NoiseTech Microwaves Ltd.

Product Manual for Impedance Generators for “Cold” Noise-Parameter Measurements with C-IG0160CT at Cryogenic Temperature

Rev. 2 – November 24, 2020

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2. Introduction

NoiseTech Microwave ltd. (NoiseTech) has developed cryogenic impedance generators (C-IGs) for “cold” noise-parameter measurements.

Together with a proprietary impedance generation and a data processing algorithm [1], these compact impedance generators allow for fast and accurate measurement of noise parameters [1] for a large number of frequencies.

The small size and fully electronic design permit noise-parameter measurements of packaged and on-wafer devices extending to low frequencies. On-board memory stores calibration data. A bias-T provides means for biasing devices under test.

The C-IG consists of two parts: a room-temperature controller and a cryogenic temperature RF part. The two parts are connected with three low-frequency control lines. Additional options include a temperature sensor and a cold attenutor or a cold termination option.

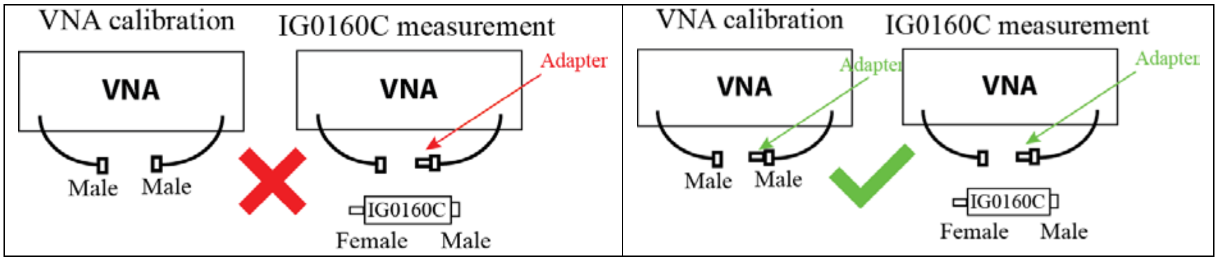
Fig. 1: Photograph of a C-IG0160CT Impedance Generator.

This document describes the procedure for using impedance generators developed for the “cold” noise parameter extraction method.

3. Dos and Don’ts

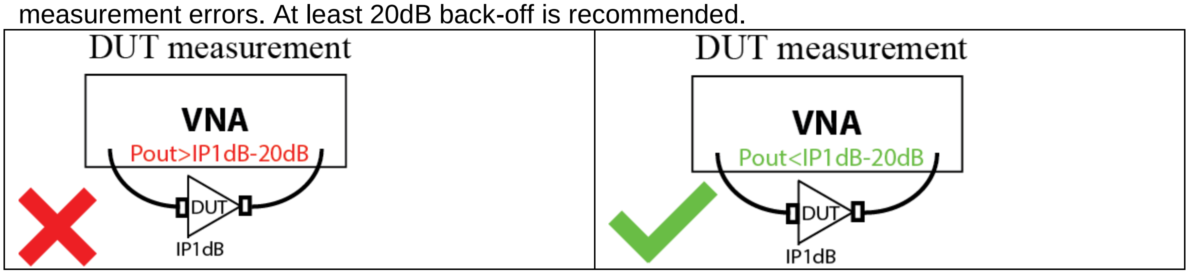
3.1 Use of adapters

When measuring S-parameters, calibration and measurement planes of the vector network analyzer (VNA) should be the same, i.e. if you need to use an adapter then for accurate measurements the network analyzer should be recalibrated to the adapter output plane.



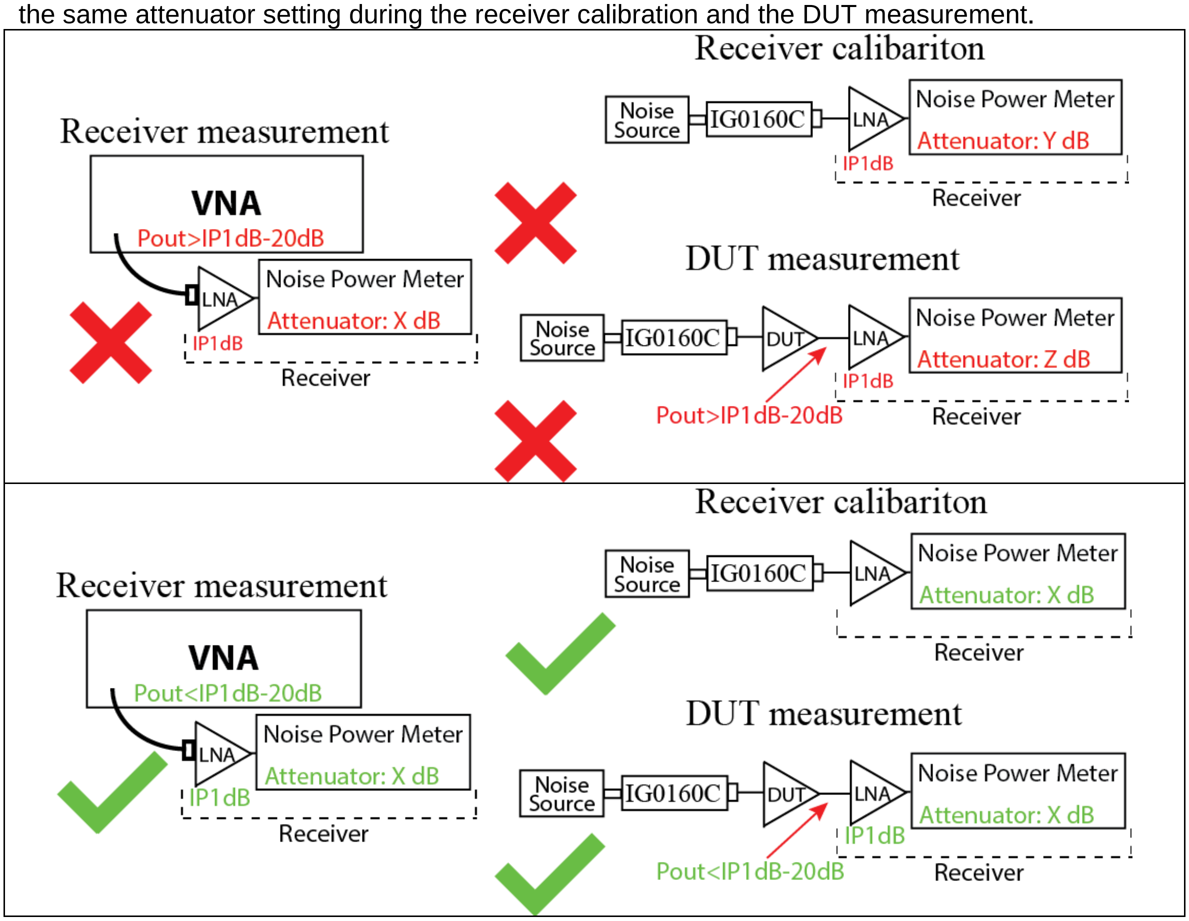
3.2 Gain saturation

Avoid saturating the DUT during its S-parameter measurements as that will result in measurement errors. At least 20dB back-off is recommended.



