Agilent E5505A Phase Noise Measurement System

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User's Guide

Agilent Technologies

Notices

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1 Getting Started

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Introduction

This guide introduces you to the Agilent E5505A Phase Noise Measurement System software and hardware. It provides procedures for configuring the E5500 Phase Noise Measurement software, executing measurements, evaluating results, and using the advanced software features. It also covers phase noise basics and measurement fundamentals to get you started.

Use Table 1 on page 27 as a guide to:

- Learning about the E5505A phase noise measurement system
- Learning about phase noise basics and measurement fundamentals
- Using the E5505A system to make specific phase noise measurements.

In this guide you'll also find information on system connections and specifications, and procedures for re-installing phase-noise-specific hardware and software in the system PC.

NOTE Installation information for your system is provided in the *Agilent E5505A Phase Noise Measurement System Installation Guide*.

Documentation Map

Table 1 E5505A user's guide map

Learning about the E5505A System	Learning Phase Noise Basics & Measurement Fundamentals	Using the E5505A for Specific Phase Noise Measurements
Chapter 1, "Getting Started"		
Chapter 2, "Introduction and Measurement"	Chapter 3, "Phase Noise Basics"	
Chapter 4, "Expanding Your Measurement Experience"	Chapter 5, "Absolute Measurement Fundamentals"	Chapter 6, "Absolute Measurement Examples"
	Chapter 7, "Residual Measurement Fundamentals"	Chapter 8, "Residual Measurement Examples"
	Chapter 9, "FM Discriminator Fundamentals"	Chapter 10, "FM Discriminator Measurement Examples"
	Chapter 11, "AM Noise Measurement Fundamentals"	Chapter 12, "AM Noise Measurement Examples"
		Chapter 13, "Baseband Noise Measurement Examples"
		Chapter 14, "Evaluating Your Measurement Results"
		Chapter 15, "Advanced Software Features"
		Chapter 16, "Reference Graphs and Tables"
Chapter 17, "System Specifications"		
Chapter 18, "System Interconnections"		
Chapter 19, "PC Components Installation"		
Chapter 20, "PC Digitizer Performance Verification"		
Chapter 21, "Preventive Maintenance"		
Chapter A, "Service, Support, and Safety Information"		

Additional Documentation

You can access the complete set of PDF documents that support the E5505A system through the system GUI. (Adobe® Acrobat Reader® is supplied.) Navigate the menu as shown in Figure 1. The files are stored on the system PC hard drive and on the E5500A software CD. Be sure to explore the E5500 Help menu for additional information.

The E5505A system documentation includes:

- *Agilent E5505A Phase Noise Measurement System Installation Guide*
- *Agilent E5505A Phase Noise Measurement System User's Guide*
- *Agilent N5501A/N5502A Phase Noise Downconverter User's Guide*
- *Agilent N5507A Phase Noise Downconverter User's Guide*
- *Agilent N5500A Phase Noise Test Set User's Guide*
- *Agilent E5500 Series Phase Noise Measurement Systems SCPI Command Reference*
- *Agilent E5500 Phase Noise Measurement System Online Help*

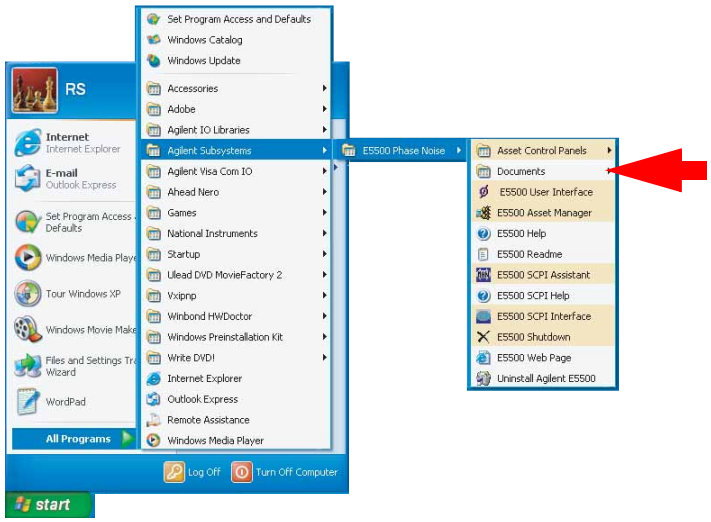

Figure 1 Navigate to system documentation

System Overview

The E5505A Phase Noise Measurement System provides flexible sets of measurements on one-port devices such as voltage controlled oscillators (VCOs), dielectric resonator oscillators (DROs), crystal oscillators, and synthesizers, and on two-port devices such as amplifiers and converters. The E5505A system measures absolute and residual phase noise, AM noise, and low-level spurious signals, as well as CW and pulsed signals. It operates in the frequency range of 50 KHz to 26.5 GHz.

The E5505A phase noise measurement system combines standard instruments, phase noise components, and PC software for maximum flexibility and re-use of assets. The system PC operates under Windows 7 and controls the system through the E5500 measurement software. The E5500 software enables many stand-alone instruments to work in the system. This standalone-instrument architecture easily configures for various measurement techniques, including the phase-lock-loop (PLL)/reference-source technique, and delay-line and FM-discriminator methods.

The E5505A system is available as a one-bay wide, System II rack and as a benchtop model. Due to the system's flexibility, the hardware in the system varies greatly with the options selected. You may be installing instruments you already own in the system as well. A typical system includes these components:

- Advantech or Kontron custom PC with digitizer card assembly
- 15-inch display (flat-panel or standard), keyboard, and mouse
- Windows 7operating system
- Agilent E5500 Phase Noise Measurement software
- Phase noise test set
- Downconverter
- RF source

Additional instruments may include a spectrum analyzer, oscilloscope, RF counter, power meter, and power splitter.

NOTE For detailed information on the instruments in your E5505A phase noise measurement system, refer to the individual instrument user guides (provided on DVD-R).

Figure 2 shows a typical configuration of an E5505A benchtop system.

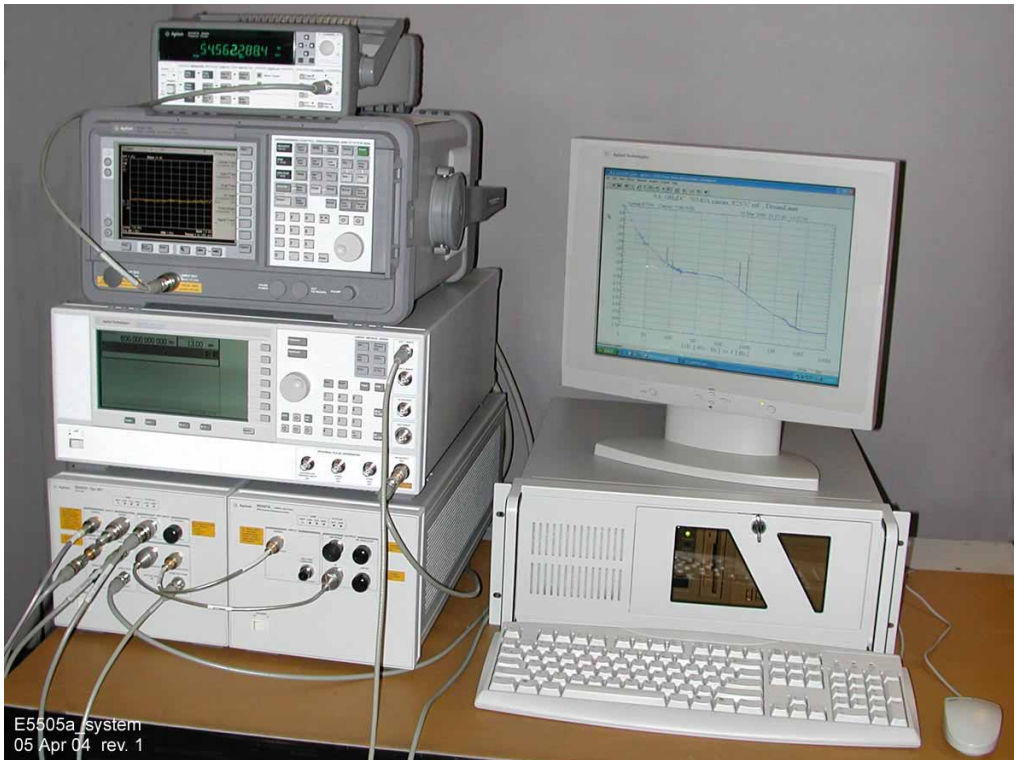

Figure 2 E5505A benchtop system, typical configuration

The E5505A replaces earlier Agilent E5500A/B series phase noise systems, which are based on MMS technology. The E5505A system uses GPIB communication and certain instruments have been redesigned with GPIB functionality. However, the E5505A system and E5500 software are backwards compatible with earlier systems and instruments, including the MMS mainframe. You may easily integrate existing assets into your E5505A system. Table 2 shows the E5505A instruments and earlier-model equivalents.

