Measurement of Sub 0.5 dB Noise Figure

Introduction

Understanding and accurately measuring noise figure below 0.5 dB has become particularly important to development of next generation communication systems. This application note provides detail considerations of sub 0.50 dB noise figure measurement of WanTcom's super low noise amplifiers.

The considerations begin by looking into the uncertainty factors of the low noise figure measurement. Then, several noise sources are used with the same noise figure meter of HP8970B to measure a WBA0510AN wide band super low noise amplifier.

Noise Figure Measurement Uncertainty

Today's wireless communication applications use more and more WanTcom's cutting edge low noise amplifiers with increasingly-diminishing noise figures. This intensifies the pressure on engineers to reduce noise figure measurement uncertainty. Many factors can affect the uncertainty of NF measurements, including:

- Interference signals;
- Instrumentation uncertainty;
- ENR uncertainty;
- Mis-match issues;
- Measurement setup;

The following equation can be used to predict the NF measurement uncertainty.

$$\Delta NF = \{[(F_t\delta F_t)/F_1]^2+[(F_t\delta F_2)/(F_1G_1)]^2+$$

$$[(F_2\text{-}1)\ \delta G_1/(F_1G_1]^2+[(F_tG_1\text{-}F_2)\ \delta ENR/(F_1G_1)]^2\}^{0.5} \qquad (1)$$

where F_1 is the linear noise figure of the DUT, F_2 is the linear noise figure of the noise figure meter, F_t is the total linear noise figure of DUT and the noise figure meter, G_1 is the linear gain of the DUT, and all δ terms in (1) are related to the mentioned uncertainties. The unit is in dB. For an amplifier with higher gain (over 20 dB), equation (1) can be reduced to the following.

$$\Delta NF \approx (F_t/F_1)(\ \delta F_t^2+\delta ENR^2)^{\ 0.5} \qquad (2)$$

From equation (2), the dominating factors are the total noise figure uncertainty and the noise source uncertainty.

In the following sections, the various uncertainty factors are explored in more detail.

a) Interference Signals

Pagers, wireless phones, and entertainment radio stations are all common interference signals to affect the noise figure reading at certain frequencies. These signals can enter the measuring system from the connections or the DUT itself. A good EMI shielding or EMI free environment is necessary for the correct noise figure measurement. In some cases, the whole measuring system has to be in an EMI shielding room. The other interference signal type can be the week parasitic oscillation from the DUT itself or the source generated from the noise figure meter internally. The unconditional stable of a DUT is essential to eliminate the week parasitic oscillation. A bandpass filter may be needed at the input of the noise figure meter to filter out the un-wanted signal out of the pass band.

b) Instrumentation Uncertainty

The primary instrumentation uncertainty is the linearity of the noise power detector. The non-linear effects of the noise power detector, regardless of the calibration, will be there despite of the DUT characteristics. The non-linear effects may be reduced using a low ENR noise source such as a HP346A of 6 dB ENR instead of HP346B or C of 15 dB ENR. The HP 8970B has 0.05 dB uncertainty which is one of the best choice in the market.

c) ENR Uncertainty

The ENR uncertainty of the noise source can be a larger factor of the noise measurement system. The typical uncertainty for an existing noise source is about 0.10 dB. The plots of ENR for noise source are shown in Fig. 1, despite of the calibration of the noise sources.

Since the specifications for ENR uncertainty in noise sources are presently recommended by NIST, there is little that an engineer can do to improve this uncertainty. However, care should be taken at least such as routinely calibration of the noise sources and use the correct ENR table.

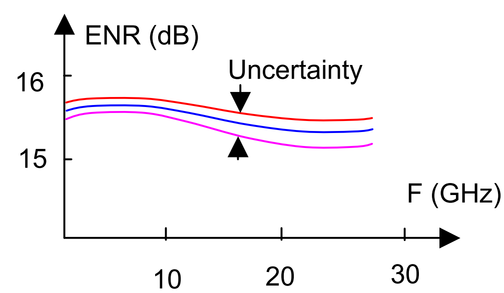

Fig. 1 Uncertainty of ENR for a typical noise source such as HP346C

d) Impedance Mis-match

Noise power reflections between the noise source and the DUT could produce complicated effects. The VSWR of the noise source presents a potential large error. Low ENR source such as Agilent 346A (ENR of 6 dB range) with higher attenuation provides the best accuracy. Also, the input VSWR of the DUT is another source of error. VSWR of 1.25 or below is recommended for a sub 0.50 dB noise figure measurement.

e) Measurement Setup Uncertainty

The primary of the setup uncertainty is the various frequency components get into the IF input of the noise figure meter. These sources error could occur during the frequency translation or unwanted frequency ingredient get into the pass band. The later factor can be filtered out using a bandpass filter at the IF input of the noise figure meter. For the frequency translation configuration (in the case of the measured frequency is higher than the IF input frequency of the noise figure meter), there are two IF signals produced. The DSB signal represents both IF signals are fed into the noise figure meter. The SSB signal represents only single side (either upper band or lower band) is used for the IF signal. SSB signal is desired for the better accuracy measurement with a certain filter in between the output of the converter and the IF input of the noise figure meter.

