Pulsed Noise Figure measurements

Application Note

Products:

- R&S®FSW
- R&S®FSW-K30

Components used in mobile communication and for radar systems often operate under pulsed or bursted conditions. In a wide range of applications, these devices must be characterized in pulsed condition to get valid measurement data as the devices might change their performance when tested in continuous mode. The noise figure, one of the important parameters for low noise amplifiers, can only be determined for continuous operation with conventional test equipment.

This application note provides information how to perform noise figure measurements under pulsed or bursted conditions with spectrum analyzers and noise sources, and introduce the capabilities of the Rohde & Schwarz FSW signal and spectrum analyzer to perform this measurement.

Application Note
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1 Introduction

Measurements with pulsed stimulus signals are performed for a number of reasons. For instance, in a wide range of applications, devices under test (DUT) must be characterized by using pulsed signals instead of CW signals. Here, the DUT is stimulated either with a pulsed RF signal, or the device itself is put into pulsed conditions by an external or internal control signal. In many of these cases, the test device only operates properly with pulsed stimulus signals. Power amplifiers that would exhibit their desired output power when operated with CW stimulus are one example for this case. In other cases, the supply current drives the amplifier only during the active time of the duty cycle to save power. In this case, the bias voltage for the amplifier is pulsed. Typical examples for this kind of DUT are amplifiers used in cell phones, or amplifiers build into T/R (Transmit/Receive) modules for radar applications. Using conventional measurement equipment, the noise figure as one of the important parameters for an amplifier must be tested in continuous operation.

This application note describes a technique to perform the noise figure measurement for pulsed or bursted amplifiers. The R&S®FSW-K30 noise figure measurement application performs this important measurement with a signal and spectrum analyzer using the Y-factor method. The option uses a gated sweep method, and besides evaluating the noise figure, the option displays the amplitude gain, Y-factor and measurement uncertainty. Key for this technique is a function generator that stimulates the device under test with a pulsed signal, and a spectrum analyzer that captures the signal from the device on the active time. The next sections will give further details.

2 Noise figure measurement

2.1 Fundamentals of Noise figure measurements

The measurement described in this application note uses the Y-factor technique to measure noise figure with a spectrum analyzer. This technique utilizes a characterized broadband noise source that contains two temperature states: A high temperature state T_{on}, with a higher output of noise power, and a low temperature state T_{off}, with reduced noise output. The noise source is connected to the DUT input and the noise power at the output of the DUT is measured for each of the two input noise states.

The required equipment for this task is a spectrum analyzer and a noise source. An integrated noise source control port (28 V supply for the noise source) in the R&S®FSW spectrum analyzer is used to supply the noise source, switching it between its hot and cold states.

There are three primary steps for making the measurement:

- Calibration where the noise figure of the test equipment is measured
- Measurement of the DUT cascaded with the test equipment.
- Calculate of the DUT's parameters by using the cascaded noise figure equation.

Most modern spectrum analyzers offer a personality that will make the noise figure measurement automatically. The R&S®FSW-K30 Noise Figure measurement determines the noise figure and gain of the DUT at each frequency point. The noise source is switched on and off at every point and the average power is measured with the spectrum analyzer. Noise figure and gain are calculated from these measurements.

