

Agilent Noise Source Calibration

*Using the Agilent N8975A Noise Figure Analyzer
and the N2002A Noise Source Test Set*

Product Note



Agilent Technologies

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Introduction

The N2002A noise source test set is designed to assist you in achieving accurate and fast noise source calibration and is part of Agilent's continued commitment to improve your noise figure measurement capability.

Accurate noise source calibration is a critical ingredient in making quality noise figure measurements because the overall level of measurement uncertainty is strongly related to the level of uncertainty in the noise source. Having the tools to conveniently calibrate your noise sources in-house can reduce manufacturing downtime and increase throughput. On the other hand, sending noise sources to an external laboratory or test house can be both time-consuming and expensive. The N2002A noise source test set, as part of a noise source calibration system, can make highly accurate, in-house noise source calibration a cost-effective reality.

This product note details the equipment required to calibrate noise sources to traceable standards, as well as the calibration process, which consists of the excess noise ratio (ENR) measurement and the reflection coefficient magnitude and phase measurements.

The test procedures outlined within this document will verify the electrical performance of the following Agilent noise sources¹ in accordance with their published specification: 346A, 346B, 346C, N4000A, N4001A, N4002A.

1. This process can be adapted for any noise sources operating between 10 MHz and 26.5 GHz

Required Equipment

Hardware

The ENR measurement requires the following equipment:

- N8975A noise figure analyzer (NFA)
- N2002A noise source test set
- 11713A attenuator/switch driver
- Reference standard noise source²

The reflection coefficient magnitude and phase measurement requires the following equipment:

- N8975A noise figure analyzer
- 8753ES or 8753ET network analyzer³ with Option 004
- 8722ES or 8722ET network analyzer³ or with Option 004
- Appropriate network analyzer calibration kits

Cables and adapters

The noise source calibration process requires various adapters and cables⁴. For the best results Agilent recommends using high quality cables and precision adapters. Care should be taken to ensure all cables and adapters are specified for the frequency range in which they are used and that they are in good electrical and mechanical condition.

For assistance in choosing the appropriate cables and adapters please contact your local Agilent sales office.

N2002A Noise Source Test Set

The N2002A noise source test set is a stand-alone instrument used when performing accurate ENR measurements on a noise source. The N2002A provides isolation between the noise source under test and the equipment performing the measurement. Minimizing the interaction between the device under test (DUT) and the measuring receiver ensures accurate and repeatable measurement results and significantly reduces measurement uncertainty.

The N2002A operates over a frequency range of 10 MHz to 26.5 GHz; it has no power supply and performs no measurements. The 11713A attenuator/switch driver is used to control the N2002A. The switch driver can be controlled manually, or remotely using GPIB. Agilent recommends using the N8975A NFA to perform measurements on the noise source under test.

Software is supplied with the N2002A that automates both the ENR and reflection coefficient measurements. The software is described in the *Automating the calibration process* section.



Figure 1. N2002A noise source test set with SNS series and 346 series noise sources

2. More than one reference standard may be required as for best results Agilent recommends using the same type of reference standard as the noise source being measured.
3. Any Agilent network analyzer with the appropriate frequency limits can be used for the reflection coefficient magnitude and phase measurement. The 8753ES/ET and 8722ES/ET are recommended because the software supplied with the N2002A was developed specifically for these models.
4. Cables and adapters are available as an option with the N2002A

Noise Source Calibration Process

The noise source calibration process consists of two performance verification tests:

1. ENR measurement
2. reflection coefficient magnitude and phase measurement

If the noise source fails either one of the performance verification tests it may require repair. Please contact your local Agilent sales and service office for replacement parts or repair service information.

Excess noise ratio (ENR) measurement

The ENR measurement is based on comparing the DUT to a reference standard, which is a calibrated noise source with known ENR values. The accuracy of the measurement results for the DUT is highly dependent on the calibration accuracy of the reference standard. To maximize measurement accuracy, and minimize measurement uncertainty, use a reference standard that has been calibrated by a national standards laboratory. Agilent recommends the National Physical Laboratory in the United Kingdom (www.npl.co.uk) for reference standard calibration.

