On Comparing Noise Output Powers Of Amplifiers With Simple Equipment
And
A Simple Way To Calculate Noise Figure Using An Amplifier With A Calibrated Noise Figure

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Wide null aperture, low signal output, MW arrays like the DDFA and QDFA (see The Dallas Files), and compact rotatable, top band (160 meter band), high RDF, low signal output, dual flag arrays, like the WF, Big WF, Giant WF, and HWF (see NX4D , N4IS , and here), require a preamp with as low as possible noise figure as the preamp (or first preamp in the preamp cascade). Noise figures of about 1.0 dB or less are necessary for best weak signal performance with these kinds of antenna arrays. Such preamps are not "off the shelf" items, and have only recently been developed for the MW band and top band. As a matter of fact, the development is still ongoing. Because of this, it seems appropriate to make available current information on these developments even though that information is subject to change. This article provides some of that information.

The noise power output N(dBm) of an amplifier in dBm is

$$N(dBm) = 10 \log(F) + 10 \log(G) + 10 \log(B) - 174 = NF + 10 \log(G) + 10 \log(B) - 174$$

where F is the amplifier's noise factor, G is the amplifier's gain, and B is the noise power bandwidth in Hertz of the noise power measuring system, and NF is the noise figure of the amplifier.

The formula above assumes that the input impedance of the amplifier is real and equal to the value of the thermal noise source resistor.

Neither the noise factor nor the noise figure of an amplifier are easy to measure accurately. However, an amplifier has a definite noise factor which does not change with time. The power bandwidth of a noise power measuring system is not easy to measure accurately. However, a noise power measuring system has a definite noise power bandwidth which does not change with time. Generally two amplifiers constructed from two different schematics will not have the same noise factor or gain. Let the subscripts 1 and 2 denote the two amplifiers. If the same measuring system is used in both cases, and the noise power bandwidth is not changed, then

$$N_1(dBm) - 10 \log(F_1) - 10 \log(G_1) = N_2(dBm) - 10 \log(F_2) - 10 \log(G_2),$$

which can be algebraically rearranged to

$$[N_1(dBm) - N_2(dBm)] - [10 \log(G_1) - 10 \log(G_2)] = 10 \log(F_1) - 10 \log(F_2) = NF_1 - NF_2 .$$

If $G_1 \geq 25.12$ (14 dB) , $G_2 > G_1$, and amplifier 1 is cascaded with a third amplifier with the same noise figure as amplifier 1 but with gain $10 \log(G_2) - 10 \log(G_1)$, then the gain of the cascade G_c is

$G_c = G_2$, and it can be shown that

$NF_1 = 0.16 + NF_2$, so that

$[N_c(dBm) - N_2(dBm)] - [10 \log(G_c) - 10 \log(G_2)] = NF_c - NF_2$, from which is follows that

$[N_c(dBm) - N_2(dBm)] - [10 \log(G_2) - 10 \log(G_2)] = 0.16 + NF_1 - NF_2$, or

$[N_c(dBm) - N_2(dBm)] = 0.16 + [N_1(dBm) - N_2(dBm)] - [10 \log(G_1) - 10 \log(G_2)]$, so that

$N_c(dBm) = 0.16 + N_1(dBm) + [10 \log(G_2) - 10 \log(G_1)]$.