Table 2 Equivalent system/instrument model numbers

System or Instrument	New Number	Old Number
Phase noise measurement system	E5505A	E5501A, E5501B, E5502B, E5503A, E5503B, E5504A, E5504B
Test set	N5500A	70420A
6.6 GHz downconverter	N5501A	70421A
18 GHz downconverter	N5502A	70422A
26.5 GHz downconverter	N5507A	70427A, 71707A
Microwave source	N5508A	70428A, 71708A

2
Introduction and Measurement

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Introducing the GUI

The graphical user interface (GUI) gives the user instant access to all measurement functions, making it easy to configure a system and define or initiate measurements. The most frequently used functions are displayed as icons on a toolbar, allowing quick and easy access to the measurement information.

The forms-based graphical interaction helps you define your measurement quickly and easily. Each form tab is labeled with its content, preventing you from getting lost in the defining process.

The system provides three default segment tables. To obtain a quick look at your data, select the “fast” quality level. If it is important to have more frequency resolution to separate spurious signals, use the “normal” and “high resolution” quality levels. If you need to customize the offset range beyond the defaults provided, tailor the measurement segment tables to meet your needs and save them as a custom selection.

You can place up to nine markers on the data trace that can be plotted with the measured data.

Other features include:

- Plotting data without spurs
- Tabular listing of spurs
- Plotting in alternate bandwidths
- Parameter summary
- Color printouts to any supported color printer

Figure 3 on page 33 shows an example of the GUI.

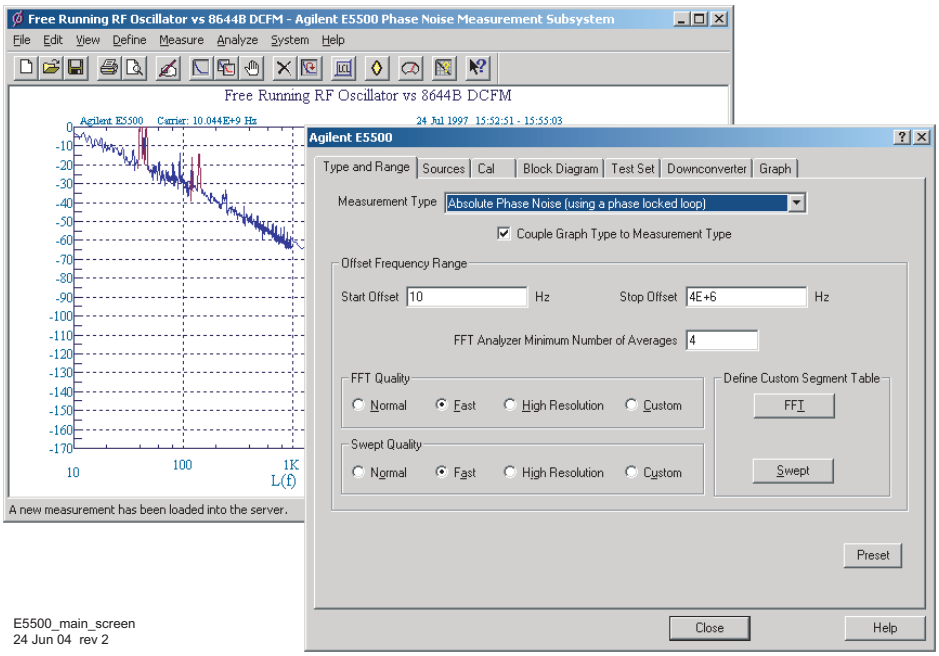

Figure 3 E5500 graphical user interface (GUI)

Designing to Meet Your Needs

The E5505A Phase Noise Measurement System is a high performance measurement tool that enables you to fully evaluate the noise characteristics of your electronic instruments and components with unprecedented speed and ease. The phase noise measurement system provides you with the flexibility needed to meet today's broad range of noise measurement requirements.

In order to use the phase noise system effectively, it is important that you have a good understanding of the noise measurement you are making. This manual is designed to help you gain that understanding and quickly progress from a beginning user of the phase noise system to a proficient user of the system's basic measurement capabilities.

NOTE

If you have just received your system or need help with connecting the hardware or loading software, refer to your *Agilent E5505A Phase Noise Measurement System Installation Guide* now. Once you have completed the installation procedures, return to "E5505A Operation: A Guided Tour" on page 35 to begin learning how to make noise measurements with the system.

Beginning

The section "E5505A Operation: A Guided Tour" on page 35 contains a step-by-step procedure for completing a phase noise measurement. This measurement demonstration introduces system operating fundamentals for whatever type of device you plan to measure.

Once you are familiar with the information in this chapter, you should be prepared to start Chapter 4, "Expanding Your Measurement Experience. After you have completed that chapter, refer to Chapter 14, "Evaluating Your Measurement Results for help in analyzing and verifying your test results.

E5505A Operation: A Guided Tour

This measurement demonstration introduces you to the system's operation by guiding you through an actual phase noise measurement.

You will be measuring the phase noise of the Agilent N5500A Phase Noise Test Set's low noise amplifier. (The measurement made in this demonstration is the same measurement that is made to verify the system's operation.)

As you step through the measurement procedures, you will soon discover that the phase noise measurement system offers enormous flexibility for measuring the noise characteristics of your signal sources and two-port devices.

Required equipment

The equipment shipped with this system is all that is required to complete this demonstration. (Refer to the *E5505A Phase Noise Measurement System Installation Guide* if you need information about setting up the hardware or installing the software.)

How to begin

Follow the setup procedures beginning on the next page. The phase noise measurement system displays a setup diagram that shows you the front panel cable connections to make for this measurement.

NOTE If you need additional information about connecting instruments, refer to Chapter 18, "System Interconnections."

Powering the System On

This section provides procedures for powering on a racked or benchtop system. First connect your system to an appropriate AC power source, then follow the steps below.

WARNING Before applying power, make sure the AC power input and the location of the system meet the requirements given in Chapter 17, “System Specifications.” Failure to do so may result in damage to the system or personal injury.

NOTE

Warm-up Time: The downconverter and RF source instruments contain ovenized oscillators which must warm up for 30 minutes to produce accurate measurements.

Standby Mode: The RF source uses a standby mode to keep the ovenized oscillator warm when the instrument is connected (plugged in) to AC power, *even when the power switch is in the off position*. To completely shut down the instrument, you must disconnect it from the AC power supply.

To power on a racked system

1. Press the system power switch (front, top right of the rack) to the on position.
2. Verify that all instrument power switches are on.
3. Allow the system to warm up for 30 minutes.

To power on a benchtop system

1. Press the power switch on each instrument to the on position.
2. If you have the system connected to a safety power strip, turn the strip’s power switch to the on position.
3. Allow the system to warm up for 30 minutes.

Starting the Measurement Software

1 Place the E5500 phase noise measurement software disk in the DVD-R drive.

2 Using Windows **Start** menu as in Figure 4, navigate to the **E5500 User Interface.**

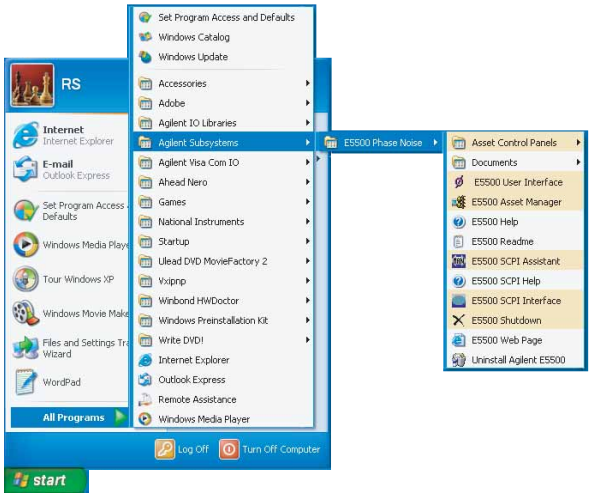

Figure 4 Navigation to the E5500 user interface

3 The phase noise measurement subsystem main screen appears (Figure 5 on page 38).

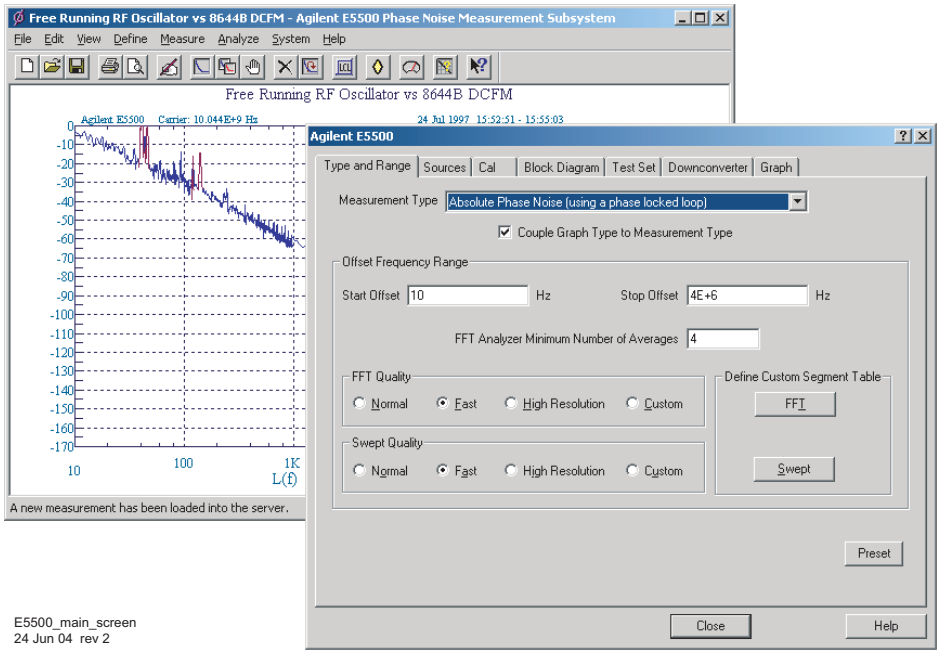

Figure 5 Phase noise measurement subsystem main screen

NOTE The default background for the screen is gray. You can change the background color by selecting **View/Display Preferences** and clicking on the **Background Color** button.