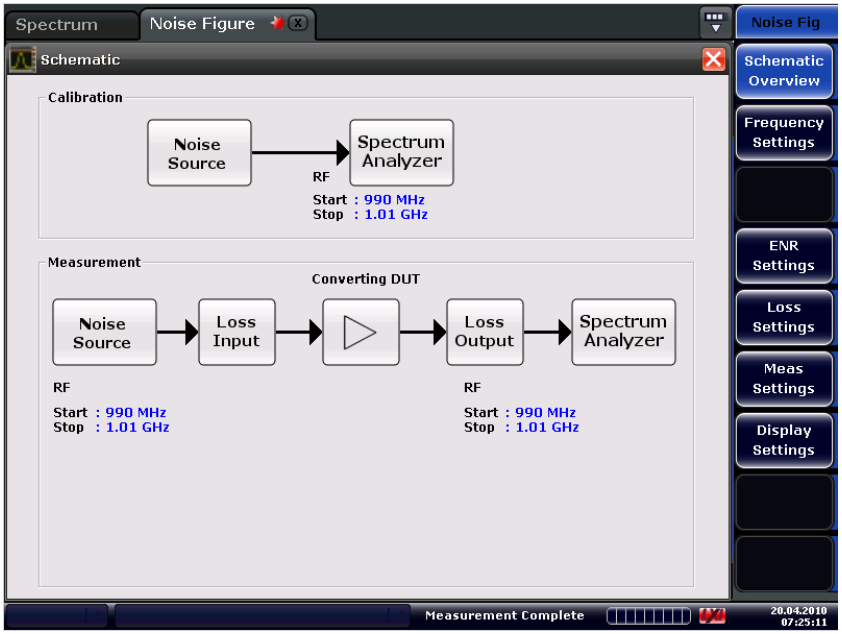

Figure 1: Configuration window for making noise figure measurements

The above figure shows the measurement overview screen in the R&S®FSW-K30 Noise Figure application. The Noise Figure application also factors in any losses at the input and output of the DUT, compensating for items such as matching pads, isolators or attenuators. The impact of the temperature of the noise source on the ENR value is automatically compensated. Measurements on frequency converting devices such as a mixer or a receiver (RF to IF) front end are possible as well.

Further details about the fundamentals of noise figure measurements are explained in the application note 1MA178 available on the Rohde & Schwarz website.

2.2 Pulsed Noise figure measurement

To determine the noise figure of an amplifier in pulsed operation, the measurement of the hot and cold power must only be performed in the active part of the periodic pulse. Because the sampling process should only happen during the on-phase of the pulse, a trigger signal synchronous to the RF pulse is necessary to synchronize the data acquisition of the spectrum analyzer with the on-period of the pulse. The spectrum analyzer is using a gated sweep mode, which means that the data sampling only happens during the active period of the RF burst. Active devices might show settling or ringing effects at the beginning of the pulse. Typically, the user is not interested in the behavior during the settling process, only the stable part of the pulse shall be measured. By selecting a suitable trigger delay, the start of the sampling process can be shifted.

3 Test setup for pulsed Noise figure and gain

The gated sweep mode in the R&S®FSW signal and spectrum analyzer captures the active part of a pulsed signal and omits the time between subsequent pulses. To determine the correct timing, the analyzer needs a corresponding periodic trigger signal connected to one of the trigger input connectors.

