

Noise Figure Measurements with Rubidium™ Signal Generator

1. Introduction

This application brief outlines a quick and simple method for a noise figure measurement method of up/down converters using Rubidium Signal Generator and a spectrum analyzer. A definition of noise figure and the underlying concepts are provided with discussion of two methods of measuring noise figure along with their relative merits, and a description of the test set up. Section 2 outlines the definition of noise figure and the underlying concepts. Section 3 discusses two methods of measuring noise figure along with their relative merits, and describes the test set up and method of measurement used.

2. Noise Figure Definition

The noise figure F of a device is defined as ratio of signal to noise power ratio at the input to signal to noise power ratio at the output.

$$F = \frac{S_i/N_i}{S_o/N_o} \quad (1)$$

where

S_i , S_o are input and output signal powers

N_i , N_o are the input and output noise powers

The noise figure of a device is a measure of decrease in signal-to-noise ratio as the signal is processed by the device. A perfect device would process the signal without any degradation in signal-to-noise ratio. Such a device would have a noise figure of zero. However, a realistic device would add its own noise generated internally, to the input signal. This results in a lower signal to noise ratio at the output of the device than at the input. The lower the noise added by the device, the lower is its noise figure.

If G is the gain of the device under test and N_a is the thermal noise added by the device, equation (1) can be rewritten as:

$$F = \frac{N_a + GN_i}{GN_i} \quad (2)$$

The gain G of the device is defined as the ratio of actual power delivered to the load and maximum power available from the source. This is often termed as transducer gain G_t of the device.

The noise figure is dependent on the noise N_i at the input of the device, which is usually the thermal noise and is quantified by kT_oB . The temperature T_o is the reference source temperature defined to be 290 °K, which is close to the temperature seen by the receiving terrestrial antennae in proximity to ground. The universal constant k is the Boltzman constant equal to -228.6 dB; the bandwidth B is the bandwidth of the signal. Then equation (2) can be written as:

$$F = \frac{N_a + kT_oBG}{kT_oBG} \quad (3)$$

The noise figure of a device is independent of the signal level so long as the device is operating in the linear region. The noise figure F expressed in dB is:

$$NF = 10 \log(F) \quad (4)$$

Quite often the noise figure is also expressed in deg K, referred to as noise temperature and is given by:

$$T = T_o(F - 1) \quad (5)$$

3. Measurement Methods

Y Factor Method

The noise figure is measured with the device under test being operated in the linear region. The most common method to measure the noise figure is by measuring the noise added (N_a) as shown in equation (3). A noise source is used to inject two different levels of noise into the device and the power level at the output of the device is measured for each noise level with either a power meter or spectrum analyzer. A low capacitance noise diode is used in the reverse biased mode as a noise source. If the noise temperatures at the two noise levels are T_h and T_c , the excess noise ratio of the noise source is defined as:

$$ENR = \frac{T_h - T_c}{T_o} \quad (6)$$

Noise power at the output of the device under test is measured with noise source at T_h and T_c . Y factor is then determined as:

$$Y = \frac{N_2}{N_1} \quad (7)$$

where N_1 is the output noise power at source temperature T_c and N_2 is the output noise power at the source temperature T_h .

With ENR and Y factor defined as above, the noise factor is given by:

$$F = \frac{ENR}{Y - 1} \quad (8)$$

The noise figure in equation (8) includes the noise contribution by the measuring device used in an output noise power measurement. Assuming the gain of the device under test G is much greater than 1, it can be neglected. The T_c , T_h , and ENR parameters are specified by the noise source vendor across the frequency band of operation. If the noise figure of the device under test is much higher than the ENR of the noise source, Y is very close to 1 and the accuracy of measurement is dependent on the precision with which Y , the noise power ratio, is measured. It is difficult to measure power ratios in the vicinity of 1. This method is not used when the noise figure to be measured is more than 10 dB above the ENR.