3.3 Receiver saturation and automatic attenuator control

Similar to the DUT measurements, avoid saturating receiver during calibration and the DUT measurements. Some receivers have automatic attenuation control. Care must be taken to have the same attenuator setting during the receiver calibration and the DUT measurement.



4. Impedance generator installation, functionality, and control

4.1 Installation

When first connected to a host computer via a USB 2.0, C-IG0160C is a composite device and appears as a mass storage device and as a COM device. For the COM device to work properly, appropriate drivers must be installed. Windows 10 is capable of installing these drivers automatically. For Windows 8 and Windows 7 computers, driver installation is performed with the following steps:

- Navigate to: Control Panel -> Device Manager
- Locate “NoiseTech Microwaves Ltd” device under “Other devices” and right click on it to select “Update Driver Software”
- Select “Browse my computer for driver software”
- Browse to as USB device labelled “IG0160C” and select an appropriate subdirector in directory “COM Drivers” and click “Next”
- A “Windows Security” window might pop-up, click on “Install this driver software anyway”
- The following window should inform of successful driver installation. Close this window.
- NoiseTech Microwave’s C-IG0160C should now appear as one of COM devices under “Ports (COM & LPT)” in the “Device Manager”. Record the COM port number for future use.
- Close “Device Manager” and “Control Panel”.
- Installation is complete.

4.2 Functionality

The impedance generator is powered and controlled via a USB connection to a host computer. When connected to the computer and the drivers are installed, C-IG0160C appears as a COM port in the windows Device Manager. SCPI commands can be sent to control and configure the device. The following is a list of commands, which control the device:

setStateA: sets the C-IG into the thru state “A”

setStateB: set C-IG to impedance state “B”.

setStateC: set C-IG to impedance state “C”.

setStateD: set C-IG to impedance state “D”.

getIGtemperature: read C-IG temperature and output result in degrees Kelvin and a hexadecimal ADC code for troubleshooting.

getNStemperature: read noise source temperature and output result in degrees Centigrade and a hexadecimal ADC code for troubleshooting. If a noise source is not connected, the resultant temperature will be a large negative value, typically -61.45°C.

setAttenuatorOn: turn on the cold attenuator (or cold termination).

setAttenuatorOFF: turn off the cold attenuator (or cold termination).

noiseSourceOn: Enables USB noise source (NoiseTech Microwave Devices only)

noiseSourceOff: Disabled USB noise source (NoiseTech Microwave Devices only)

setUpdateMode: Sets device in update mode. Requires hard reset by power cycling unit.

4.3 Control

This section shows examples of using C-IG0160C(T) device.

4.3.1 Putty

The quickest way to communicate with the device is by using Putty, which can be downloaded from http://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html.

After Putty is downloaded and installed, it should be configured as follows:

- Click on “Serial” for Connection type
- Set “Serial line” to the COM port number (e.g., COM16) associated with C-IG0160C in “Device Manager”
- Baud rate: 115200
- An example of the Putty configuration is shown in Fig. 2.

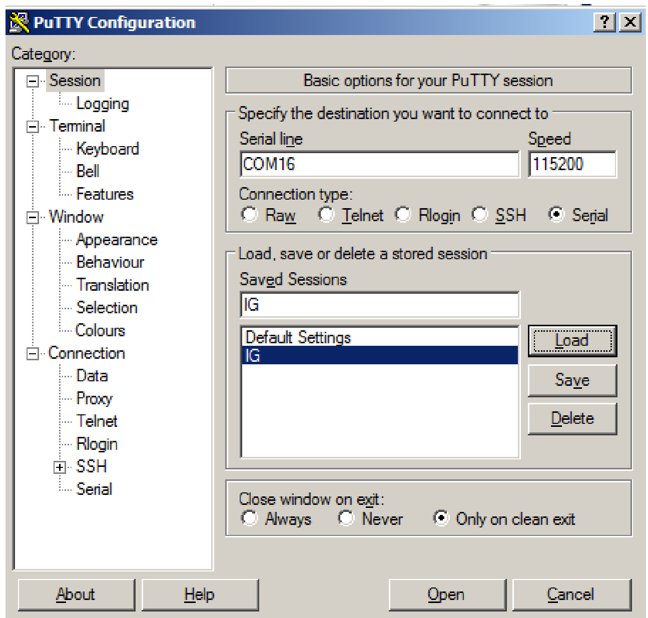


Fig. 2. Putty serial connection configuration.

- Navigate to “Terminal” category.
- Select: “auto wrap mode initially on”, “implicit CR in every LF”, “implicit LF in every CR”, and “Local echo: Force On”. See Fig. 3 for example.

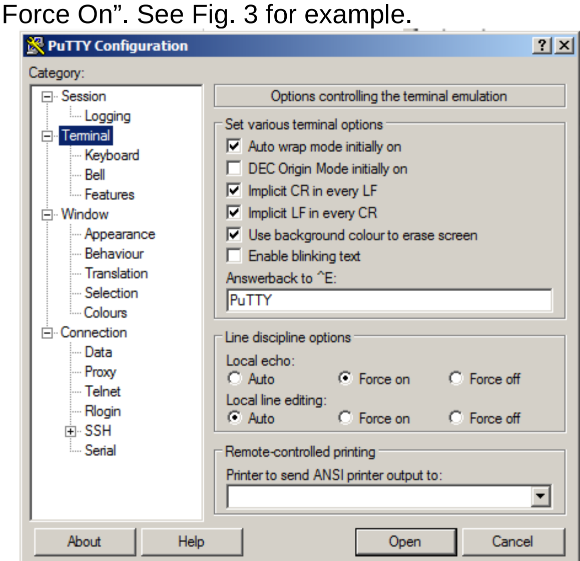


Fig. 3. Putty "Terminal" category configuration.

- Click “Open” to open the C-IG0160C port in Putty.
- This opens a terminal window.
- Typing C-IG0160C commands in the terminal window controls the device.

4.3.2 Matlab

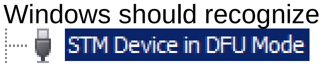
Matlab can be used for communicating with C-IG0160C. Since other instruments can be also controlled through Matlab, an automated measurement system can be developed to perform noise parameter measurements. Contact NoiseTech Microwave for advice and assistance with developing such a system.

The following shows an example code for controlling C-IG0160C.