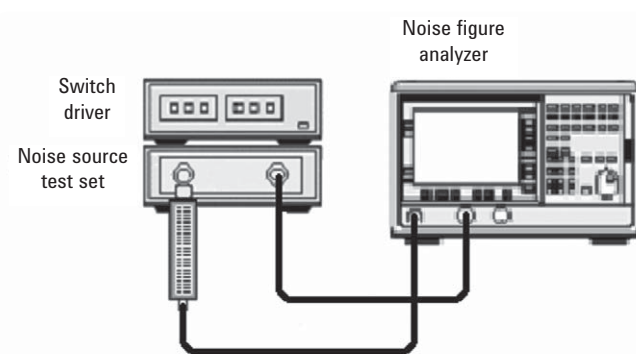


Figure 2. ENR measurement setup

Measurement setup

The following procedure describes how to configure the N2002A noise source test set to perform the ENR measurement (Figure 2).

1. Switch the 11713A attenuator/switch driver and N8975A NFA on and let them warm up for one hour⁵. The reference standard and DUT must be able to reach thermal equilibrium before performing this test.
2. Connect the reference standard to the input port of the N2002A noise source test set using the correct torque setting.
3. Connect the output from the N2002A to the input of the N8975A NFA using the correct torque setting.
4. Connect the 11713A control cables from the rear of the 11713A attenuator/switch driver to the rear of the N2002A.

Performing the ENR measurement

Measurements are usually taken at all cardinal frequencies for the reference standard and the DUT. The ENR values for the reference standard (ENR_1) are already known.

1. Set the equipment to the first measurement frequency. Perform a linear Y-Factor measurement and note the result (Y_1).
2. Set the equipment to the next measurement frequency and repeat this process.
3. Repeat this process until all measurements are complete.

Remove the reference standard from the N2002A input and replace it with the DUT.

1. Set the equipment to the first measurement frequency. Perform a linear Y-Factor measurement and note the result (Y_2).
2. Repeat this process for the remaining measurement points.

⁵. All test equipment must be within the manufacturer's recommended calibration period.

Calculating the ENR Values

The ENR value (ENR_2) at each measurement frequency for the DUT is calculated using the following equation:

$$ENR_2 = 10 \times \text{Log}_{10} \left[\frac{(Y_2 - 1) \times \left(T_0 \times \frac{10^{\frac{ENR_1}{10}}}{(Y_1 - 1)} \right)}{T_0} \right]$$

Where:

ENR_2 = ENR value calculated for the DUT at a selected frequency point

And:

ENR_1 = ENR value for reference standard at a selected frequency point

Y_1 = linear Y-factor measured for reference standard at a selected frequency point

Y_2 = linear Y-factor measured for DUT at a selected frequency point

T_0 = 290 kelvin

The measurement uncertainty for each DUT ENR value is calculated using the following equation:

The measurement uncertainty for each DUT ENR value is calculated using the following equation:

$$U_c ENR_2 = \sqrt{(U_c ENR_1)^2 + (U_c Sys)^2}$$

Where:

$U_c ENR_2$ = DUT ENR uncertainty value at a selected measurement frequency

And:

$U_c ENR_1$ = reference standard ENR uncertainty value at a selected measurement frequency

$U_c Sys$ = overall test system uncertainty at a selected measurement frequency

Reflection coefficient magnitude and phase measurements

The reflection coefficient test measures the input magnitude and phase of the DUT and verifies that it meets its published specification. The magnitude and phase are measured with the DUT powered on and repeated with the DUT powered off.

Measurement setup

The following procedure describes how to configure the appropriate equipment to perform the reflection coefficient magnitude and phase measurement (Figure 3).

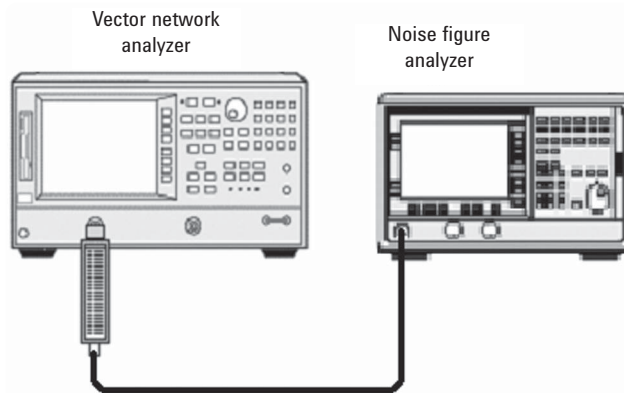


Figure 3. Reflection coefficient measurement setup

1. Switch on all test equipment and let it warm up for one hour.
2. Calibrate the 8753ES/ET from 10 MHz to 3 GHz using the appropriate calibration kit⁶.
3. Calibrate the 8722ES/ET from 3 GHz to either 18 GHz, or 26.5 GHz (depending on the type of DUT) using the appropriate calibration kit⁶.