If N_c(dBm) and N_1(dBm) differ by 1 dB or more, then

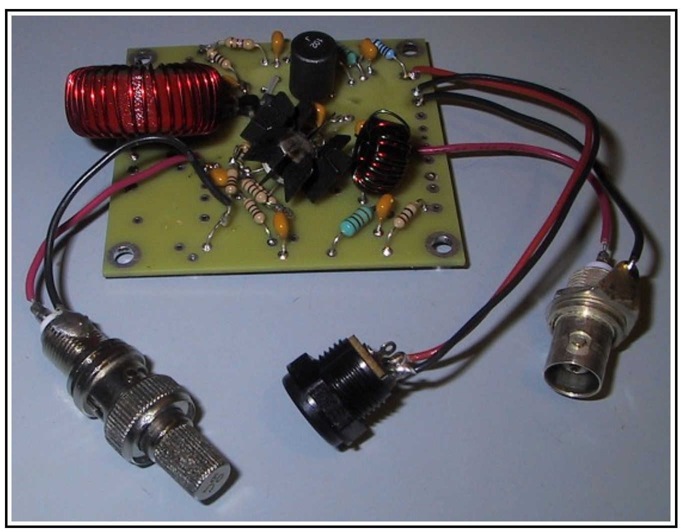
$N_c(\text{dBm}) \approx N_1(\text{dBm}) + [10 \log(G_2) - 10 \log(G_1)]$
with an error of no more than 20% for 14 dB or greater gain (no more than 3% for 22 dB or greater gain as in Example 1 and Example 2 below), and when G2 > G1 , and so N_c(dBm) is greater than N_1(dBm) by approximately $10 \log(G_2) - 10 \log(G_1)$.

In other words, the cascaded noise N_c(dBm) is the "normalized" noise of amplifier 1 (by mathematically adjusting the gain of the cascade to be the same as amplifier 2). If the normalized noise N_c(dBm) of amplifier 1 is greater than the noise N_2(dBm) of amplifier 2, then amplifier 1 has poorer noise performance on weak signals than amplifier 2 by $N_c(\text{dBm}) - N_2(\text{dBm})$. If equal, then they have equal performance. If the normalized noise N_c(dBm) of amplifier 1 is less than the noise N_2(dBm) of amplifier 2, then amplifier 1 has better noise performance on weak signals than amplifier 2 by $N_c(\text{dBm}) - N_2(\text{dBm})$.

The test frequency for all of the following examples was 1.9 MHz unless otherwise stated.

Example 1: The noise output power of a 23 dB gain BF981 with high Q LC tuned circuit front end resonant at 1.83 MHz was measured as – 102 dBm while the noise output power of two cascaded 14 dB NIL amplifiers (28 dB gain total) was measured as – 97 dBm. The gain difference was 5 dB, from which 5 + (– 102) = – 97 dBm, so the amplifiers have virtually identical weak signal amplifier noise output performance. It is assumed that the noise powers are measured sufficiently far above the measuring receiver noise floor so that inaccuracies due to the receiver noise floor are not introduced. In this case, the measuring receiver was a Perseus preceded by a 10.8 dB gain push-pull Norton transformer feedback amplifier. The Perseus meter was operated in maximum averaging mode, and the BF981 was shielded from external RF with all ports blocked by high attenuation common mode chokes. Without the common mode chokes, external noise ingress was obvious.

Example 2: The noise output power of a 22 dB gain W7IUV amplifier was measured as –99 dBm while the noise output power of two cascaded 14 dB NIL amplifiers (28 dB total gain) was measured as –97 dBm. The gain difference was 6 dB, from which 6 + (–99) = –93, so the two NIL amplifiers cascade (as well as the BF981 amplifier) has a 4 dB noise power output advantage over the W7IUV amplifier. I believe that this advantage was observed recently by NX4D as he was comparing a N4IS amplifier using 6 paralleled BF981's with a cascade of two W7IUV amplifiers connected to his (dual) rotatable GWF flag array listening to European CW on top band. It is believed that the N4IS amplifier has considerably greater gain and a lower noise figure than the single BF981 amplifier discussed above.



At right are the two amplifiers, a BF981 amplifier and a W7IUV amplifier. They were constructed on the same PC board, a PC board originally developed for push-pull MRF581A Norton transformer feedback amplifiers. The BNC input and output are moved from one amplifier to the other for measurements. An air variable capacitor which was used to tune the BF981 amplifier to 1.83 MHz is not shown.