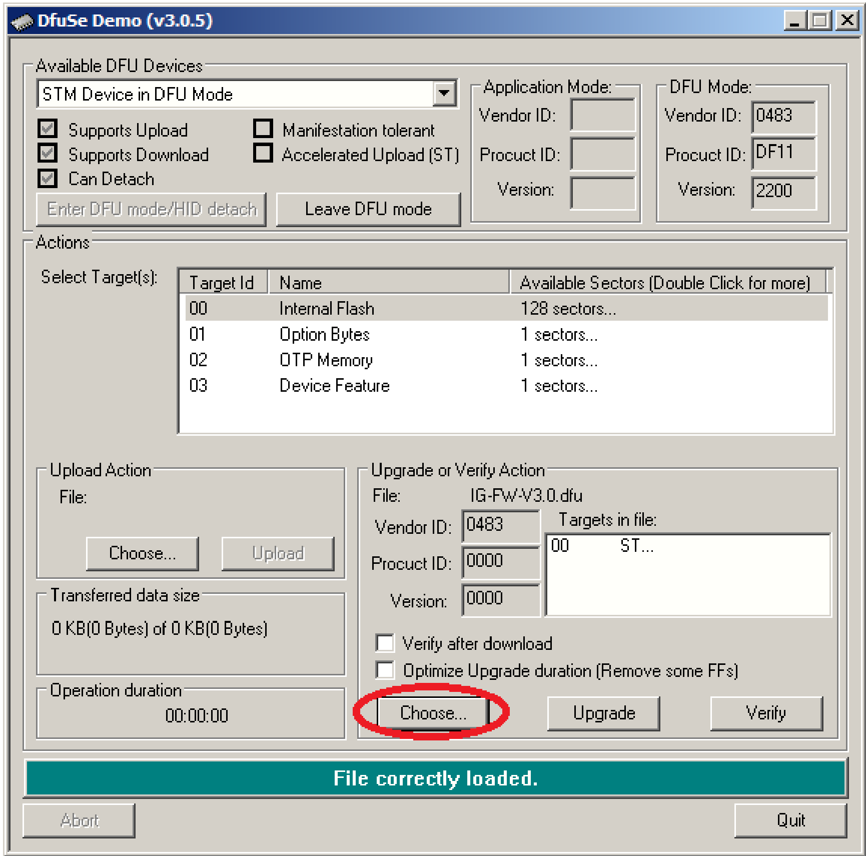
```
% Replace this COM port number in windows "Device Manager"
COM_port = 'COM16';
```

```
% Set Impedance Generator to State A (THRU)
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'setStateA');
fgets(s1)     % Optional command to check on C-IG0160C status.
fclose(s1);

% Set Impedance Generator to State B (THRU)
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'setStateB');
fgets(s1)     % Optional command to check on C-IG0160C status.
fclose(s1);

% Set Impedance Generator to State C (THRU)
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'setStateC');
fgets(s1)     % Optional command to check on C-IG0160C status.
fclose(s1);

% Set Impedance Generator to State D (THRU)
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'setStateD');
fgets(s1)     % Optional command to check on C-IG0160C status.
fclose(s1);

% Set cold attenuator (or cold termination) ON
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'setAttenuatorON');
fgets(s1)     % Optional command to check on C-IG0160C status.
fclose(s1);

% Set cold attenuator (or cold termination) OFF
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'setAttenuatorOFF');
fgets(s1)     % Optional command to check on C-IG0160C status.
fclose(s1);

% Get Impedance generator Temperature (Kelvin)
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'getIGtemperature');
IGtemperatureString = fgets(s1);
IGtemperatureString_value = strsplit(IGtemperatureString,' ');
IGtemperature = str2num(IGtemperatureString_value{3});
fclose(s1);
disp(['IG0160C temperature is: ',num2str(IGtemperature),'K'])

% Get Noise Source generator Temperature (Celsius)(if attached)
s1 = serial(COM_port,'BaudRate',115200);
fopen(s1);
fprintf(s1,'getNStemperature');
NStemperatureString = fgets(s1);
NStemperatureString_value = strsplit(NStemperatureString,',');
NStemperature = str2num(NStemperatureString_value{2});
fclose(s1);
disp(['Noise source temperature is: ',num2str(NStemperature),'C'])
```

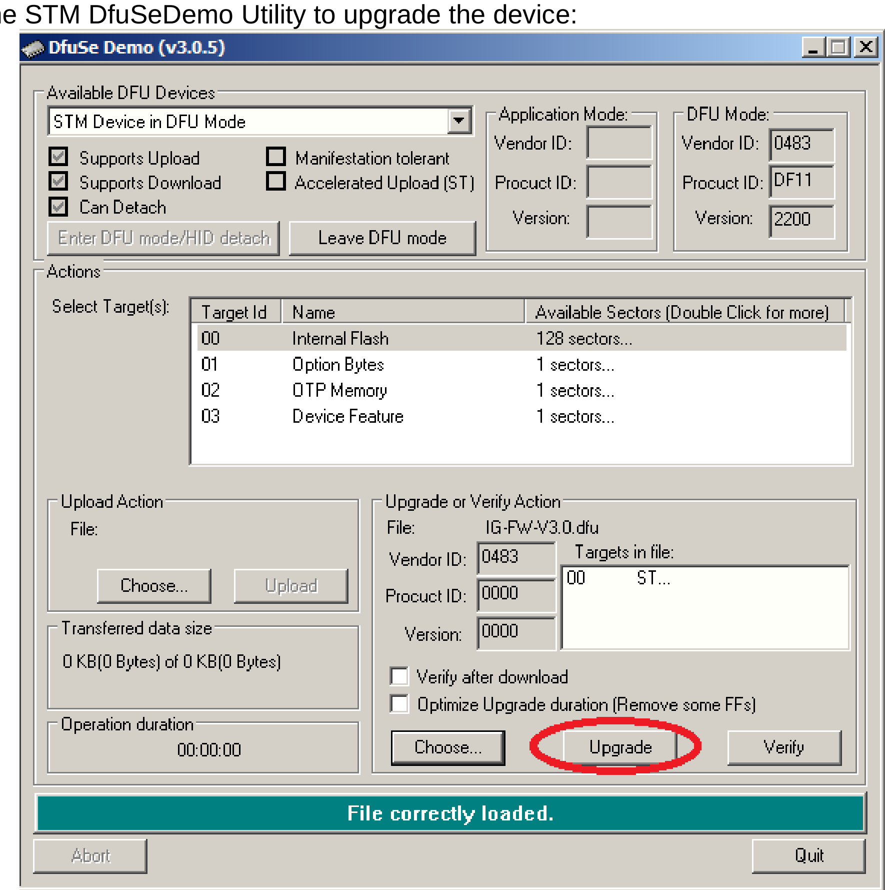
4.4 Firmware Update

1. Connect to receiver through Putty (4.3.1).
2. Issue command “setUpdateMode”.
3. Power cycle the unit (disconnect power and reconnect)
4. Windows should recognize the USB device as an STM device in bootloader mode


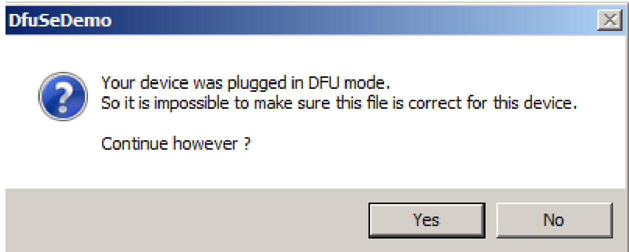
5. Use the STM DfuSeDemo Utility to upload the desired firmware (only .dfu files supported):