Performing a Confidence Test

This first measurement is a confidence test that functionally checks the N5500A test set's filters and low-noise amplifiers using the test set's low noise amplifier. The phase detectors are not tested. This confidence test also confirms that the test set, PC, and analyzers are communicating with each other. To conduct the test, use a file with pre-stored parameters named Confidence.pnm.

1 On the E5500 GUI main menu, select **File\Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, select **Confidence.pnm** (Figure 6).

4 Click the **Open** button.

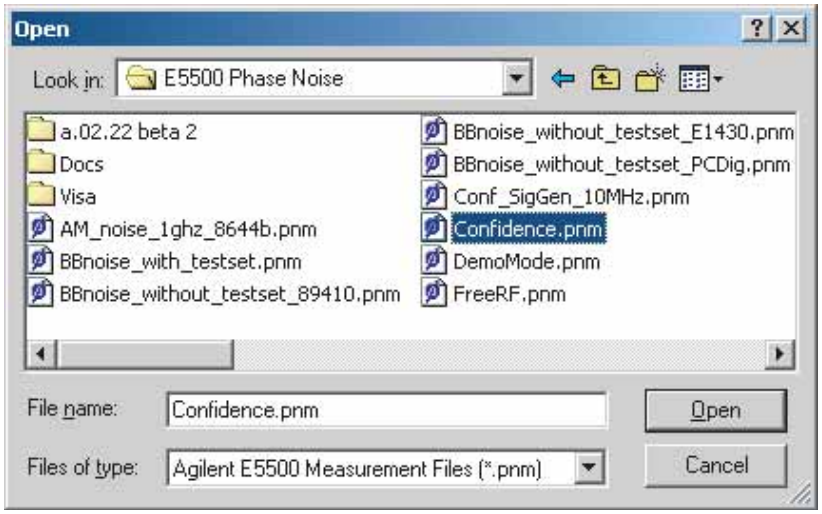

Figure 6 Opening the file containing pre-stored parameters

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 3 on page 43 lists the parameter data that has been entered for the N5500A confidence test example.

5 To view the parameter data in the software, navigate to the Define Measurement window. Use Figure 7 on page 40 as a navigation guide. The parameter data is entered using the tabbed windows. Select various tabs to see the type of information entered behind each tab.

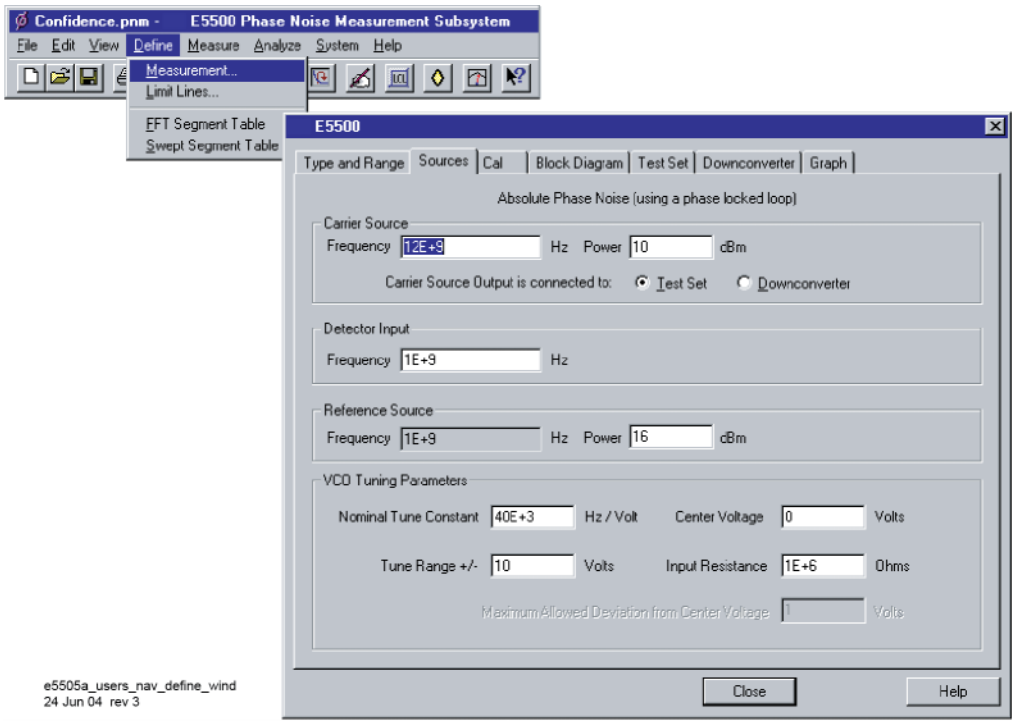

Figure 7 Navigating to the Define Measurement window

6 Click the **Close** button.

Beginning a measurement

1 From the **Measure** menu, choose **New Measurement. See** Figure 8.

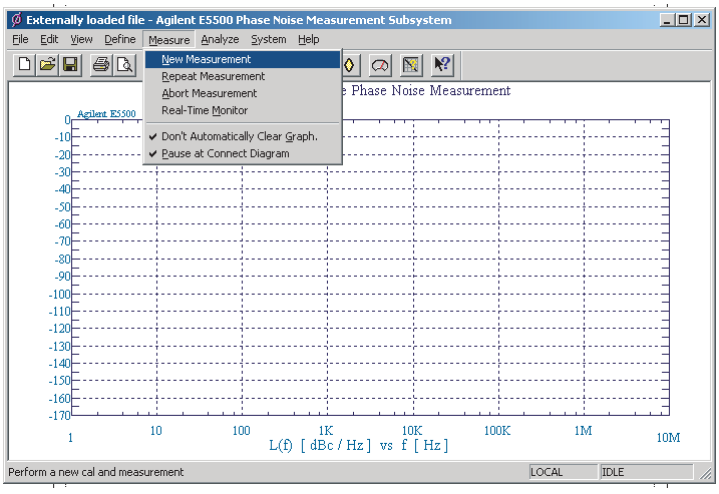

Figure 8 Navigating to the New Measurement window

2 When the **Do you want to Perform a New Calibration and Measurement?** dialog box appears, click Yes. See Figure 9.

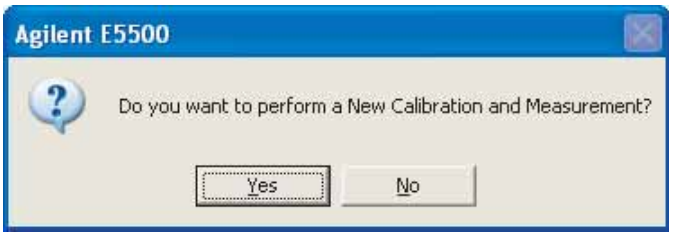

Figure 9 Confirm new measurement

3 Connect the equipment per Figure 10 and ensure the signal output is turned off.

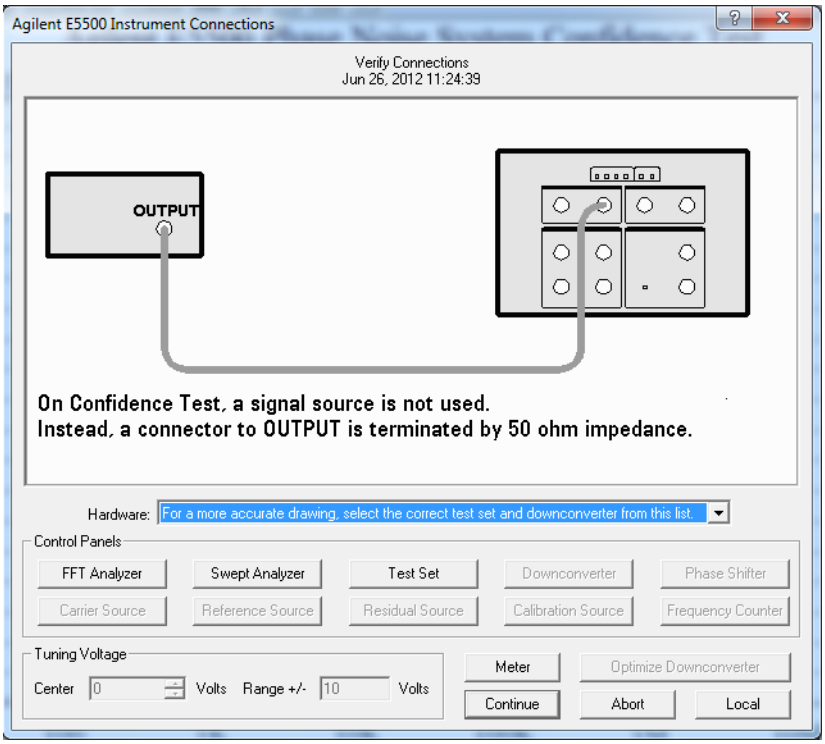

Figure 10 Setup diagram displayed during the confidence test.