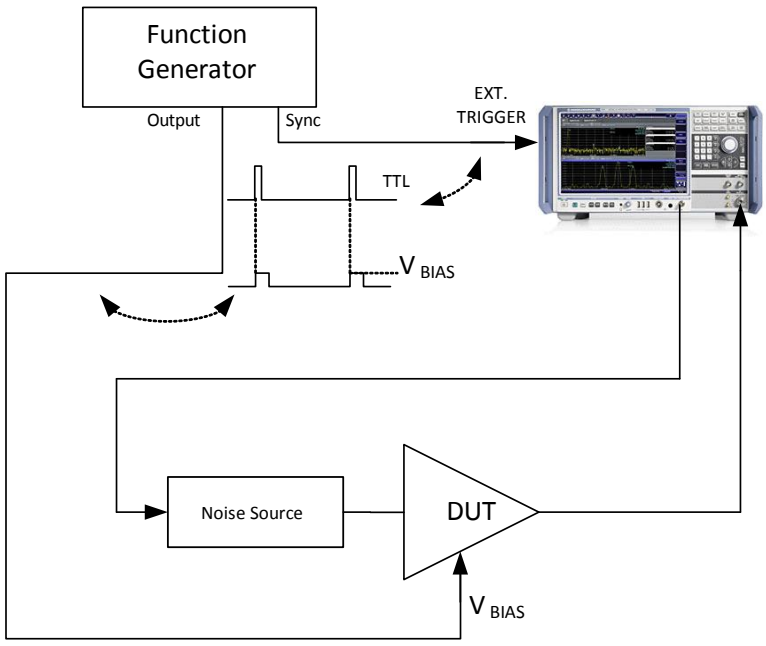

Figure 2: Test setup for pulsed noise figure measurements

Figure 2 shows the test setup for determining the pulsed noise figure: A function generator generates a pulsed signal, the pulse width and repetition period can be set to meet the requirements of the DUT. The pulse amplitude is set depending on the DUT bias requirements to enable correct pulse modulation. The external trigger of the spectrum analyzer is driven by the TTL synch or trigger output from the function generator synchronous to the pulse applied to the amplifier. The noise source is connected to the control output on the spectrum analyzer and the DUT RF input.

In a first step a calibration without the device under test (DUT) is carried out, in order to determine the noise figure and gain of the spectrum analyzer. During the calibration measurement, the noise source is connected directly to R&S®FSW without a DUT. The calibration process does not require the use of the trigger and gated sweep and can be performed independent of the above setup.

In order to determine the pulsed noise figure, the pulsed noise signal is then measured at the output of the DUT. The R&S®FSW-K30 noise figure application allows the setup of the gated sweep mode in the trigger menu.

3.1 Setup for Gated Sweep measurement

To determine the noise figure of an amplifier in pulsed operation, the measurement must be performed in the active part of the periodic pulse. The active measurement part is visible in the Trigger/Gate configuration dialog of the FSW.

When the noise figure gain is configured as required by the DUT and the calibration has been performed, connect the DUT, function generator and noise source as explained in figure 2.

In the noise figure and gain measurement, press the Trigger key on the front panel and open the Trigger/Gate config dialog.

Fig. 3: Trigger and Gate configuration dialog

Perform the following settings in the Trigger/Gate dialog:

- Change the Frequency setting to a value that is within the passband of the DUT (mid band).
- Select a sweep time to a suitable value to be able to identify the active part of the pulsed signal.
- Set “Gated Trigger” to ON and activate the Ext. Trigger port that is connected to the synch pulse signal.

In the preview screen, you see a stable (triggered) preview of the pulsed noise signal at the input of the spectrum analyzer.

- Adjust the trigger settings (slope, level, rising or falling edge) to get a stable preview.
- Now adjust the Gate delay and the Gate length to select the active part of the pulse.

To achieve reproducible results, the sweep time or the number of averages can be adjusted after the trigger configuration in order to get stable results.

4 Measurement results

This application note describes the additional steps required to make a noise figure measurement on pulsed devices using a spectrum analyzer, noises source and the “Y Factor” technique.

This chapter provides a short comparison of test results for noise figure measurement on a pulsed amplifier. The DUT in this test is an amplifier in a radar T/R module that is pulsed to switch between transmit and receive mode. While the amplifier is always in pulsed mode, the Noise figure measurements are performed in continuous mode and using the gated sweep for pulsed mode.

