



Noise Figure Measurement Setup with VDI Noise Source and SAX Modules



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Introduction

This document provides information on how to make millimeter-wave Noise Figure and Gain measurements using a VDI Spectrum Analyzer Extension (SAX) Module and Noise Source.

For input power limitations, safety guidelines, general operating practices and recommendations for all equipment used in this measurement solution, please refer to the appropriate user manuals and/or datasheets.

This document is accurate as of June 1, 2021.

Equipment Requirements

The following equipment will be needed for this measurement solution:

- VDI Noise Source (WRX.xNS)
- VDI Spectrum Analyzer Extension Module (WRX.xSAX in Configuration C)
- Keysight Spectrum Analyzer (N90x0B with N9069M0E Noise Figure Measurement Application Option)
- Keysight Signal Generator (MXG or similar)*
- PreAmplifier**
- Waveguide Isolator+
- DUT (e.g. LNA Low Noise Amplifier)
- Low Frequency Noise Source (for Mixer / Down-Converter measurements)

*Other signal generators may be used, but will need to communicate and be controlled by the Keysight Spectrum Analyzer. The signal generator must be able to drive the LO Input Port of the VDI SAX Module across the required frequency range and power level.

**Connected between the IF Output Port of the SAX and the RF Input Port of the Spectrum Analyzer. This may not be required for certain applications.

†VDI recommends the use of a waveguide isolator between the DUT output and the RF Input Port of VDI SAX Module to improve impedance match and reduce possible standing waves.



Typical block diagram for the Noise Figure Measurement setup is shown below to measure an amplifier.





Typical block diagram for the Noise Figure Measurement setup is shown below to measure an amplifier.



10 MHz Reference



Generating ENR File Compatible with Spectrum Analyzer

ENR vs. Frequency data values can be entered manually using the "Edit Meas Table" menu item described in the "Verify ENR Table" section, later in this document.

Alternatively, you can upload a .csv file with ENR vs. Frequency data values (see example below for ENR file format). VDI Noise Sources will have an appropriately formatted ENR file included in the shipped documentation.

Sample ENR File Format

Comments shown in red. Red text is not included on the .csv file.

```
[Filetype ENR],
[Version A.27.05], Instrument (Spectrum Analyzer) Software Revision Number*
[Serialnumber b1-05], Noise Source Serial Number
[Model vdi6.5ns_r1], Noise Source Model Number
1.09995E+11,11.02815447
1.10995E+11,11.17974241
1.11995E+11,11.01899908
1.12995E+11,11.08859996
1.13995E+11,10.90244843
1.14995E+11,11.08731449
...
```

*Software Revision Number on the ENR files provided by VDI will default to A.27.05. Software Revision Number does not need to be modified to load onto user's Keysight Spectrum Analyzer.



Spectrum Analyzer Setup (Amp DUT)

Verify Hardware Configuration

-

Verify hardware connections, as shown on Page 4 of this document.

Software Configuration and Setup

- Press [Mode/Meas] soft key



- Default Mode should be set to 'Spectrum Analyzer'
- Set to 'Noise Figure'
- Press 'OK'





- After pressing 'OK', you should see the following screen (showing Noise Figure and Gain plots)



- Press [Meas Setup] soft key



- Click on 'Ext LO Setup'





- Click on 'LO Select'

	Ext LC) Setup	5	2	?	Close
		Sys Downconverter LO				
Ext LO Control	On Off	Ext LO Control Off				
DUT LO Setup	\rightarrow	Sys Downconv LO Set	< qu			
DUT LO		None				
Sys Downconv LO	Agilent Technologies					
	LO Select					

- Identify the correct Signal Generator connected to the Spectrum Analyzer (via USB) and click 'Select Highlighted Source As Sys Downconverter LO' then click 'Ext LO Setup' in the upper left hand corner of the window.