Making a measurement

1 Press the **Continue** button.

- Because you selected **New Measurement** to begin this measurement, the system starts by running the routines required to calibrate the current measurement setup.
- Figure 11 on page 42 shows a typical baseband phase noise plot for an phase noise test set.

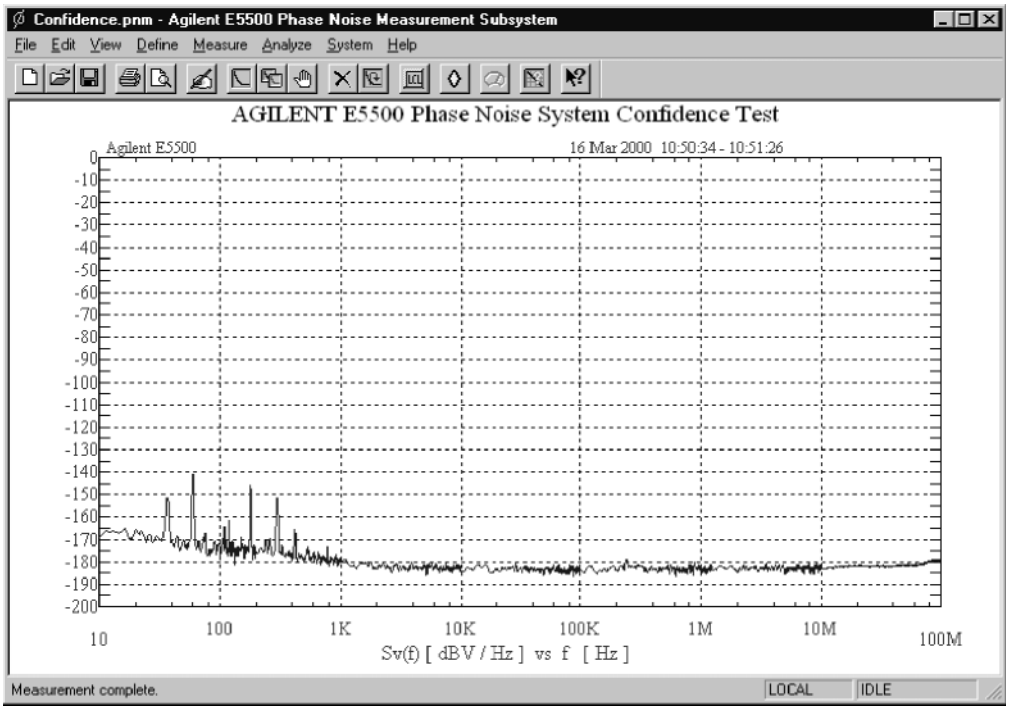

Figure 11 Typical phase noise curve for test set confidence test

Sweep segments

When the system begins measuring noise, it places the noise graph on its display. As you watch the graph, you see the system plot its measurement results in frequency segments.

The system measures the noise level across its frequency offset range by averaging the noise within smaller frequency segments. This technique enables the system to optimize measurement speed while providing you with the measurement resolution needed for most test applications.

Congratulations

You have completed a phase noise measurement. This measurement of the test set's low noise amplifier provides a convenient way to verify that the system hardware and software are properly configured for making noise measurements. If your graph looks like that in Figure 11, you can be confident that your system is operating normally.

Learning more

Continue with this demonstration by turning to Chapter 4, "Expanding Your Measurement Experience to" learn more about performing phase noise measurements.

Table 3 Parameter data for the N5500A confidence test example

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Baseband Noise (using a test set)
	Start Frequency	• 10 Hz
	Stop Frequency	• 100 E + 6 Hz[1]
	Minimum Number of Averages	• 4
	FFT Quality	• Fast
	Swept Quality	• Fast
2	**Cal Tab**	
	Gain preceding noise input	0 dB
3	**Block Diagram Tab**	
	Noise Source	Test Set Noise Input
4	**Test Set Tab**	
	Input Attenuation	• 0 dB
	LNA Low Pass Filter	• 20 MHz (Auto checked)
	LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	DC Block	• Not checked
	PLL Integrator Attenuation	• 0 dBm

Table 3 Parameter data for the N5500A confidence test example

Step	Parameters	Data
5	**Graph Tab**	
	Title	• Confidence Test, N5500A low noise amplifier.
	Graph Type	• Base band noise (dBv/Hz)
	X Scale Minimum	• 10 Hz
	X Scale Maximum	• 100 E + 6 Hz
	Y Scale Minimum	• 0 dBv/Hz
	Y Scale Maximum	• –200 dBv/Hz
	Normalize trace data to	• 1 Hz bandwidth
	Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	Shift trace data DOWN by	• 0 dB
	Trace Smoothing Amount	• 0
	Power present at input of DUT	• 0 dB

1 The Stop Frequency depends on the analyzers configured in your phase noise system.

Powering the System Off

To power off a racked system

1 On the E5500 software menu, select **File\Exit**. Always shut down the E5500 software before powering off the E5505A system.

2 Press the system power switch (front, top right of the rack) to the off position.

CAUTION Always shut down the E5500 software before powering off the E5505A system.

Failure to do so may produce errors in the stem, and result in an inoperable system or inaccurate measurements. If you do receive errors during shutdown, startup, or operation, use the E5500 Shutdown utility to restore functionality to the system.

To power off a benchtop system

1 On the E5500 software menu, select **File\Exit**.

2 Press the power switch on each instrument to the off position.

Using the E5500 Shutdown Utility

If you receive error messages during the power on or off procedures, or during operation, use the E5500 Shutdown utility to shut down the system. This utility automatically fixes most errors and restores functionality to the system. If you still receive errors after running the E5500 Shutdown utility, call your local Agilent Technologies Service Center.

To run the E5500 Shutdown utility

1 Double-Click on the E5500 Shutdown utility shortcut on the PC desktop and follow the onscreen instructions. (You can also navigate to it using the menu path Start/Agilent Subsystems/E5500 Phase Noise/Shutdown.)

Figure 12 Shutdown utility icon

2 When the shutdown utility has finished, use the Start menu to shut down the PC. Then power the system off.

3
Phase Noise Basics

What is Phase Noise? 48
Phase terms 49

What is Phase Noise?

Frequency stability can be defined as the degree to which an oscillating source produces the same frequency throughout a specified period of time. Every RF and microwave source exhibits some amount of frequency instability. This stability can be broken down into two components:

- long-term stability
- short-term stability

Long-term stability describes the frequency variations that occur over long time periods, expressed in parts per million per hour, day, month, or year.

Short-term stability contains all elements causing frequency changes about the nominal frequency of less than a few seconds duration. The chapter deals with short-term stability.

Mathematically, an ideal sinewave can be described by

$$V(t) = V_O \sin 2\pi f_O t$$

Where V_O = nominal amplitude,

$V_O \sin 2\pi f_O t$ = linearly growing phase component,

and f_O = nominal frequency

But an actual signal is better modeled by

$$V(t) = |Vo + \varepsilon(t)| \sin |2\pi f_O t + \Delta\phi(t)|$$

Where $\varepsilon(t)$ = amplitude fluctuations,

and $\Delta\phi(t)$ = randomly fluctuating phase term or phase noise.

This randomly fluctuating phase term could be observed on an ideal RF analyzer (one which has no sideband noise of its own) as in Figure 13 on page 49.

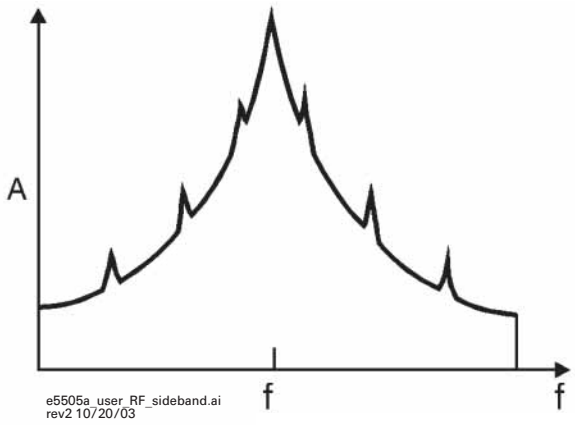

Figure 13 RF sideband spectrum

Phase terms

There are two types of fluctuating phase terms:

- spurious signals
- phase noise

Spurious signals

The first are discrete signals appearing as distinct components in the spectral density plot. These signals, commonly called spurious, can be related to known phenomena in the signal source such as power line frequency, vibration frequencies, or mixer products.

Phase noise

The second type of phase instability is random in nature, and is commonly called phase noise. The sources of random sideband noise in an oscillator include thermal noise, shot noise, and flicker noise.