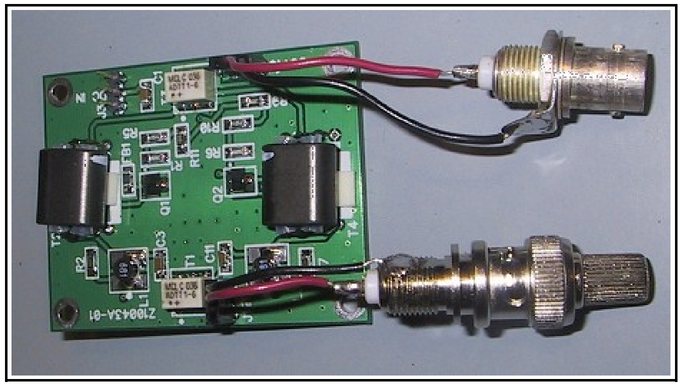
Example 3: A 10.4 dB gain standard push-pull Norton transformer feedback amplifier with MRF581A's was compared to a 11.0 dB gain push-pull Mini-Norton transformer feedback amplifier with calibrated NF from Jack Smith of Clifton Laboratories. The noise power output of the standard Norton was 0.3 ± 0.2 dB less than the Mini-Norton. Using the formula

$[N_1(\text{dBm}) - N_2(\text{dBm})] - [10 \log(G_1) - 10 \log(G_2)] = NF_1 - NF_2$ it follows that

$-0.3 - (10.4 - 11.0) = NF_1 - NF_2$.

To help avoid mistakes, let $NF_{N\text{-}MRF581A} = NF_1$ and $NF_{MiniN} = NF_2$. From the above we have

$NF_{N\text{-}MRF581A} - NF_{MiniN} = -0.3 - (10.4 - 11.0) = 0.3$ (± 0.2).



The Clifton Laboratories Mini-Norton has a calibrated noise figure of about 1.4 dB ± 0.2 dB at 10 MHz. Assuming the Mini-Norton NF at 1.9 KHz is also 1.4 dB ± 0.2 dB , it follows that

$NF_{N\text{-}MRF581A} = 1.7$ dB (± 0.4 dB).

A photo of the Mini-Norton is given at right.

Example 4: Inspired by the N4IS 6x // BF981 top band preamp, a 24 dB gain single BF981 preamp with high Q tuned circuit front end resonant at 1.8 MHz was built recently and had a measured NF more or less identical to the LIN-MRF581A, namely 0.9 dB (+/- 0.4 dB). It is believed that the N4IS preamp has a lower NF because of its 6 // BF981's.

Example 4 may be inaccurate because the input impedance of the preamp was not matched to the thermal noise source resistor. The measurement should be repeated with the input impedance of the preamp matched to the thermal noise source resistor.

Example 5: The noise figure of a 22 dB gain W7IUV amplifier was measured as 4.7 dB. As discussed in Example 2, the W7IUV amplifier is not suitable for top band WF arrays. It is also not suitable for DDFA and QDFA MW arrays.

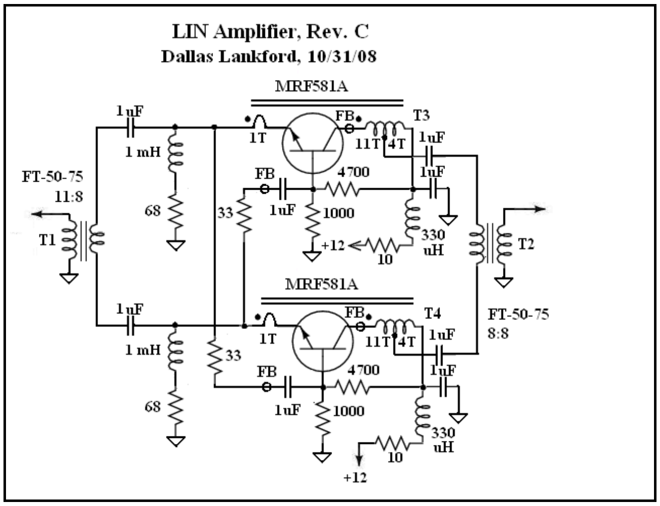
Example 6: A 13.4 dB gain LIN transformer feedback amplifier with MRF581A BJT's was compared to a 10.9 dB gain (sometimes my system measures it as 11.0, sometimes 10.9, here 10.9 will be used) push-pull Mini-Norton transformer feedback amplifier with calibrated NF which has been developed recently by Clifton Laboratories. The noise power output of the LIN was 2.0 dB greater than the Mini-Norton. Similar to Example 3 it follows that