- Click on 'Sys Downconv LO Setup'

	Ext LO Setup	
	Sys Downconverter LO	
Ext LO Control	Ext LO Control Off	
DUT LO Setup	Sys Downconv LO Setup	
DUT LO	None	
Sys Downconv LO Agilent Teo	chnologies USB0::2391::7937::MY59101060::0::INSTR	
103	elect	



- Enter appropriate settings for the LO Signal Generator (See Example below)
- Click 'Close' when complete

Ext LO Setup		Sys [Downconv LO Setup	5	? Close
O Settings		LO Commands			
LO Power	4.00 dBm	Command Set	SCPI Custom		
ettling Time	100 ms	Power Prefix	POW		
Aultiplier Jumerator	1	Power Suffix	DBM		
/lultiplier Denominator	6	Freq Prefix	FREQ		
/lin Freq	9.00000000 kHz	Freq Suffix	нz		
Max Freq	40.00000000 GHz	Auxiliary	OUTP:STAT ON		

Example System Down-Converter LO Setup

- LO Power: 4dBm [This sets the output power from the external signal generator]
 - This may depend on system down-converter LO input power specifications. Set LO power appropriately based on system down-converter module.
- Settling Time: 100ms (Default, can be adjusted if needed)
- Multiplier Numerator: 1
- Multiplier Denominator: 6 [Set by the LO Harmonic Factor of the system down-converter]
- Min Freq: 9kHz [Default, Based on your Signal Generator]
- Max Freq: 40 GHz [Default, Based on your Signal Generator]



- Click on 'DUT Setup & Calibration'



- Click on 'Sys Downconv' drop down menu and turn it on.



- Set parameters as shown below:
 - o Sys Downconv: ON
 - o Sideband: DSB
 - o LO Mode: Swept
 - Ext LO Control: ON
 - o LO Power: 4dBm [Set based on previous LO Signal Generator settings in System Down-Converter LO Setup]



- Set remaining system parameters based on your system requirements.
- Example shown below to measure waveguide low noise amplifiers across 110-170 GHz using a WR6.5NS and a WR6.5SAX
- Click 'Close' when complete.





Load ENR .csv File onto Spectrum Analyzer

- Load ENR File onto a USB Drive
- Connect USB Drive to Spectrum Analyzer
- Press [Recall] soft key



- Click on 'ENR Table' on the list of menu options (left column).
- Click on 'Meas (Common) Table'
- Click on 'Recall From'
- Navigate to and Click on the ENR .csv file you want to upload
- Click on 'Recall'



Verify ENR Table

Verify ENR Table has loaded correctly

- Click on 'ENR'

Noise Figure 1			Meas Setup	- 湯
KEYSIGHT Input: RF L Coupling: DC Align: Auto	Atten: 0 dB DUT: Amplifier Sy: Averaging: Off	IS Downconv: Off FREQ = RF Cal State: UNCAL ENR State: ~ENR	Avg/Hold Num 10	Settings
Noise Figure v			Averaging On	Cal Setup
Scale/Div 1.500 dB	Ref Value 30.0 dB		Off	Noise Source
36.0			DUT 1 T	Loss Comp
33.0 31.5 30.0 28.5			Calibration	Limits
27.0			K Ext LO Setup	Advanced
24.0			Calculator	
Gain Y Scale/Div 1.000 dB	Ref Value 15.0 dB		Optimize Preselector	
19.0			Meas Preset	
17.0 16.0 15.0			CALIBRATE	
14.0				
12.0				
Start 10.000 MHz BW 4.0 MHz T cold 301.00 K	Freq Mode: Swept (Default) Noise Source: Auto (Normal	Stop 3.000 GHz I) Points 11		
May 24, 2021 6:53:01 AM	User Cal; Cal invalidated			

- Verify that ENR Mode is set to 'Table' not 'Spot'
- o 'Spot' can be used if user wants to set a flat, fixed ENR value across the full band
- Click on 'Edit Meas Table' to verify that the ENR data has loaded correctly
- Click 'Close' after ENR data has been verified