Many terms exist to quantify the characteristic randomness of phase noise. Essentially, all methods measure the frequency or phase deviation of the source under test in the frequency or time domain. Since frequency and phase are related to each other, all of these terms are also related.

Spectral density One fundamental description of phase instability or phase noise is spectral density of phase fluctuations on a per-Hertz basis. The term spectral density describes the energy distribution as a continuous function, expressed in units of variance per unit bandwidth. Thus $S_\phi(f)$ (Figure 14 on page 50) may be considered as:

$$S\phi(f) = \frac{\Delta\phi^2_{rms}(f)}{BW\ used\ to\ measure\ \Delta\phi_{rms}} = \frac{rad^2}{Hz}$$

Where BW (bandwidth is negligible with respect to any changes in S_ϕ versus the fourier frequency or offset frequency (f).

L(f) Another useful measure of noise energy is L(f), which is then directly related to $S_\phi(f)$ by a simple approximation which has generally negligible error if the modulation sidebands are such that the total phase deviation are much less than 1 radian ($\Delta\phi_{pk}$<< radian).

$$L(f) = \frac{1}{2}S_{\Delta\phi}(f)$$

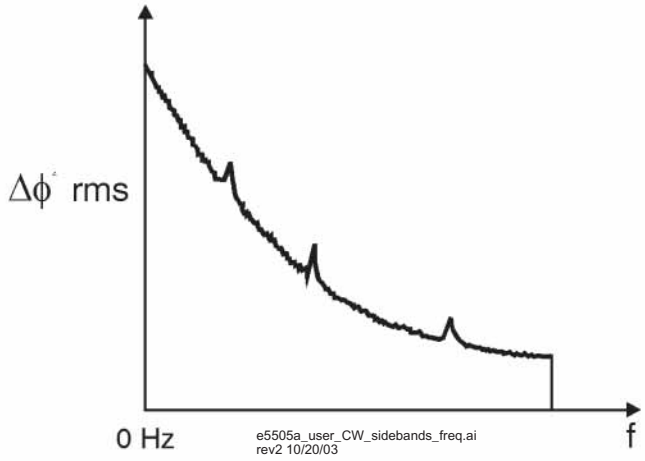

Figure 14 CW signal sidebands viewed in the frequency domain

L(f) is an indirect measurement of noise energy easily related to the RF power spectrum observed on an RF analyzer. Figure 15 shows that the National Institute of Standards and Technology (NIST) defines L(f) as the ratio of the power--at an offset (f) Hertz away from the carrier. The phase modulation sideband is based on a per Hertz of bandwidth spectral density and or offset frequency in one phase modulation sideband, on a per Hertz of bandwidth spectral density and (f) equals the Fourier frequency or offset frequency.

$$L(f) = \frac{power\ density\ (in\ one\ phase\ modulation\ sideband)}{total\ signal\ power} = \frac{P_{ssb}}{P_s}$$

= single sideband (SSB) phase noise to carrier ration (per Hertz)

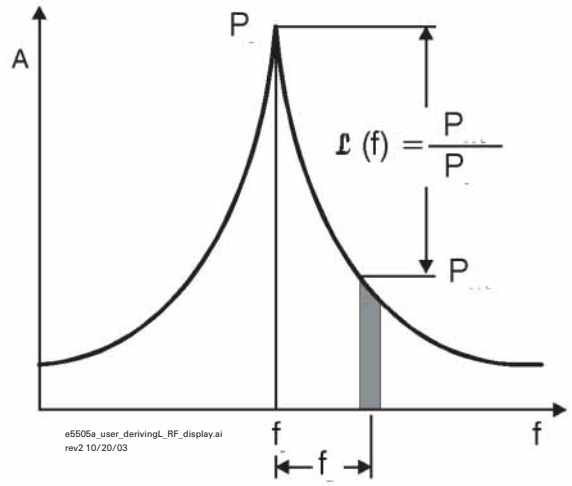

Figure 15 Deriving L(f) from a RF analyzer display

$L(f)$ is usually presented logarithmically as a spectral density plot of the phase modulation sidebands in the frequency domain, expressed in dB relative to the carrier per Hz (dBc/Hz) as shown in Figure 16. This chapter, except where noted otherwise, uses the logarithmic form of $L(f)$ as follows: $S_{\Delta f}(f) = 2f^2 L(f)$.

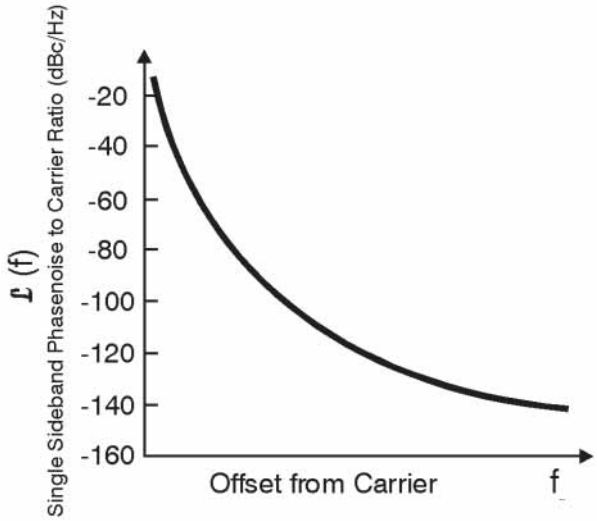

Figure 16 L(f) Described Logarithmically as a Function of Offset Frequency

Caution must be exercised when $L(f)$ is calculated from the spectral density of the phase fluctuations $S_\phi(f)$ because the calculation of $L(f)$ is dependent on the small angle criterion. Figure 17, the measured phase noise of a free running VCO described in units of $L(f)$, illustrates the erroneous results that can occur if the instantaneous phase modulation exceeds a small angle line. Approaching the carrier $L(f)$ obviously increases in error as it indicates a relative level of +45 dBc/Hz at a 1 Hz offset (45 dB more noise power at a 1 Hz offset in a 1 Hz bandwidth than in the total power of the signal); which is of course invalid.

Figure 17 shows a 10 dB/decade line drawn over the plot, indicating a peak phase deviation of 0.2 radians integrated over any one decade of offset frequency. At approximately 0.2 radians the power in the higher order sidebands of the phase modulation is still insignificant compared to the power in the first order sideband which insures that the calculation of $L(f)$ remains valid. Above the line the plot of $L(f)$ becomes increasingly invalid, and $S_\phi(f)$ must be used to represent the phase noise of the signal.

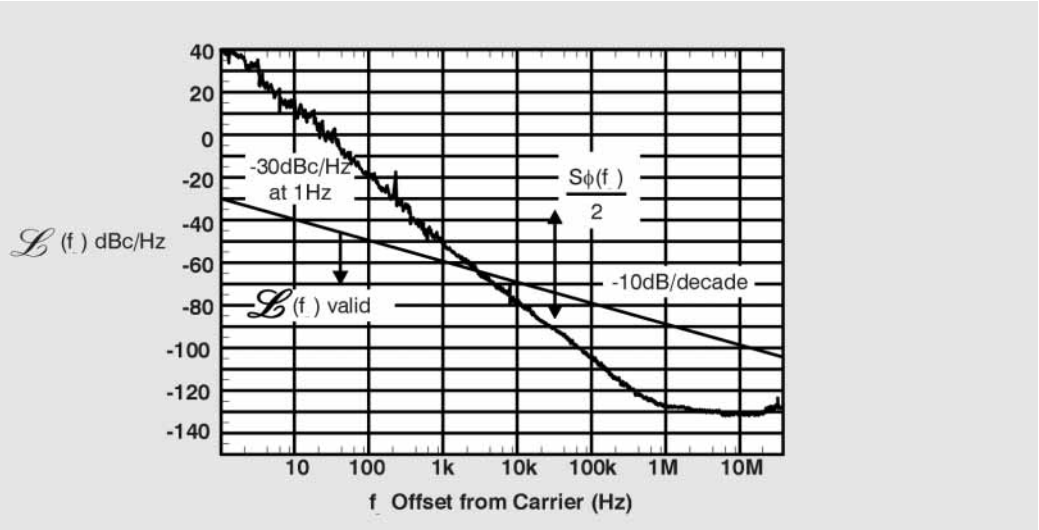

Figure 17 Region of validity of L(f)

4 Expanding Your Measurement Experience

Starting the Measurement Software 54
Using the Asset Manager 55
Using the Server Hardware Connections to Specify the Source 60
Testing the 8663A Internal/External 10 MHz 66
Testing the 8644B Internal/External 10 MHz 81
Viewing Markers 96
Omitting Spurs 97
Displaying the Parameter Summary 99
Exporting Measurement Results 101

Starting the Measurement Software

1. Make sure your computer and monitor are turned on.
2. Place the E5500 Phase Noise Measurement System software disk in the disc holder and insert in the DVD-R drive.
3. Using Figure 18 as a guide, navigate to the **E5500 User Interface.**

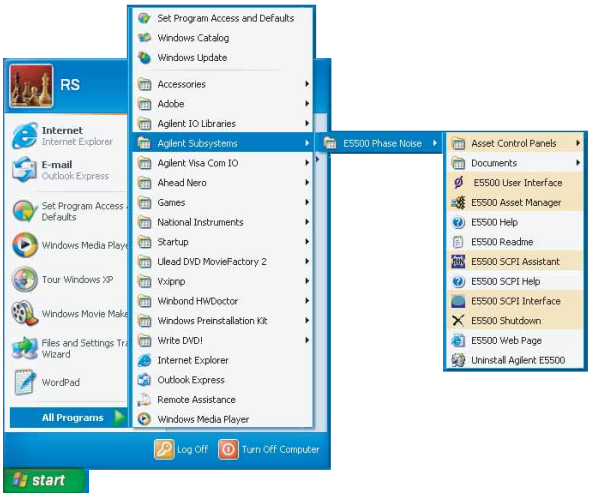

Figure 18 Navigate to E5500 user interface

Using the Asset Manager

Use the Asset Manager to add assets to your E5505A system. The process is essentially the same for any asset, including reference sources. In fact, the procedure in this section uses an Agilent 8663 source as an example. (The procedure applies to all Agilent sources, including the 8257x series.)