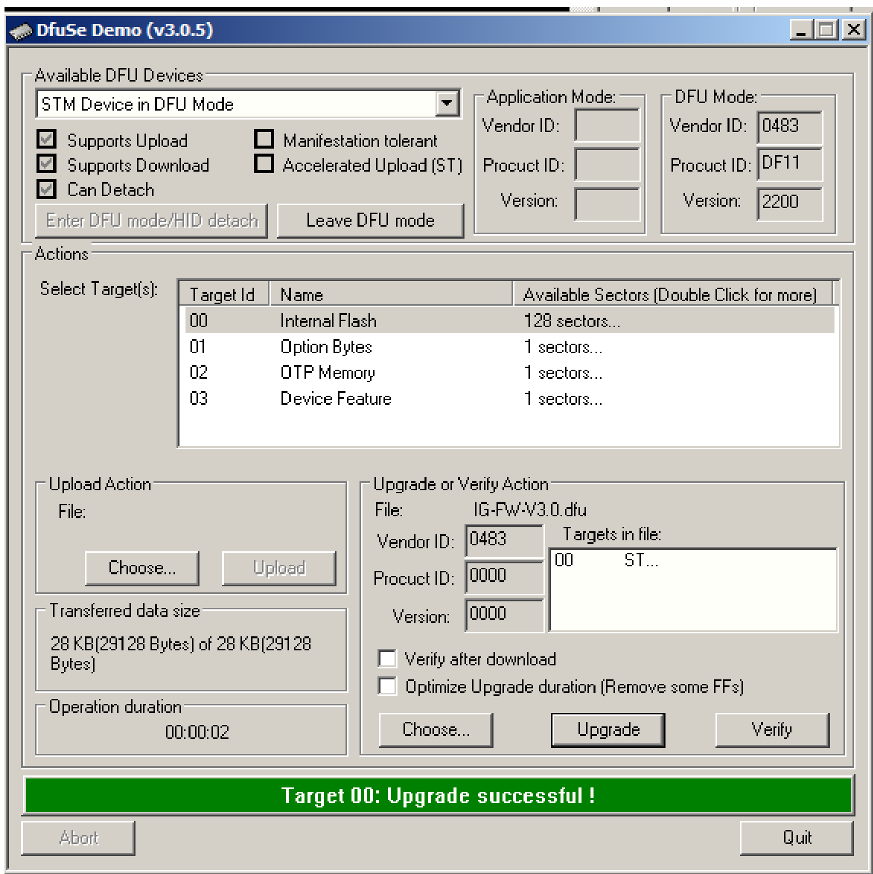
6. Use the STM DfuSeDemo Utility to upgrade the device:



7. Select Yes in the pop-up window:



8. If successful you should see the follow screen:



5. Noise parameter measurement procedure

The following procedure talks mostly about a calibration method. It should be understood that a device-under-test (DUT) measurement follows exactly the same procedure during which the DUT is placed at the calibration plane and the DUT noise parameters are corrected using the calibration data.

5.1 Required equipment

Noise parameters fully describe noise performance of a linear two-port device. To conduct noise parameter measurements the following equipment is required:

- NoiseTech’s C-IG0160C impedance generator (C-IG)
- Vector network analyzer (VNA) with an appropriate calibration kit
- Noise power meter (aka “receiver”). This can include a Noise Figure Analyzer (NFA) or a spectrum analyzer (SA) or a VNA, which is able to measure noise power, such as Keysight’s PNA-X or Rohde and Schwarz ZVA, both with the noise figure measurement

option. *Note: ZVA does not need a noise source and therefore the procedure described below is slightly different. Contact NoiseTech for a ZVA-specific measurement procedure.*

- Noise source (NS). An NS is used to measure the gain of the receiver. In case of a ZVA, NS is not required but an external power meter is used instead to calibrate the ZVA gain.
- Low noise amplifier (LNA) may be used at the input to the receiver to reduce receiver noise and improve measurement uncertainty.
- Appropriate RF cables
- A computer connected to the C-IG via a USB port and running software that controls the C-IG.

5.2 Cryogenic Measurement process

Note: Example Matlab code is supplied with the impedance generator

A block diagram of the measurement setup is shown in Fig. 4.

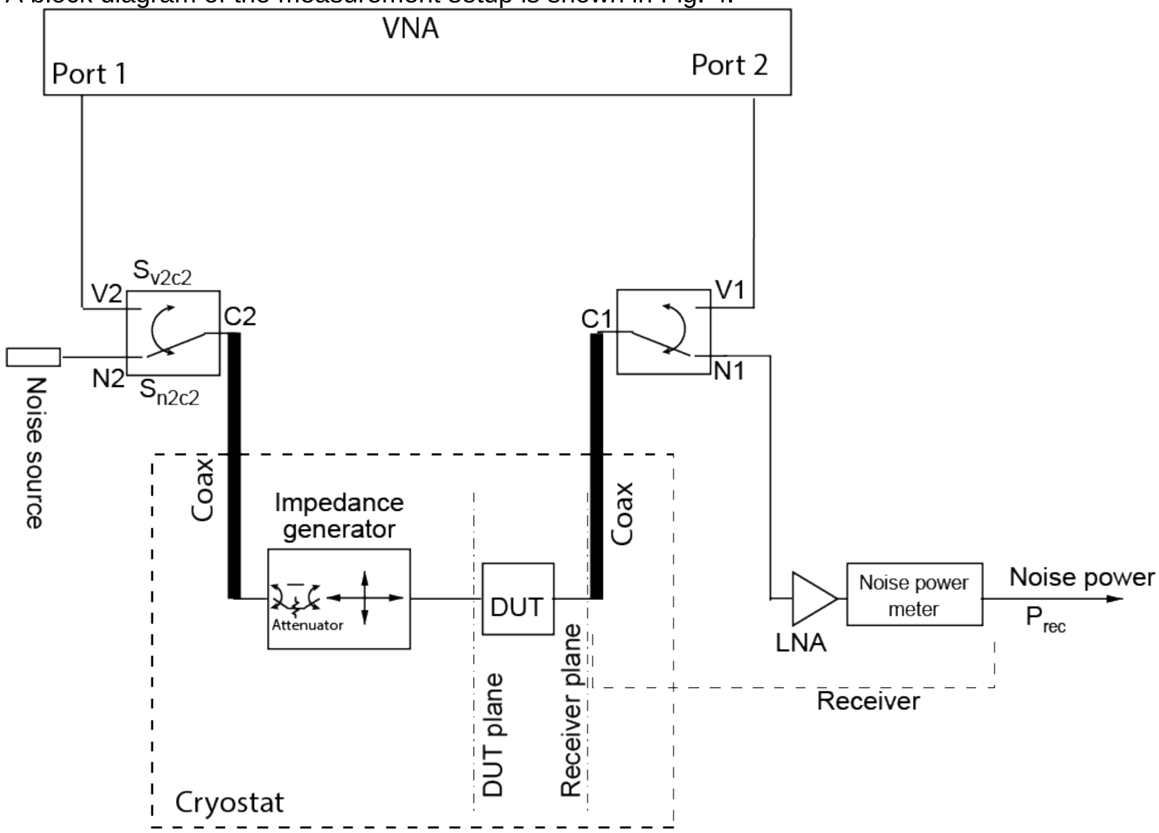


Fig. 4. Block diagram of the noise-parameter measurement system.