S/N Ratio Method

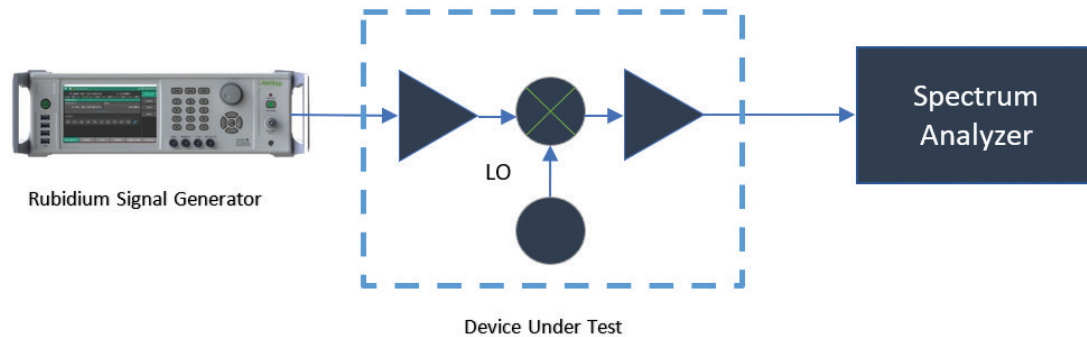
The noise figure is defined as the ratio of input S/N to output S/N as in equation (1) above. The noise figure of the device under test can be measured by measuring the input and output signal-to-noise ratios. However, it should be ensured that the input noise power fed in to the device while making this measurement is equal to the thermal noise floor at 290 °K as per the definition in equation (3). The thermal noise floor at 290 °K is -174 dBm/Hz. The input signal into the device under test could be attenuated by a large enough dB factor to ensure that the noise level hits the thermal noise floor, but at the same time keeps the signal level within the sensitivity limits. Then the noise figure is given by:

$$F = 174 \text{ dBm/Hz} + P_{in} - P_{out} - No - 3 \text{ dB} \quad (9)$$

where P_{in} is the input signal power, P_{out} is the output signal power and N_o is the output noise power per Hz. When the device under measurement constitutes a frequency conversion such as an up/down converter, the noise figure measured is discounted by 3 dB to account for double sideband noise measurement. It is not necessary to know the gain of the device under test as in the Y factor method. Since a ratio of S/N is being measured, it is not necessary to make accurate power measurements. Measurements can be made with a signal generator and a spectrum analyzer.

Measurement Setup

The test setup for measuring noise figure of an up/down converter device using Rubidium is as shown below. Rubidium is set to attenuator decouple mode with output level set to -40 dBm and ALC mode ON. The step attenuator is set to a high value such as +50 dB. This will ensure that Rubidium's output noise floor is equal to thermal noise floor, which is -174 dBm/Hz at room temperature.



The CW output of Rubidium is input into the up/down converter device under test (DUT). Up or down converted output from the DUT is fed into a spectrum analyzer. Carrier-to-noise ratio per Hz (C/N_o) of the output is measured on the spectrum analyzer at a suitable far-off offset such as 5 MHz from the carrier frequency. It is recommended that the input attenuator of the spectrum analyzer is set to zero dB so that noise figure of the spectrum analyzer front end has minimal impact on carrier-to-noise per Hz ratio measurement.

With the measured C/N_o value, the noise figure of the DUT is given by equation (10):

$$F = 174\text{dBm/Hz} - 70\text{dBm} - (C/N_o) - 3\text{dB} \quad (10)$$

The noise figure as calculated by equation (10) is single sideband noise figure.

4. Conclusion

For users who want a quick, simple, and cost effective way to measure noise figure of devices, Rubidium signal generator with its high signal purity is ideal. With the S/N ratio method of noise figure measurement, it is not necessary that the gain of the device under test be high as in the Y factor method. Since a ratio of S/N is being measured, it is not necessary to make accurate power measurements. Measurements can be made efficiently with minimal set up i.e., with a Rubidium signal generator and a spectrum analyzer.