Adding an asset involves two steps once the hardware connections have been made:

- Configuring the asset
- Verifying the server hardware connections.

WARNING Be sure to power off the system before making all hardware connections other than GPIB. Connecting assets with the power applied can result in personal injury and damage to the hardware. (For more information on connecting assets, see **Chapter 18, "System Interconnections"**)

Configuring an asset

This procedure demonstrates how to add an asset to the E5505A system.

1 Using Figure 19 as a guide, navigate to **Asset Manager**. For this example we invoke the Asset Manager Wizard from the E5500 main screen. This is the most common way to add assets.

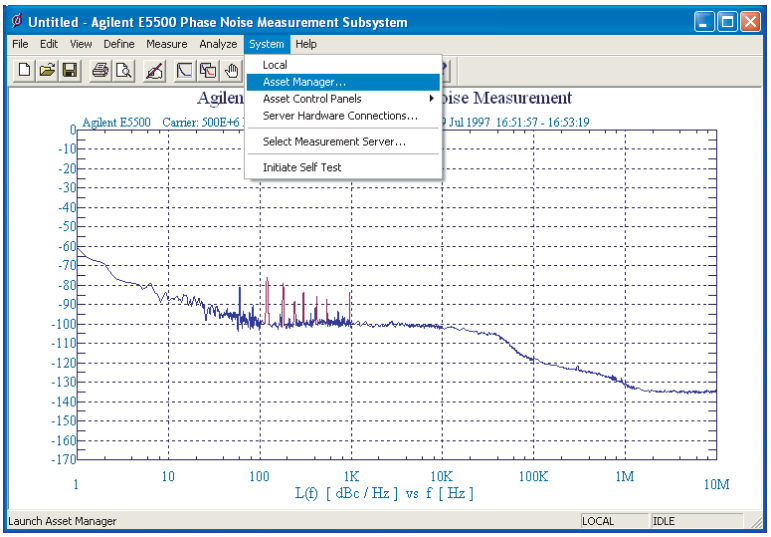

Figure 19 Navigate to Asset Manager

2 Select **Add** in the Asset Manager window. See Figure 20.

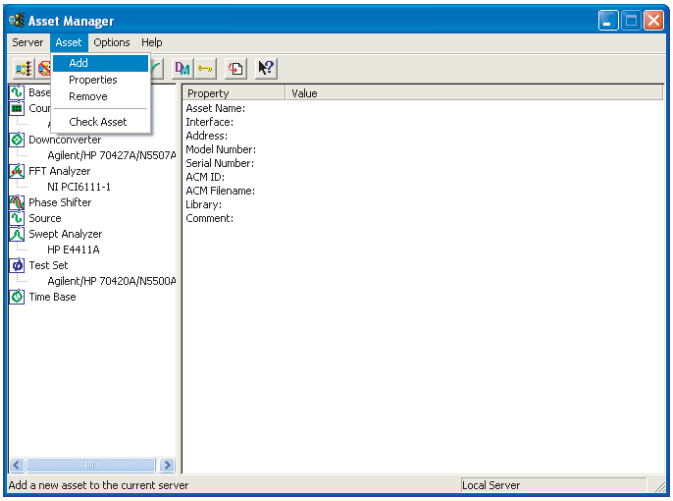

Figure 20 Navigate to Add in Asset Manager

3 From the **Asset Type** pull-down list in **Choose Asset Role** dialog box, select **Source,** then click **Next**. See Figure 21.

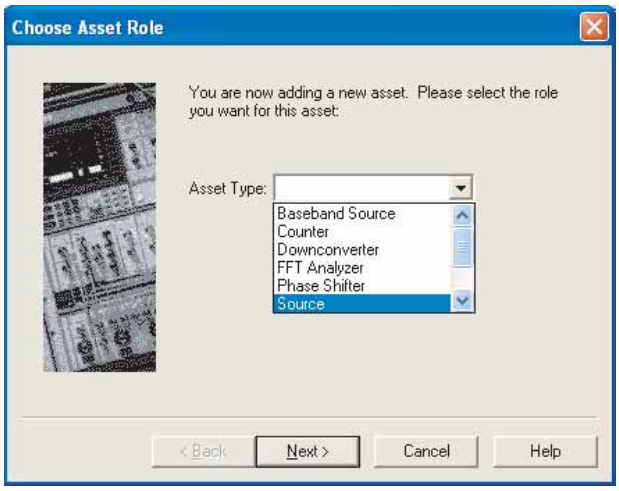

Figure 21 Select source as asset type

4 Click on the source to be added, then click the **Next** button (see Figure 22).

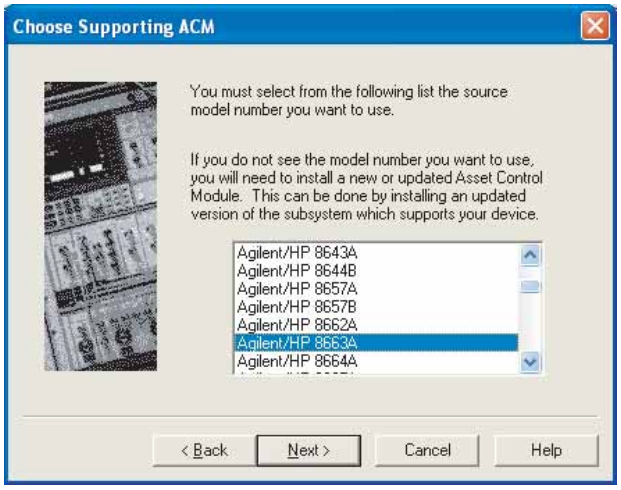

Figure 22 Choose source

5 From the **Interface** pull-down list, select **GPIB0**. See Figure 23.

6 In the **Address** box, type **19.**

NOTE 19 is the default address for a source. Table 4 on page 63 shows the default GPIB address for all system instruments.

7 In the **Library** pull-down list, select the **Agilent Technologies VISA**. Click the **Next** button.

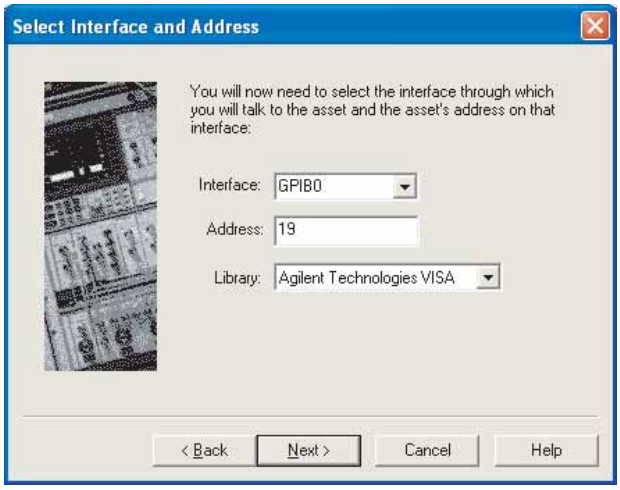

Figure 23 Select I/O library

8 In the **Set Model & Serial Numbers** dialog box, type in your source name and its corresponding serial number. Click the **Next** button. See Figure 24.

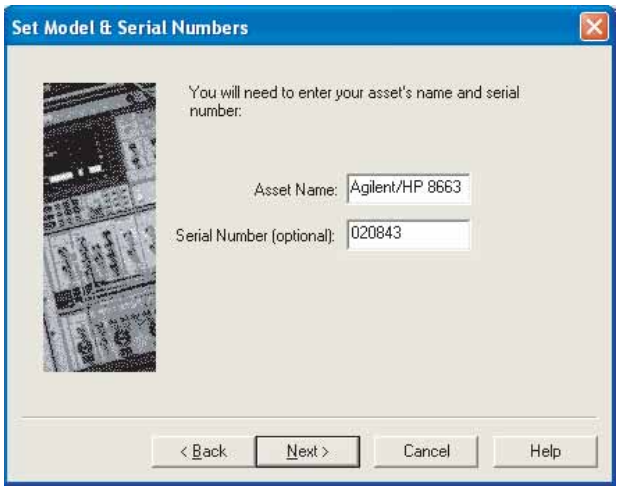

Figure 24 Enter asset and serial number

9 In the **Enter A Comment** dialog box, you may type a comment that associates itself with the asset you have just configured. Click **Finish**. See Figure 25.