The following is a general procedure for calibrating the receiver by measuring its noise parameter. All steps are performed over the required frequency range. It is suggested to perform a large number of measurements for adequate averaging, especially for noise-power measurements. (*If a VNA is used as a receiver, please contact NoiseTech for an updated procedure.)*

<u>NoiseTech’s C-SW00160 Dual SPDT switch matrix is shown in Fig. 4 to speed up the measurement procedure. For more information and for a different measurement procedure please contact NoiseTech or download C-SW00160 Manual from NoiseTechMicrowaves.com.</u>

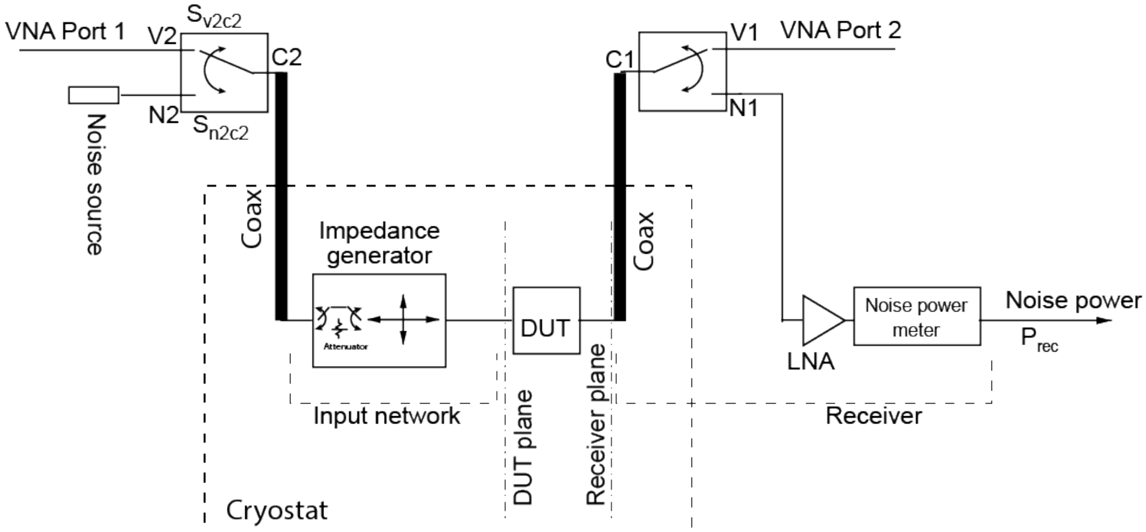
<u>“Cold-attenuator” measurement setup is shown in Fig. 4. Other measurement options are available. Some measurements can be performed at room temperature. Please contact NoiseTech for more information.</u>

5.2.1 Before measurement starts:

- It is suggested to make the DUT have a Female input port and Male output port by adding an adapter at the DUT output. It is not necessary to have all DUTs like that, but for demonstration purposes, this makes steps more straightforward. We can later show what to do when DUT has other ports.
- Setup VNA cables so that Port 1 has a Male port and Port 2 has a Female Port.
- Setup Switch 1 to have C1 as Female, V1 as Male, N1 and either Male or Female
- Setup Switch 2 to have C2 as Male, N1 as Female, and V1 as Female port
- Input Coax transition cable: the room temperature port is Female, the cryogenic port Male
- Output Coax transition cable: the room temperature port is Male, the cryogenic port Female
- Setup a “Measurements” directory where the measured data is placed. This directory is expected in the last step of the process. If another directory is used, modify the last script to grab the data from the correct directory.

5.2.2 Cryogenic noise-parameter measurement

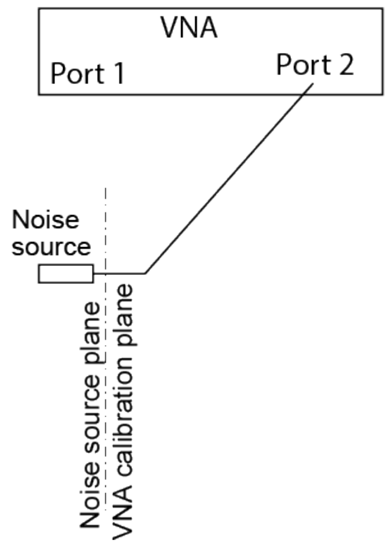
For cryogenic measurements, the switch can be placed either in the cryostat or external to the cryostat. NoiseTech switches can be used in either location, but it is often preferred to have the switch placed outside the cryostat as that configuration
- reduces the number of coaxial cables entering the cryostat
- enables easier changes to the setup without the need to warm up
- reduces the thermal load on the cryostat
- reduces the required size of the cryostat.
The measurement system that uses a cold-attenuator measurement method is depicted below



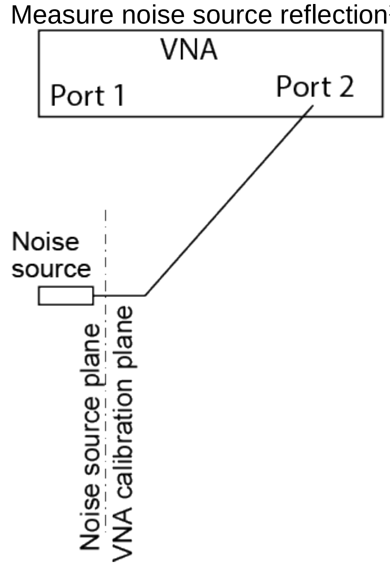
The following describes the calibration and measurement steps.
Note that for all steps, the VNA is calibrated once with the calibration plane being at the ends of the coax cables connected to the VNA.

5.2.2.1 Calibration

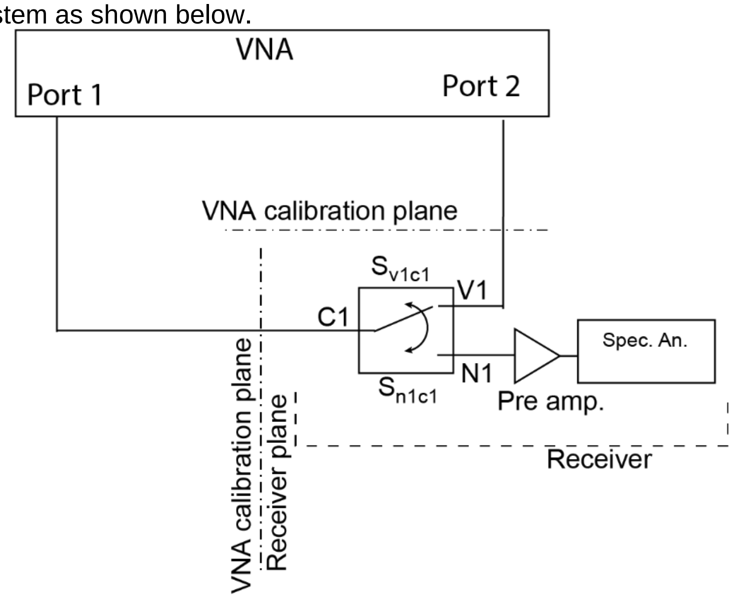
Step #1: Measure S-parameters of “Coax” cables
Step #2: Measure noise source reflection[1] coefficient when the noise source is OFF. Connect the system as shown below.