			ENR		って? Close>
ENR					
ENR Mode	Table Spot				
Table ENR			Spot ENR		
Use Meas Table Data for Cal	On Off		Spot Mode	ENR T Hot	
Edit Meas Table	>	Κ			
Edit Cal Table	\rangle		Spot T Hot	9892.80 K	
T cold T cold Mode	User T cold	301.00 K	User T cold		
User			FIOM SNS		
Default (301.00 K)	SNS T cold	_301.00 KOff			



Calibration

- Connect equipment as shown on Page 4, without the DUT (i.e. connect VDI Noise Source directly to VDI SAX Module Additional waveguide sections may be needed for proper waveguide flange connections)
- Click 'Calibrate'
 - \circ $\,$ Can be a slow sweep, depending on sweep parameters
- After Calibration procedure is complete, Noise Figure and Gain plots should be close to 0dB, as shown below.





Measurement

- Once Calibration procedure is complete, disconnect the VDI Noise Source and the VDI SAX.
- Connect DUT between the VDI Noise Source and VDI SAX Module (as shown on Page 4).
- Apply Voltage Biases to DUT, as needed.
- Example plot of VDI WR8.0AMP-LN is shown below

Noise Figure 1 Noise Figure	•	+						Meas Setup	· · · ※
	Input: RF Coupling: DC Align: Auto	Input Ζ: 50 Ω Freq Ref: Int (S)	Atten: 0 dB	DUT: Amplifier Averaging: Off	Sys Downconv: DSB IF: 500.00000 MHz	FREQ = RF Cal State: CAL ENR State: ~ENR	Avg/H 10	Hold Num	Settings
Noise Figure	•						Avera	aging On	Cal Setup
Scale/Div 3.00	D dB		Ref Value 16.0 dl	B				Off	Noise Source
28.0 25.0 22.0								1 v	Loss Comp
19.0 16.0							<	OUT Setup & Calibration	Limits
10.0				~~~~~~			< 1	Ext LO Setup	Advanced
4.00 0							<	Uncertainty Calculator	
Scale/Div 7.00	0 dB		Ref Value -1.0 dl	3				Optimize Preselector	
27.0								Meas Preset	
13.0 6.00 -1.00					-			CALIBRATE	
-8.00							<	ENR	
-29.0		_							
Start 110.000 G BW 4.0 MHz	Hz	T cold 301.00 K (D	Freq Mode: Swe efault) Noise S	pt ource: Auto (Nori	St mal)	op 170.000 GHz Points 241			
		May 24, 2021 8:51:56 AM	Calibration	n; ENR table extra	polater				



The following procedure is specific for measuring Gain and Noise Figure of a mixer / down-converter.

- Press [Meas Setup] soft key



- Click on 'Ext LO Setup'



- Click on 'LO Select'

			_
	Ext LO Setup	ی ر	Close
	Sys Downconverter LO		
Ext LO Control	Off Ext LO Control Off		
DUT LO Setup	Sys Downconv LO	Setup	
DUTIO	Adjust Technologies N5183B		
Sys Downconv LO	None		
	LO Select		



Spectrum Analyzer Setup (Mixer DUT) – continued

- Identify the correct Signal Generator connected to the Spectrum Analyzer (via USB) and click 'Select Highlighted Source As DUT LO' then click 'Ext LO Setup' in the upper left hand corner of the window.

Setup		LO Select		って	? Close>
	Add Source to List	GPIB GPIB Address 19	LAN IP Address 0.0.0.0		
	Add Installed USB Source	Add Specified GPIB Address Scan & Add GPIB Source	Add Specifier Address Run Connection Expert Co	Add From nnection Expert	
	Available Source List -	Model Serial Number \///	A Address		
	Agilent Technologies	N5183B M ¹ D101000 HoBo coot			
	Keysignt leonnologies	ICPIPUI (ICPIPUI)	Sele Sour Sele Sour Sour Sour	zt Highlighted ze As DUT LO zt Highlighted irce As Sys icconverter LO	
			Dele	e Highlighted Source	

- Click on 'DUT LO Setup'