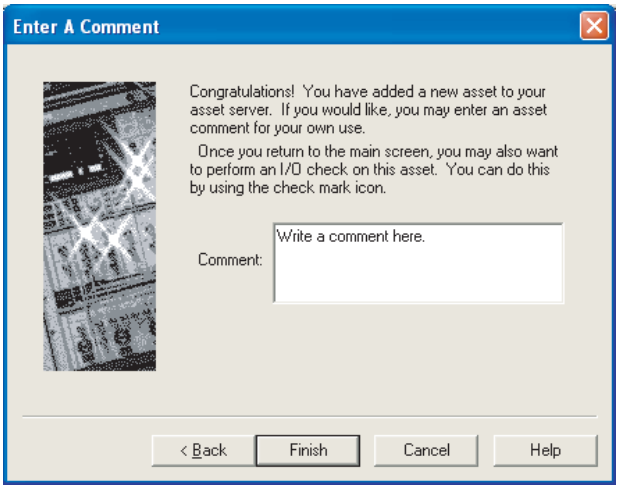

Figure 25 Enter comment

10 In the Asset Manager window, select the source in the left window pane. Click the **check-mark** button on the toolbar to verify connectivity. See Figure 26.

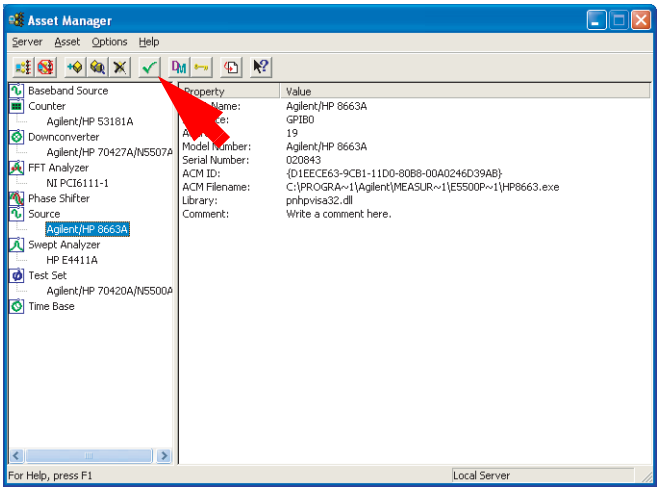

Figure 26 Click check-mark button

- The Asset Manager displays a message verifying the connection to your asset. This indicates that you have successfully configured a source. (See Figure 27.)

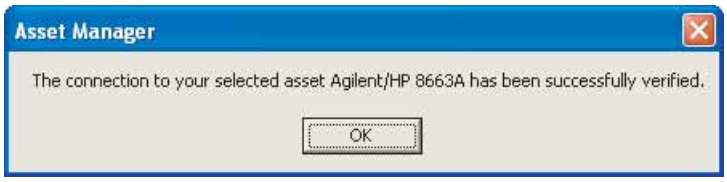

Figure 27 Confirmation message

11 To exit the Asset Manager, on the menu select **Server/Exit**.

12 Perform the procedure "Using the Server Hardware Connections to Specify the Source" on page 60.

Using the Server Hardware Connections to Specify the Source

1 From the **System** menu, choose **Server Hardware Connections.** See Figure 28.

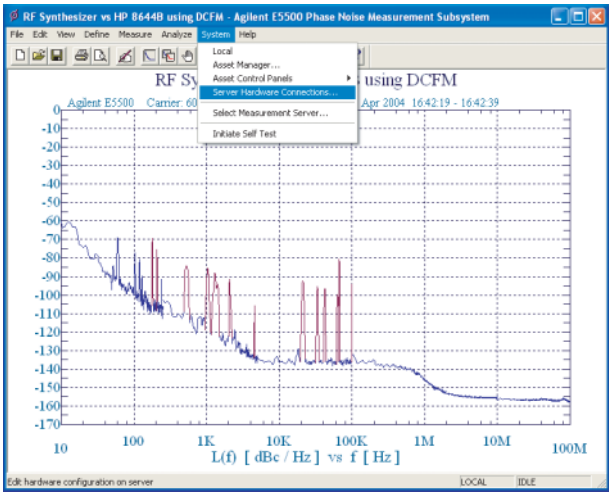

Figure 28 Navigate to server hardware connections

2 Select the **Sources** tab shown in Figure 29.

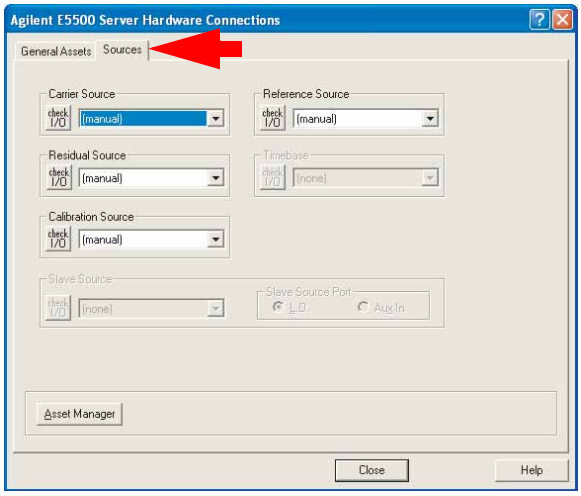

Figure 29 Select Sources tab

3 From the **Reference Source** pull-down list, select Agilent 8663A.

a A green check-mark appears after an automatic I/O check has been successfully performed by the software. If nothing happens, click the **Check I/O** button to manually initiate the check.

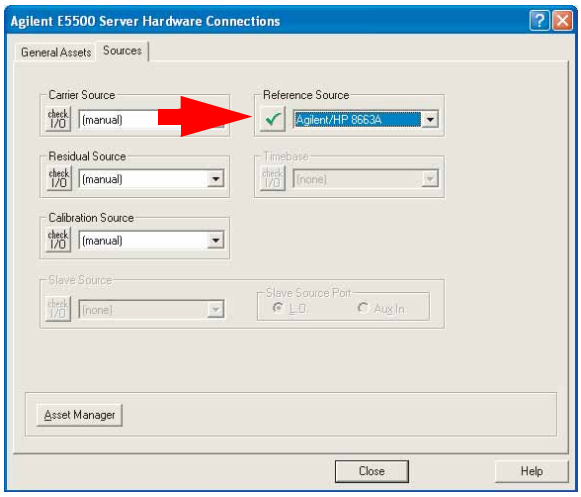

Figure 30 Successful I/O check

b A red circle with a slash appears if the I/O check is unsuccessful.

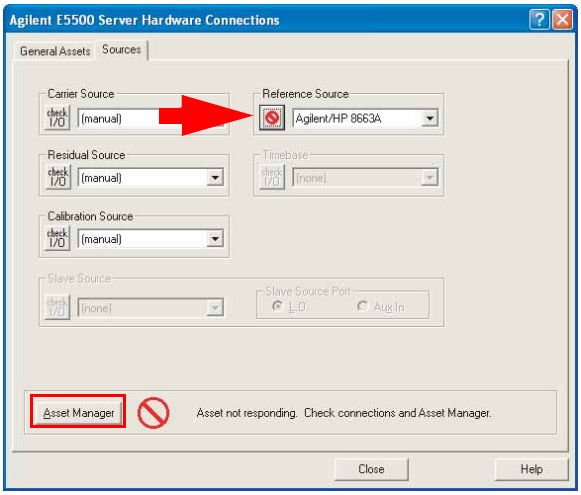

Figure 31 Failed I/O check

c If the I/O check fails, click the **Asset Manager** button to return to the Asset Manager (see Figure 31).

d In the Asset Manager, verify that the 8663A is configured correctly. Do the following:

- Check your system hardware connections.
- Click the green **check-mark** button on the Asset Manager's toolbar to verify connectivity.
- Return to **Server Hardware Connections** and click the **Check I/O** button to re-check it.

NOTE Use the same process to add additional assets to your E5505A system.

Setting GPIB Addresses

Table 4 shows the default GPIB addresses for the E5505A system instruments. If you need to change a GPIB address to prevent a conflict between assets, use the Asset Manager as shown in the easy procedure starting on page 64.