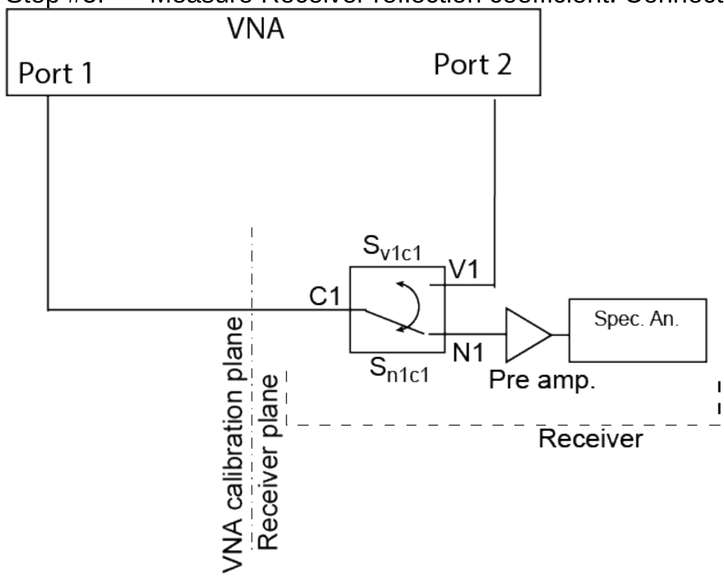
Step #3: Measure noise source reflection[1] coefficient when the noise source is ON.



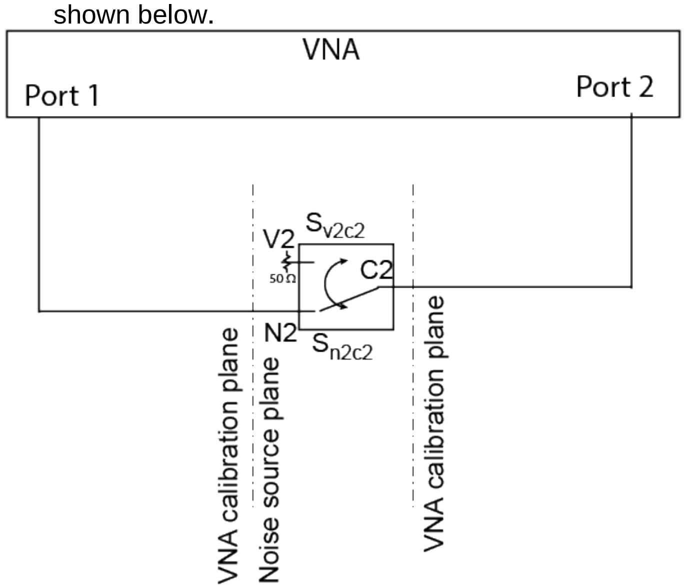
Step #4: Measure Switch v1c1 path. If the switch is not used, this step is skipped. Connect the system as shown below.



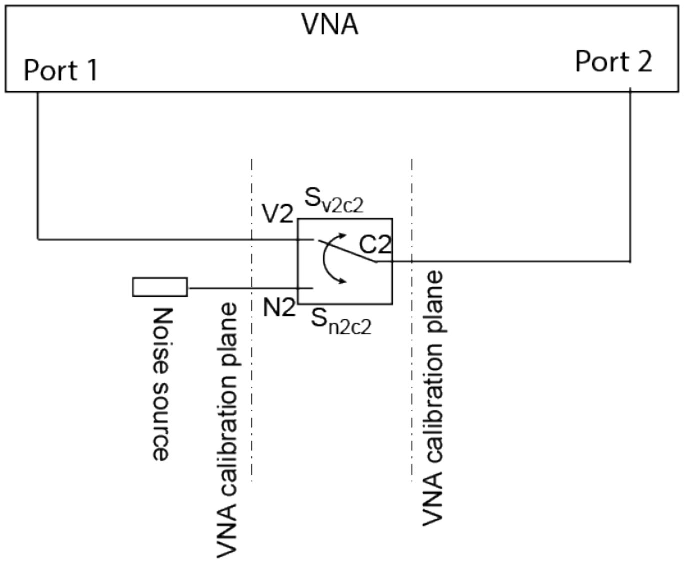
Step #5: Measure Receiver reflection coefficient. Connect the system as shown below.



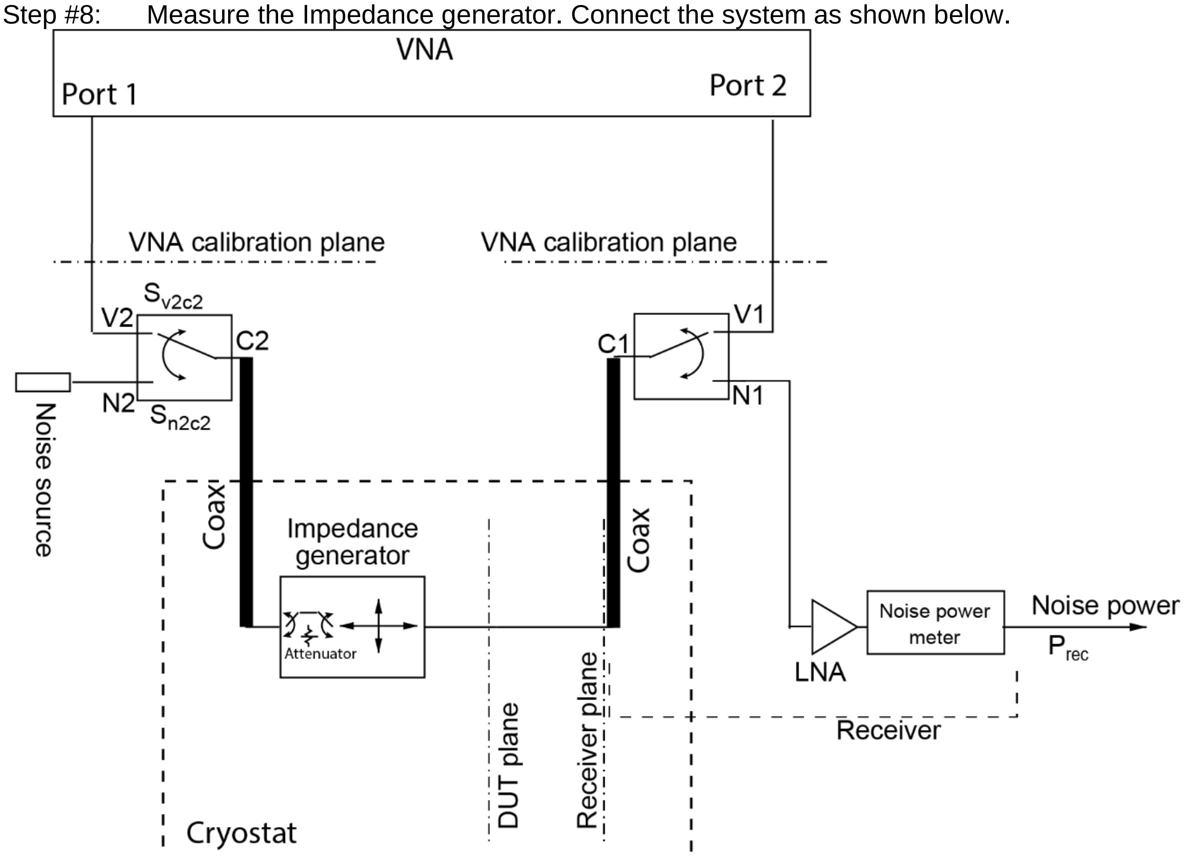
Step #6: Measure Noise Path of the input Switch in state n2c2. Connect the system as shown below.