• United States

Anritsu Americas Sales Company

490 Jarvis Drive, Morgan Hill, CA 95037-2809, U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• Canada

Anritsu Electronics Ltd.

Americas Sales and Support

490 Jarvis Drive, Morgan Hill, CA 95037-2809, U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• Brazil

Anritsu Eletronica Ltda.

Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - Sao Paulo - SP, Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

• Mexico

Anritsu Company, S.A. de C.V.

Bvd Miguel de Cervantes Saavedra #169 Piso 1, Col. Granada
Mexico, Ciudad de Mexico, 11520, MEXICO
Phone: +52-55-4169-7104

• United Kingdom

Anritsu EMEA Ltd.

200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

• France

Anritsu S.A.

12 avenue du Québec, Immeuble Goyave,
91140 VILLEBON SUR YVETTE, France
Phone: +33-1-60-92-15-50

• Germany

Anritsu GmbH

Nemetschek Haus, Konrad-Zuse-Platz 1,
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

• Italy

Anritsu S.r.l.

Spaces Eur Arte, Viale dell'Arte 25, 00144 Roma, Italy
Phone: +39-6-509-9711

• Sweden

Anritsu AB

Kistagången 20 B, 2 tr, 164 40 Kista, Sweden
Phone: +46-8-534-707-00

• Finland

Anritsu AB

Technopolis Aviapolis, Teknobulevardi 3-5 (D208.5.),
FI-01530 Vantaa, Finland
Phone: +358-20-741-8100

• Denmark

Anritsu A/S

c/o Regus Winghouse, Ørestads Boulevard 73, 4th floor,
2300 Copenhagen S, Denmark
Phone: +45-7211-2200

• Spain

Anritsu EMEA GmbH

Representation Office in Spain

Calle Manzanares 4, Primera planta, 28005 Madrid, Spain
Phone: +34-91-572-6761

• Austria

Anritsu EMEA GmbH

Am Belvedere 10, A-1100 Vienna, Austria
Phone: +43-(0)1-717-28-710

• United Arab Emirates

Anritsu A/S

Office No. 164, Building 17, Dubai Internet City
P. O. Box - 501901, Dubai, United Arab Emirates
Phone: +971-4-3758479

• India

Anritsu India Private Limited

6th Floor, Indique ETA, No.38/4, Adjacent to EMC2,
Doddanekundi, Outer Ring Road, Bengaluru - 560048, India
Phone: +91-80-6728-1300
Fax: +91-80-6728-1301

• Singapore

Anritsu Pte. Ltd.

1 Jalan Kilang Timor, #07-04/06 Pacific Tech Centre
Singapore 159303
Phone: +65-6282-2400
Fax: +65-6282-2533

• Vietnam

Anritsu Company Limited

16th Floor, Peakview Tower, 36 Hoang Cau Street, O Cho Dua Ward,
Dong Da District, Hanoi, Vietnam
Phone: +84-24-3201-2730

• P.R. China (Shanghai)

Anritsu (China) Co., Ltd.

Room 2701-2705, Tower A, New Caohejing International
Business Center No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

• P.R. China (Hong Kong)

Anritsu Company Ltd.

Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• Japan

Anritsu Corporation

8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-6509
Fax: +81-46-225-8352

• Korea

Anritsu Corporation, Ltd.

8F, A TOWER, 20, Gwacheondaero 7-gil, Gwacheon-si,
Gyeonggi-do, 13840, Republic of Korea
Phone: +82-2-6259-7300
Fax: +82-2-6259-7301

• Australia

Anritsu Pty. Ltd.

Unit 20, 21-35 Ricketts Road, Mount Waverley, Victoria 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• Taiwan

Anritsu Company Inc.

7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

List Revision Date: 20240416



Anritsu utilizes recycled paper and environmentally conscious inks and toner.



© Anritsu All trademarks are registered trademarks of their respective owners. Data subject to change without notice. For the most recent specifications visit: www.anritsu.com

11410-02925, Rev. A Printed in United States 2024-04
©2024 Anritsu Company. All Rights Reserved.