Measurement of Sub 0.5 dB Noise Figure

There are numbers of WanTcom's low noise amplifiers having the noise figure of 0.50 dB or lower at room temperature. To measure the noise figure accurately becomes a challenge to an engineer to use these products. The typical LNAs are WA08-2433A, 820-980 MHz balance LNA, WA19-1733A, 1.75 –2.05 GHz balance amplifier, WBA0510 series LNA, 500-1000 MHz LNA, WLA08-4030A, 820-980 LNA, WLA14-3030A of GPS LNA, and WLPA08-5555A, 820-980 MHz low noise power amplifier, etc.

Without loosing generality, WBA0510AN super low noise amplifier is used for the discussion here.

a) Typical Performance of WBA0510AN LNA

Para	NF (dB)	Fre. (GHz)	Gain (dB)	IP3 (dBm)	P1dB (dBm)	DC Bias
Data	0.40	0.5-1.0	38	30	15	5V 0.1A

As one can see that the noise figure of WBA0510AN is as low as 0.40 dB at room temperature. The uncertainty of ENR alone can cause 0.10 dB measurement variation which is 25% error. By taking into account other uncertainties, the measurement error could reach as high as 50% or 0.20 dB. The uncertainty can be much worse when the LNA is measured at –40 ^{0}C which the noise figure is estimated in the range of 0.25 dB. You may wonder that modern noise figure measurement methods and systems are not quite ready for the WanTcom's cutting edge super low noise amplifiers. The answer or reality is true. We have to exercise all the precautious to minimize the measurement uncertainties as described in this note.

Due to very high gain (38 dB) of the WBA0510AN LNA, the equation (2) applies well here and can be reduced to

$$\Delta NF \approx (\delta F_t^2 + \delta ENR^2)^{0.5} \qquad (3)$$

by considering $F_t/F_1 \approx 1$

Thus, for δF_t = 0.05 dB and δENR = 0.10 dB, the total measured noise figure uncertainty can be as high as 0.11 dB. The following table summarizes the measured noise figure of WBA0510AN at room temperature using 4 different noise sources made by HP or Agilent with the same noise figure meter and system setup,

f(GHz)	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
NF_1	0.39	0.38	0.37	0.37	0.37	0.37	0.37	0.38	0.39	0.39	0.40
NF_2	0.35	0.36	0.34	0.35	0.35	0.34	0.36	0.35	0.37	0.39	0.37
NF_3	0.42	0.44	0.41	0.43	0.46	0.44	0.45	0.45	0.50	0.50	0.50
NF_4	0.39	0.39	0.37	0.39	0.41	0.40	0.42	0.42	0.47	0.48	0.46

Where NF_1—Noise source of Agilent 346A, NF_2—Noise source of HP346C-1, NF_3—Noise source of HP346C-2, NF_3—Noise source of HP346C-3.

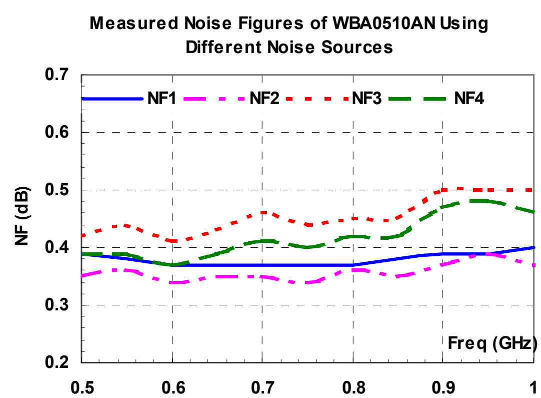

Fig. 2 The measured noise figures of WBA0501AN at room temperature using 4 different noise sources.

Fig. 2 shows the plots of the measurement results. As you can expect per the discussion in this note, the measured noise figure difference of the same LNA at the same noise figure meter can be as high as 0.13 dB. However, after all the uncertainties being analyzed and explored in this note, we can see from the **Fig. 2** that Agilent 346A noise source with lower ENR gives the flattest results across the frequency band. Since lower ENR value noise source offers better matching between the noise source and DUT and better linearity for the noise power detector, the best guess of the noise figure for WBA0510AN is NF1 that is ranging from 0.37 dB to 0.40 dB.

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