE FIGURE

USING THE

DYNAMIC IMPEDANCE METHOD

Andrew Ikin, Wellbrook Communications design engineer, discusses a simple way to measure sub dB noise figure of an LNA using an SDR and a resistor.

Common methods of measuring LNA noise figure rely on connecting a noise source to the amplifier input and then measuring the noise added to the noise source. This generally requires expensive test equipment.

Low noise amplifiers with < 3dB NF generally have an input impedance thathas a thermal noise lower than the equivalent resistive impedance. For example if the LNA input is 50 Ohms and it is a resistive impedance then this resistance would be a 3dB noise source. Therefore, the NF would be > 3dB.

Now lets consider an LNA with < 3dB NF. For the LNA to absorb power from its input terminal, the input impedance must be a Dynamic Impedance with a very low thermal noise. Examples of these LNAs are where the Dynamic Impedance is derived from the device gain and feedback.

So, we now have a situation where the LNA noise is the thermal noise due to the input Impedance plus other circuit and active device noise.

Therefore, the LNA noise figure can be derived by measuring the noise with the LNA input terminated with a resistor equal to its input impedance. Then with the measurement repeated with the resistor removed, so that the LNA input is terminated by its own Dynamic Impedance. The difference in the noise ref. the above measurements will give a figure in dB which is equal to the noise reduction of the LNA verses thermal noise at 290K. Converting the dB difference into an attenuation power ratio then multiplying this by 290K gives the LNA Noise Temperature. Then using the Noise Temperature to dB conversion table yields the LNA Noise Figure. See Table 1.

Implementing the aforementioned requires an SDR with a low noise amplifier preceding it. The amplifier requires a NF of <1dB, the gain should be approx. 50dB minus the gain of the LNA. Thus the total amplifier gain including the LNA to be measured should be approx. 50dB. This requirement will ensure that the noise figure of the SDR won't degrade the noise measurement of the LNA.

Table 2 shows some noise measurements of a few loop amplifiers at 1MHz using WinRadio Excalibur with a 23 dB pre-amplifier with a 0.14 NF

The SDR should be set to the required measurement frequency with a 1kHz bandwidth, AGC set to 2 Seconds. Detector to AM, S meter to RMS Averaging.

Notes: The 1kHz SDR bandwidth was chosen to the keep the receiver noise down to a low level.

It will be advisable to check the SDR S Meter calibration with a signal generator.

The term Dynamic Impedance use here is defined as one having a low thermal noise compared to a resistance of the same impedance.

290K is the noise temperature of a resistor at room temperature.

If there is no reduction in the noise when the LNA termination resistor is removed, then NF is >3dB.

LNA Noise Difference to Noise Temp and Noise Figure

LNA Noise Difference dB	Noise Attenuation	Noise Temp. K	Noise Figure dB
18	0.016	4.64	0.07
17	0.020	5.8	0.09
16	0.025	7.25	0.11
15	0.032	9.3	0.14
14	0.040	11.6	0.17
13	0.050	14.5	0.21
12	0.0637	18.3	0.27
11	0.079	23	0.33
10	0.10	29	0.41
9	0.126	36.5	0.51
8	0.158	46	0.64
7	0.200	58	0.79
6	0.251	73	1.00
5	0.316	92	1.20
4	0.398	115	1.45
3	0.500	145	1.76
2	0.631	183	2.12
1	0.794	230	2.54
0	1.00	290	3.00

Table 1

Noise Measurements of Loop Amplifiers at 1MHz

Model	LNA Noise Difference dB	Noise Attenuation	Noise Temp. K	Noise Figure dB
ALA1530LN/P	18	0.016	4.64	0.07
ALA1530/S+	10	0.1	29.0	0.42
ALA100LN	16	0.025	7.25	0.11
Pixel	4	0.398	115.42	1.45*

* Pixel NF does not include the additional 0.6dB loss due to the loop matching transformer.

Table 2

One may ask what is the significance of loop amplifiers having a very low noise figure. Small wideband loops only provide a very low output. Therefore, it is essential that the loop amplifier generates as little noise as possible. Up to mid 2015 the ALA1530 and ALA1530S+ had become “Bench Mark” active loop antennas with their low noise. The low NF of 0.42dB making a distinct advantage over other commercial wideband loops with amplifiers with a higher NF.

So far the above has only considered the noise as generated with the amplifier terminated by its own impedance.

However, in the Real World we need to consider the affect that the loop has on the Amplifier NF. If we assume that a 1m diameter circular loop is being used, then we need to measure the Noise Figure with the amp. terminated with the equivalent inductance of 2.2uH.

Noise Measurements with 2.2uH, ALA100LN with 9uH

Frequency	ALA1530LN/P NF dB	ALA1530 NF dB	ALA100LN 9uH loop NF dB	W6LVP N F dB	Modified M0AYF NF dB
200k	2.12	5.0	1.76	>8.0	>10
500k	1.45	4.0	1.20	>8.0	>10
1M	0.80	1.45	0.79	8.0	10
2	0.51	1.0	0.51	7.0	4.0
3	0.33	1.0	0.33	7.0	2.0
4	0.27	1.0	0.27	5.5	2.0
5	0.21	1.0	0.27	4.7	
6	0.21	1.0	0.27	4.0	1.0
7	0.21	1.0	0.33	3.0	
8	0.21	1.0	0.33	3.0	

Table 3

Looking at Table 3. It can be seen that the Noise Figure increases with descending frequency.

The reason for this is, at medium and low frequencies the loop reactance is getting close to a short circuit. This increases the noise figure as the base/emitter or the gate/source sees very low impedance. This is particular problem with simple common base and common emitter amplifiers.

The ALA1530LN/P, ALA1530 and the new ALA100LN afford much lower noise figures compared to most other loop manufacturers because t hey use transformer feedback to ensure that the base/emitter or the gate/source don't see a too low impedance at medium and low frequencies.

Notwithstanding the above, the much lower NF of the JFET amplifier of the ALA1530LNPro has demonstrated that even greater sensitivity compared to the ALA1530S+.

See
http://www.swling.com/blog/2015/11/guest-post-wellbrook-1530lnpro-vs-ala1530s-imperium-loop-antennas/

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