Performing the reflection magnitude and phase measurements

Measurements are usually taken at all cardinal frequencies for the DUT.

1. Set the 8753ES/ET to the first measurement frequency and connect the DUT to the reflection test port.
2. Set the N8975A so that power is constantly supplied to the DUT. Measure magnitude and phase for the first frequency point and note the results.
3. Set the N8975A so that no power is supplied to the DUT. Measure magnitude and phase and note the results.
4. Set the 8753ES/ET to the next measurement frequency and repeat this process.
5. Repeat this process for all remaining measurement points.

The reflection coefficient specification for each Agilent noise source is divided into a number of frequency ranges. The maximum magnitude and phase values for each range is measured, with the DUT powered on and off, to ensure the DUT does not fail to meet specification outside of the cardinal frequency points.

1. Set the N8975A so that power is constantly supplied to the DUT and measure the maximum magnitude and phase, and the corresponding frequency at this point, for each frequency range specified for the DUT.
2. Set the N8975A so that no power is supplied to the DUT and repeat.

Remove the DUT from the 8753ES/ET and connect it to the 8722ES/ET reflection test port. Repeat all previous steps using the 8722ES/ET.

⁶ Any adapters required connecting the DUT to the 8753ES/ET or 8722ES/ET should be included in the calibration

Copying Data to the N4000 SNS Series Noise Sources

The Agilent N4000 SNS series of smart noise sources have ENR and reflection coefficient data values stored within the noise source. The process required to copy new values into the noise source is supplied with the N2002A.

Automating the Calibration Process

Demonstration software is supplied with the N2002A that automates both measurements contained in the calibration process. The software is written in Agilent VEE Pro and will be available as a VEE Pro file or as VEE Pro run time file. The software supports the equipment listed in the *Required equipment* section of this document.

The system requirements are:

- Agilent VEE Pro (needed to make any changes to the VEE program)
- Agilent VEE Pro run time (supplied with N2002A)
- PC with 120 MHz Pentium™ processor (266 MHz Pentium II or higher recommended)
- Microsoft™ Windows® 98, 2000, XP, or Windows NT®, Windows™ operating system
- 32 MB RAM with Windows 98, 64 MB RAM with Windows 2000/XP/NT
- Hard disk free space:
 - Windows 98 (FAT 16/32 file system) 370 Mbytes
 - Windows 2000/XP/NT (FAT 16/FAT 32/NTFS file systems) 570/370/175Mbytes respective
- GPIB interface card (Agilent or National Instruments)

Software functionality

The demonstration software supplied with the N2002A automates the measurements contained in this document and includes the following functionality:

ENR measurement

- Single or multiple measurements
- Import multiple measurement results into Microsoft Excel for analysis
- Display measurement results plus measurement uncertainty
- Save results to file

Reference standard uncertainty values

- Save to or load from file

Reflection coefficient measurement

- Magnitude and phase results displayed with pass/fail indication
- Maximum magnitude and phase results displayed for each range
- Save results to file

Copy data to N4000 series noise source

- Format data and copy it to the DUT

Test reports

- Test report for each test can be generated after the test has completed
- Text-only reports are generated for easy importation into other software packages

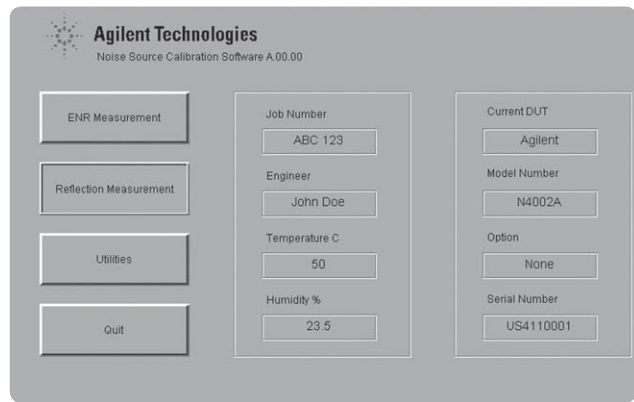


Figure 4. The main operating window for the example software supplied with the N2002A shows the measurements that are available with the software. The software gives a visual indication of the state of the measurement along with the current reference standard and DUT that are being measured.