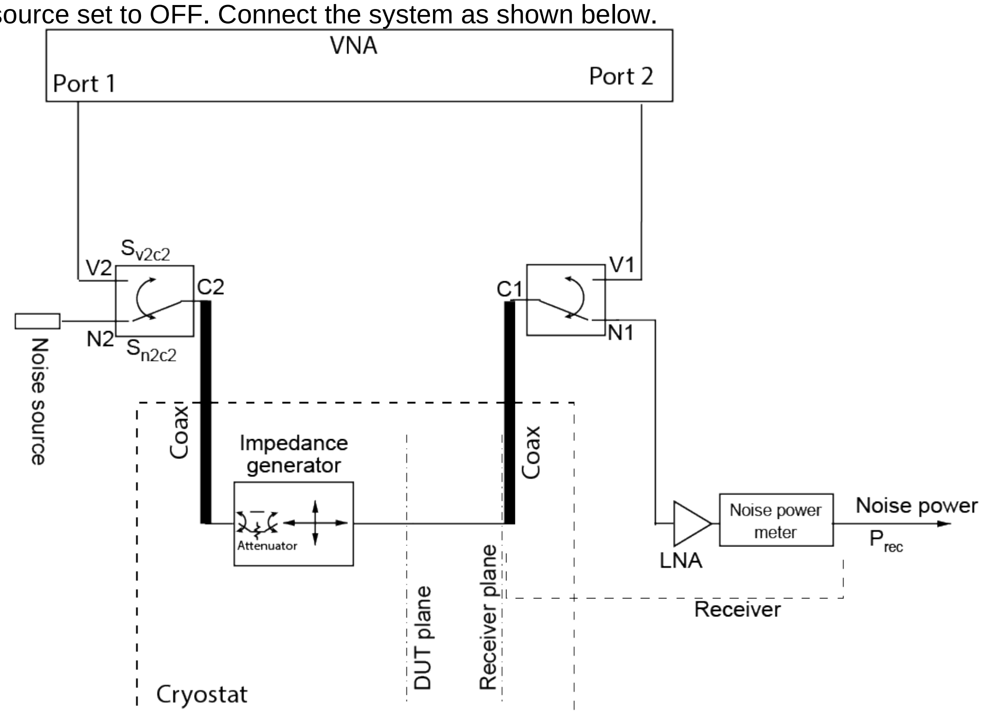
Step #7: Measure VNA Path of the input Switch in state v2c2. Connect the system as shown below.



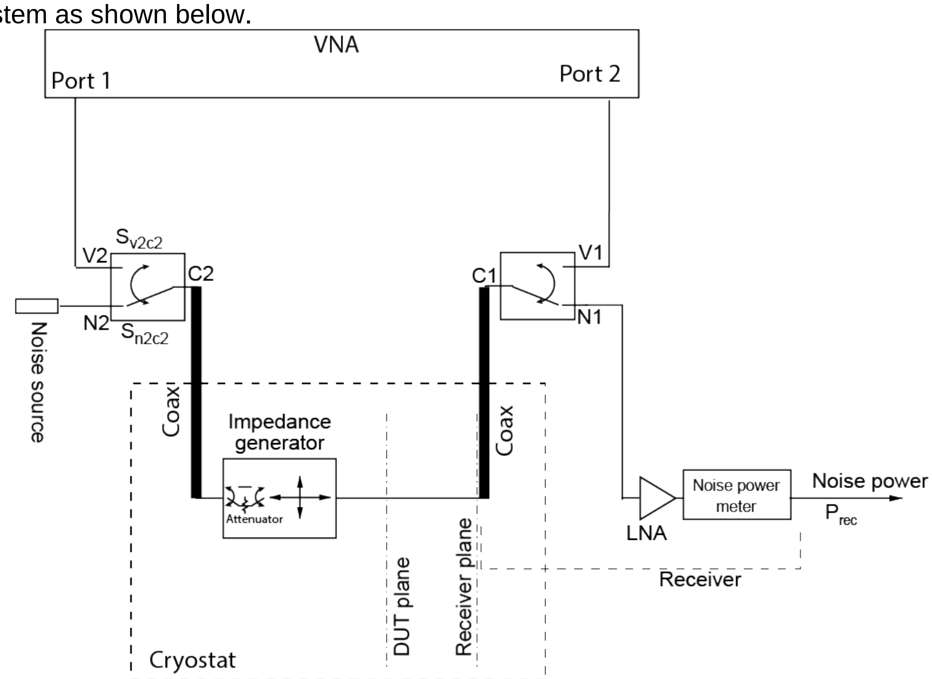
Step #8: Measure the Impedance generator. Connect the system as shown below.



Step #9: Measure noise power and switch and IG temperatures with the Receiver with the noise source set to OFF. Connect the system as shown below.