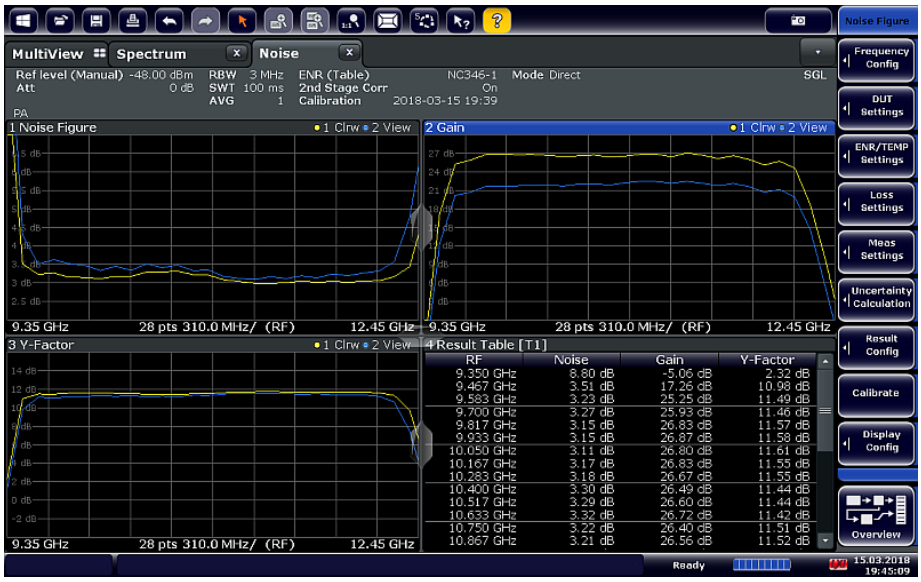

Fig. 4: Test result of pulsed amplifier (yellow: gated sweep, blue: continuous sweep)

The above plot shows the noise figure and gain results of the pulsed amplifier. In this test case the amplifier is always in pulsed mode (required by design). The measurement was performed with the R&S®FSW-K30 Noise figure application.

In the first test (blue trace) the measurement was done in the traditional way with continuous sweep, while the DUT was in pulsed mode. While the measurement data is captured, the output signal is interrupted due to the pulse modulation. This leads to a reduced power reading for the hot and cold power measurement. The amount of error depends on the duty cycle of the pulse modulation.

In the next step (yellow trace) the FSW was configured for gated sweep and connected to the trigger signal from the amplifier. In this case the data is only captured while the signal is active.

The gain measurement shows much higher gain, while the noise figure is much lower. It was verified that these measurements results agree with the real performance of the amplifier when it is operated in CW mode.

5 Conclusion

A Rohde&Schwarz FSW signal and spectrum analyzer equipped with the R&S®FSx-K30 option forms the basis of a solution to accurately measure noise figure and gain using the Y-factor method. The integrated uncertainty calculator is a powerful tool that takes into account all setup parameters such as VSWR, ENR uncertainty and additional attenuators and filters for error calculations

With the new implementation of the gated sweep mode, the functionality of the noise figure and gain measurement is extended to cover measurements on pulsed devices, like used in many communication and radar systems.

6 Literature

[1] R&S®FSW Signal and Spectrum Analyzer – Product Brochure

[2] R&S®FSW Signal and Spectrum Analyzer – Data Sheet

[3] R&S®Fxx-K30 Noise Figure Measurement – Data Sheet

[3] Application Note 1MA178, The Y Factor Technique for Noise Figure Measurements

7 Ordering Information

R&S FSW8	Signal- and Spectrum analyzer 2 Hz to 8 GHz	1312.8000.08
R&S FSW13	Signal- and Spectrum analyzer 2 Hz to 13.6 GHz	1312.8000.13
R&S FSW26	Signal- and Spectrum analyzer 2 Hz to 26.5 GHz	1312.8000.26
R&S FSW43	Signal- and Spectrum analyzer 2 Hz to 43.5 GHz	1312.8000.43
R&S FSW50	Signal- and Spectrum analyzer 2 Hz to 50 GHz	1312.8000.50
R&S FSW67	Signal- and Spectrum analyzer 2 Hz to 67 GHz	1312.8000.67
R&S FSW85	Signal- and Spectrum analyzer 2 Hz to 85 GHz	1312.8000.85
R&S®FSW-K30	Noise Figure Measurement Application	1313.1380.02

The herein described function “Gated Sweep” for pulsed noise figure measurements is available in the R&S®FSW firmware version 2.90 and above.

Rohde & Schwarz

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Sustainable product design

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