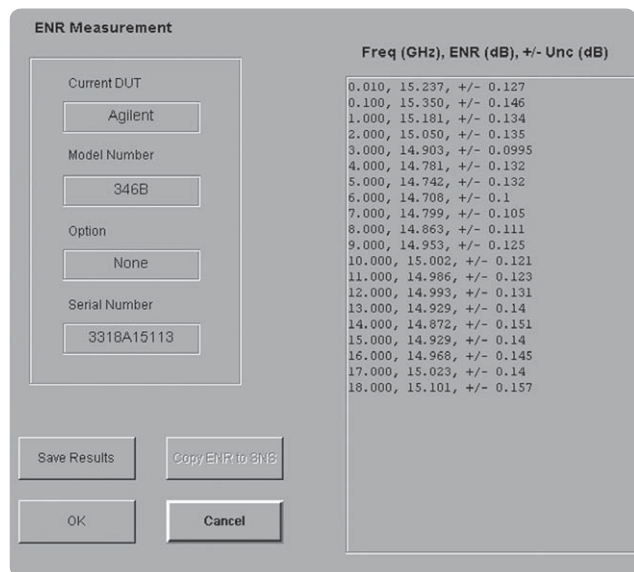


Figure 5. Demonstration software ENR measurement window

Example measurement report

An example ENR measurement report produced by the software is shown below.

These measurement results were taken using an Agilent N4002A as the DUT and an Agilent N4002A as the reference standard. The reference standard was calibrated at the National Physical Laboratory.

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ENR Measurement Results

Model N4002A Standard
Serial number US00000000
Cal date 22/May/2002
Temperature 23.5 C
Humidity 50%

Frequency GHz	ENR dB	Unc dB
0.01	12.585	+/- 0.116
0.10	12.714	+/- 0.152
1.00	12.664	+/- 0.142
2.00	12.641	+/- 0.132
3.00	12.713	+/- 0.099
4.00	12.838	+/- 0.132
5.00	12.947	+/- 0.132
6.00	13.095	+/- 0.100
7.00	13.292	+/- 0.105
8.00	13.498	+/- 0.111
9.00	13.712	+/- 0.125
10.00	13.914	+/- 0.121
11.00	14.082	+/- 0.123
12.00	14.179	+/- 0.131
13.00	14.231	+/- 0.140
14.00	14.227	+/- 0.151
15.00	14.242	+/- 0.140
16.00	14.088	+/- 0.145
17.00	13.985	+/- 0.140
18.00	13.959	+/- 0.157
19.00	14.063	+/- 0.226
20.00	14.149	+/- 0.226
21.00	14.425	+/- 0.234
22.00	14.608	+/- 0.226
23.00	14.768	+/- 0.198
24.00	14.908	+/- 0.242
25.00	14.856	+/- 0.219
26.00	14.371	+/- 0.219
26.50	14.032	+/- 0.258

Noise Figure Resources

Product literature

N2002A noise source test set, product overview	5988-7228EN
NFA series noise figure analyzers, brochure	5980-0166E
NFA series, data sheet	5980-0164E
NFA series, configuration guide	5980-0163E
NFA series, demonstration guide	5965-6068E
NFA series, programming examples	5968-9498E
SNS series noise sources, product overview	5988-0081EN

Application notes

<i>Fundamentals of RF and Microwave Noise Figure Measurements</i> , application note 57-1	5952-8255E
<i>Noise Figure Measurement Accuracy</i> , application note 57-2	5952-3706E
<i>10 hints for Successful Noise Figure Measurements</i> , application note 57-3	5980-0288EN

Web

Noise figure web page: <http://www.agilent.com/find/nf>
N2002A noise source test set: <http://www.agilent.com/find/nsts>

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