	Ext LO Setup	って? Close〉
	Sys Downconverter LO	
Ext LO Control	Dn Ext LO Control Off	
DUT LO Setup		-
DUT LO	Agilent Technologies N5183B	
Sys Downconv LO	None	
	LO Select	



- Enter appropriate settings for the LO Signal Generator (See Example below)
- Click 'Close' when complete

🕻 Ext LO Setup		DI	JT LO Setup	50	? Close>
LO Settings		LO Commands			
LO Power	1.00 dBm	Command Set	SCPI Custom		
Settling Time	100 ms		POW		
Multiplier Numerator	1				
Multiplier Denominator	6		FREQ		
Min Freq	9.00000000 kHz		HZ		
Max Freq	40.00000000 GHz				

Example System Down-Converter LO Setup

- LO Power: 4dBm [This sets the output power from the external signal generator]
 - This may depend on system down-converter LO input power specifications. Set LO power appropriately based on system down-converter module.
- Settling Time: 100ms (Default, can be adjusted if needed)
- Multiplier Numerator: 1

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- Multiplier Denominator: 6 [Set by the LO Harmonic Factor of the system down-converter]
- Min Freq: 9kHz [Default, Based on your Signal Generator]
- Max Freq: 40 GHz [Default, Based on your Signal Generator]



- Click on 'DUT Setup & Calibration'



Spectrum Analyzer Setup (Mixer DUT) – continued

- Set system parameters based on your system requirements.
- Example shown below to measure a WR10 down-converter across 75-110 GHz using a WR10NS.
- Click 'Close' when complete.





Load ENR .csv File onto Spectrum Analyzer

- Load ENR File onto a USB Drive
- Connect USB Drive to Spectrum Analyzer
- Press [Recall] soft key



- Click on 'ENR Table' on the list of menu options (left column).
- Click on 'Meas (Common) Table'
- Click on 'Recall From'
- Navigate to and Click on the ENR .csv file you want to upload
- Click on 'Recall'



Verify ENR Table

Verify ENR Table has loaded correctly

- Click on 'ENR'

Noise Figure 1		Meas Setup 🔻
KEYSIGHT Input RF L Coupling DC Align: Auto	Atten: 0 dB DUT: Amplifier Sys Downconv: Off FREQ = RF Averaging: Off ENR State: UNCA ENR State - ENR	Avg/Hold Num Settings 10 Cal Sat
Noise Figure		On Off Noise
36 0		DUT Profile Source
34.5 33.0 31.5		DUT 1 Loss Co
30.0 28.5 27.0		Calibration Limits
25.5		Uncertainty Calculator
Gain v Scale/Div 1.000 dB	Ref Value 15.0 dB	Optimize Preselector
19.0 18.0		Meas Preset
17.0 16.0		CALIBRATE
14.0 13.0 12.0		
11.0		
Start 10.000 MHz BW 4.0 MHz T cold 301.00 K (I	Freq Mode: Swept Stop 3.000 GH [Default] Noise Source: Auto (Normal) Points 1	
1 1 1 1 1 1 1 1 1 1	💬 🛕 User Cai; Cai invalidated	

- Verify that ENR Mode is set to 'Table' not 'Spot'
 - \circ $\,$ 'Spot' can be used if user wants to set a flat, fixed ENR value across the full band
- Verify that Use Meas Table Data for Cal is turned OFF
- Click on 'Edit Meas Table' to verify that the ENR data for the High Frequency Noise Source has loaded correctly
- Click on 'Edit Cal Table' to verify that the ENR data for the Low Frequency Noise Source has loaded correctly. If not, enter appropriate data manually
- Click 'Close' after ENR data has been verified





Calibration

- Connect equipment as shown on page 5, without the DUT (i.e. connect Low Frequency Noise Source to RF Input Port of Spectrum Analyzer (or Low Frequency IF Amplifier, if applicable)
- Click 'Calibrate'
 - o Can be a slow sweep, depending on sweep parameters
- After Calibration procedure, connect equipment as shown on page 5 (without the Low Frequency Noise Source, connecting the DUT to the VDI Noise Source)