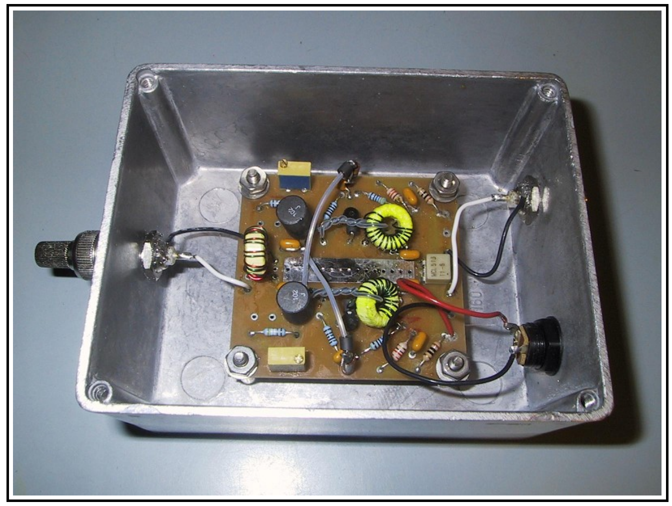
$NF_{LIN\text{-}MRF581A} - NF_{MiniN} = 2.0 - (13.4 - 10.9) = -0.5$ so that

$NF_{LIN\text{-}MRF581A} = 0.9$ dB (± 0.4 dB).

The intercepts of the LIN-MRF581 are about as high as a standard push-pull Norton transformer, namely IIP3 = +32 dBm and IIP2 = +82 dBm. Both the LIN and standard Norton draw 16 mA per MRF581A. The 3rd order intercepts of the N4IS amplifier are estimated to be about +10 dBm based on measured analogous 2 meter amplifiers. This should not be a problem because the signal level outputs of the WF antennas it is used with are low.

A schematic of the LIN amplifier is given below, followed by a photo of its PC board. The original LIN did not have the 33 ohm resistor and FB for parasitic prevention (although no parasitics were ever observed without them).





Example 7: A 13.4 dB gain Clifton Laboratories LIN-Z10042A transformer feedback amplifier with NE85634A BJT's was compared to a 10.9 dB gain (sometimes my system measures it as 11.0, sometimes 10.9, here 11.0 will be used) push-pull Mini-Norton transformer feedback amplifier with calibrated NF which has been developed recently by Clifton Laboratories. The noise power output of the LIN-Z10042A was 4.0 dB greater than the Mini-Norton. Similar to Example 3 it follows that

$NF_{LIN\text{-}Z10042A} - NF_{MiniN} = 4.0 - (13.4 - 11) = 1.6$ so that

$NF_{LIN\text{-}Z10042A} = 3.0$ dB (± 0.4 dB).

This measurement was done after Jack Smith of Clifton Laboratories reported substantially higher NF's for a LIN-Z10043A at 10 MHz and above. It appears that the Z10042A and Z10043A NF's increase substantially after doing the LIN mod. The NF of a LIN-MRF581A was subsequently measured at 10.75 MHz and found to be 0.9 dB (+/- 0.4 dB). There are circuit differences between the LIN-Z10042A / LIN-Z10043A and the LIN-MRF581A amplifiers as well as different BJT's which may explain why the LIN mod which was done on those two Clifton Laboratories amplifiers did not reduce their noise figures.

Acknowledgment

I would like to express my appreciation to Jack Smith, K8ZOA of Clifton Laboratories for sending me a Mini-Norton amplifier with a calibrated NF, for many helpful discussions about noise figure measurement and other matters, and for correcting a terrible mistake which I made in an earlier version of this article. Of course, I alone am responsible for any remaining mistakes in this article.