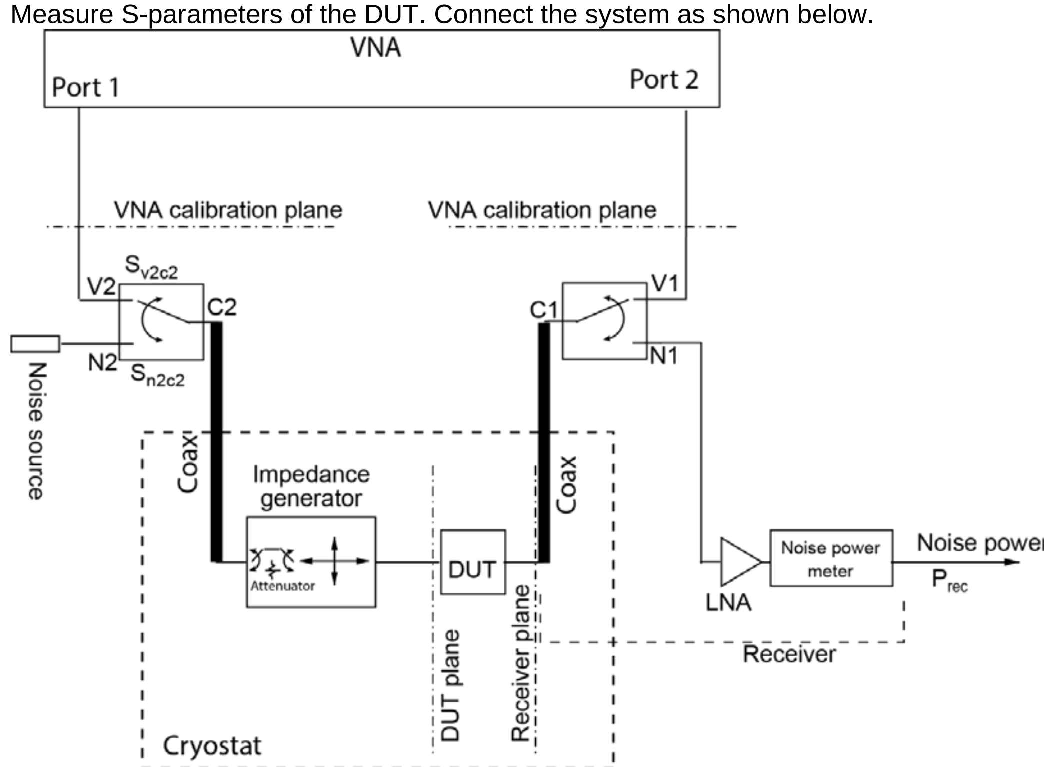


Step #10: Measure noise power with the Receiver with the noise source set to ON. Connect the system as shown below.

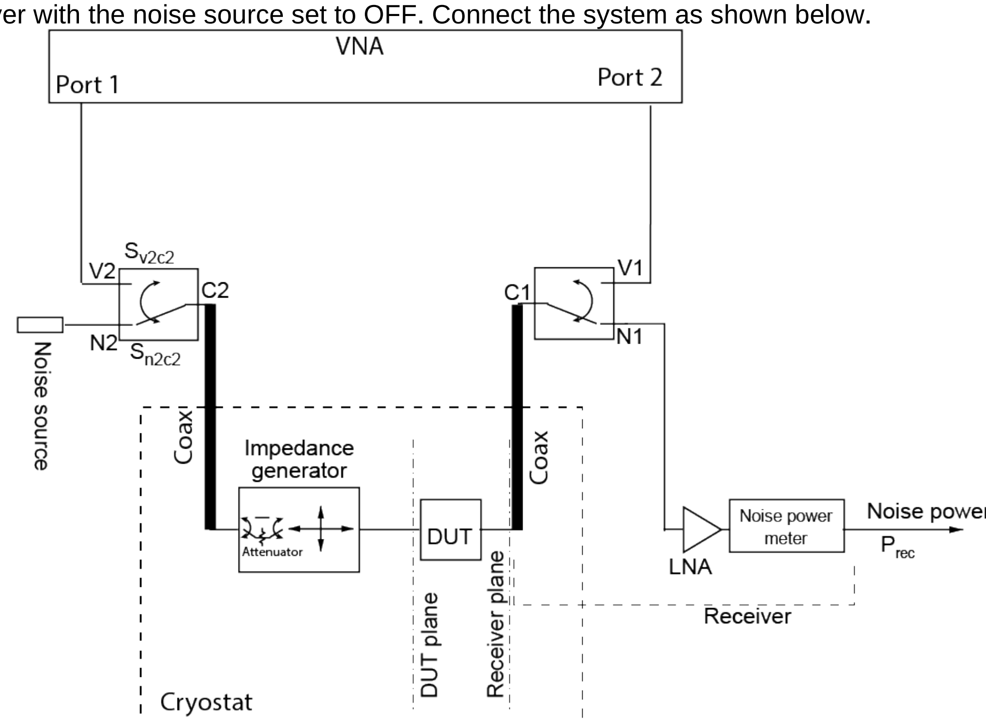


5.2.2.2 DUT Measurement

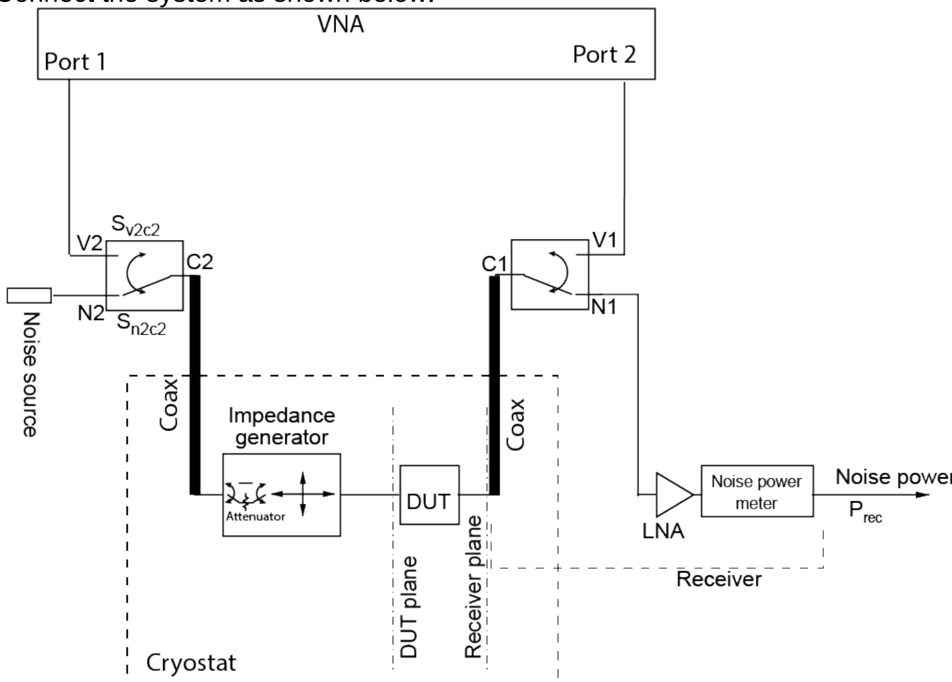
Step #11: Measure S-parameters of the DUT. Connect the system as shown below.



Step #12: Measure the physical temperatures and noise power of the DUT with the Receiver with the noise source set to OFF. Connect the system as shown below.



Step #13: Measure the noise power of the DUT with the Receiver with the noise source set to ON. Connect the system as shown below.



Step #14: Calculate noise parameters of the DUT.
Step #15: Repeat steps 12 to 14 to measure different DUTs.

[1] Because the attenuator is large and the noise source reflection coefficient is typically very low, the noise source reflection coefficients are expected to be very similar and very small. In this case Step #2 and Step #3 can be omitted by assigning reflection coefficients of 0.

6. References

[1] "System and method for measuring wideband noise parameters using an impedance generator," U.S. Patent Application No. 62/364,458

[2] M. Himmelfarb and L. Belostotski, "On Impedance-Pattern Selection for Noise Parameter Measurement," *IEEE Transactions on Microwave Theory and Techniques*, vol. 64, no. 1, pp. 258-270, January 2016.

[3] L. Belostotski and J. W. Haslett, "Evaluation of Tuner-Based Noise-Parameter Extraction Methods for Very Low Noise Amplifiers," *IEEE Transactions on Microwave Theory and Techniques*, vol. 58, no. 1, pp. 236-250, Jan. 2010.

7. Revision notes

Nov 24, 2020: Modified measurement steps process by explicitly showing measurement configuration.
Nov 24, 2020: Added attenuator on and off commands and updated IG temperature measurement code example.