Table 4 Default GPIB addresses

Instrument	Address
Test set	20
Downconverter	28
Microwave downconverter	28
RF analyzer	17
FFT analyzer (PC digitizer card)	1
FFT analyzer (89410A)	18
Source # 1	19
Source # 2	23
Counter	3
Agilent E1430 VXI digitizer[1]	129
Agilent E1437 VXI digitizer[1]	192
Agilent E1420B VXI counter[1]	48
Agilent E1441 VXI ARB[1]	80
Agilent GPIB slave Port	22

1 The E5500 software supports this instrument although it is not part of the standard E5505A system.

To change the GPIB address

1 On the E5500 main menu, select **System/Asset Manager**. See Figure 32.

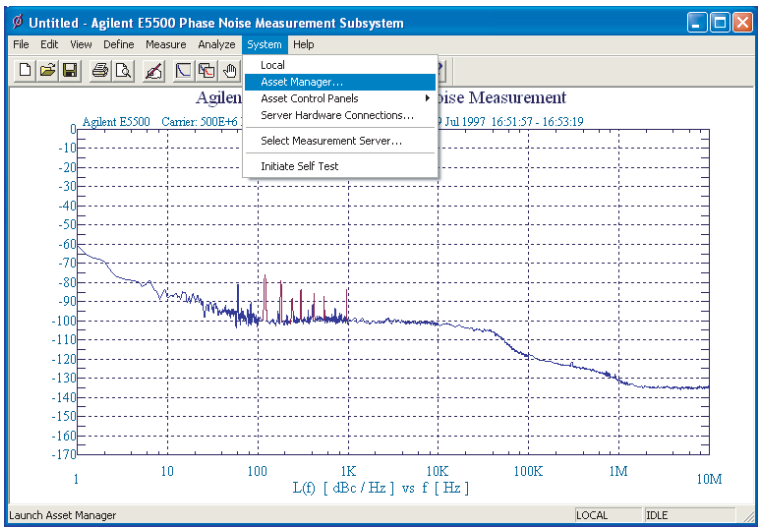

Figure 32 Asset Manager on System menu

2 Double-Click on the desired instrument in the Asset Manager list (left pane). See Figure 33.

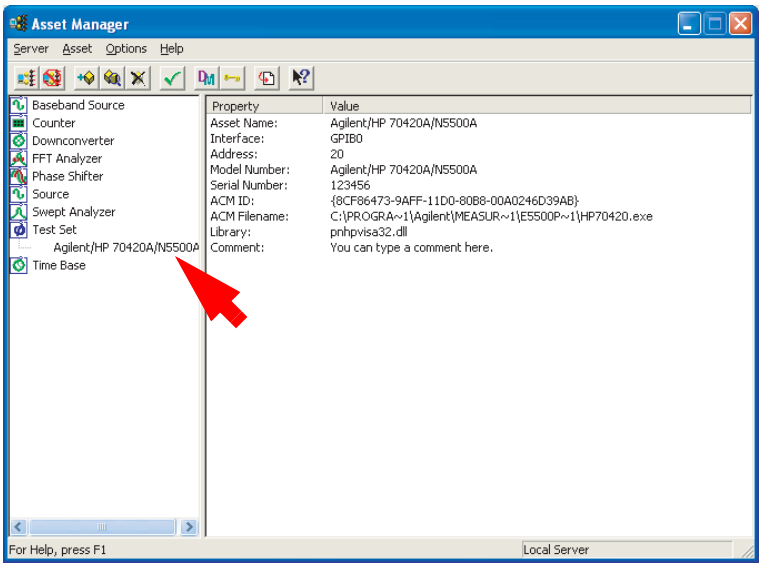

Figure 33 Asset Manager window

3 Type the desired address in the dialog box. See Figure 34.

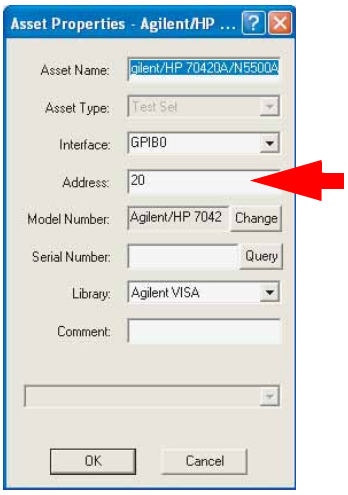

Figure 34 GPIB address dialog box

4 Click **OK**.

5 To exit the Asset Manager, on the menu select **Server/Exit**.

Next proceed to one of the following absolute measurements using either an Agilent 8257x or an Agilent 8644B source:

- “Testing the 8663A Internal/External 10 MHz" on page 66.
- “Testing the 8644B Internal/External 10 MHz" on page 81.

Testing the 8663A Internal/External 10 MHz

This measurement example helps you measure the absolute phase noise of an RF synthesizer.

CAUTION To prevent damage to the test set's hardware components, *do not* apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 6 on page 73. Apply the input signal when the connection diagram appears.

Required equipment

This measurement requires an Agilent 8663A in addition to the phase noise test system and your device under test (DUT). You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the measurement

1 From the **File** menu in the E5500 User Interface, choose **Open**. If necessary, choose the drive or directory where the file you want is stored.

2 In the **File Name** box, choose "**Conf_SigGen_10MHz.pnm**." See Figure 35.

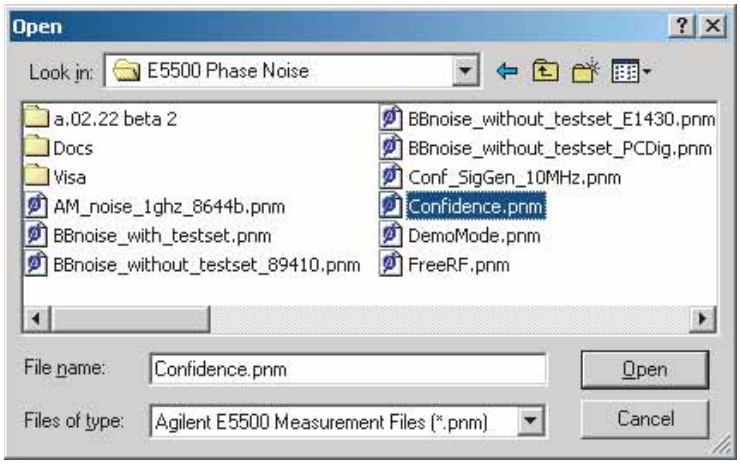

Figure 35 Select the parameters definition file

3 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 7 on page 79 lists the parameter data that has been entered for this measurement example.)

NOTE

Note that the source parameters entered for step 2 in Table 7 on page 79 may not be appropriate for the reference source you are using. To change these values, refer to Table 5 on page 68, then continue with step 4 below. Otherwise, go to "Beginning the measurement" on page 71.

4 Using Figure 36 as a guide, navigate to the **Sources** tab.

- **a** Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.
- **b** Enter the VCO (Nominal) Tuning Constant (see Table 5 on page 68).
- **c** Enter the Tune Range of VCO (see Table 5).
- **d** Enter the Center Voltage of VCO (see Table 5).
- **e** Enter the Input Resistance of VCO (see Table 5).

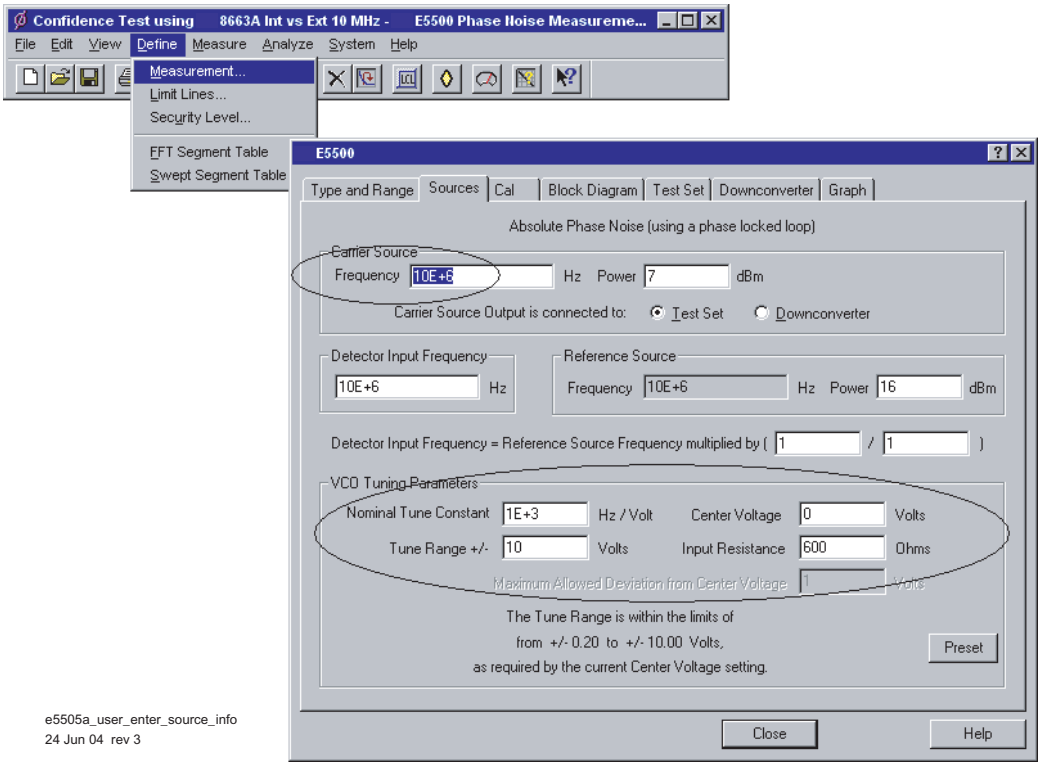

Figure 36 Enter Source Information

Table 5 Tuning characteristics for various sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (± V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A						
EFC	υ_0	5 E – 9 x υ_0	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662) 600 (8663)	Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator						
DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1. Using Figure 37 as a guide, navigate to the **Block Diagram** tab.
2. From the **Reference Source** pull-down list, select Agilent-8663.
3. When you have completed these operations, click the **Close** button.

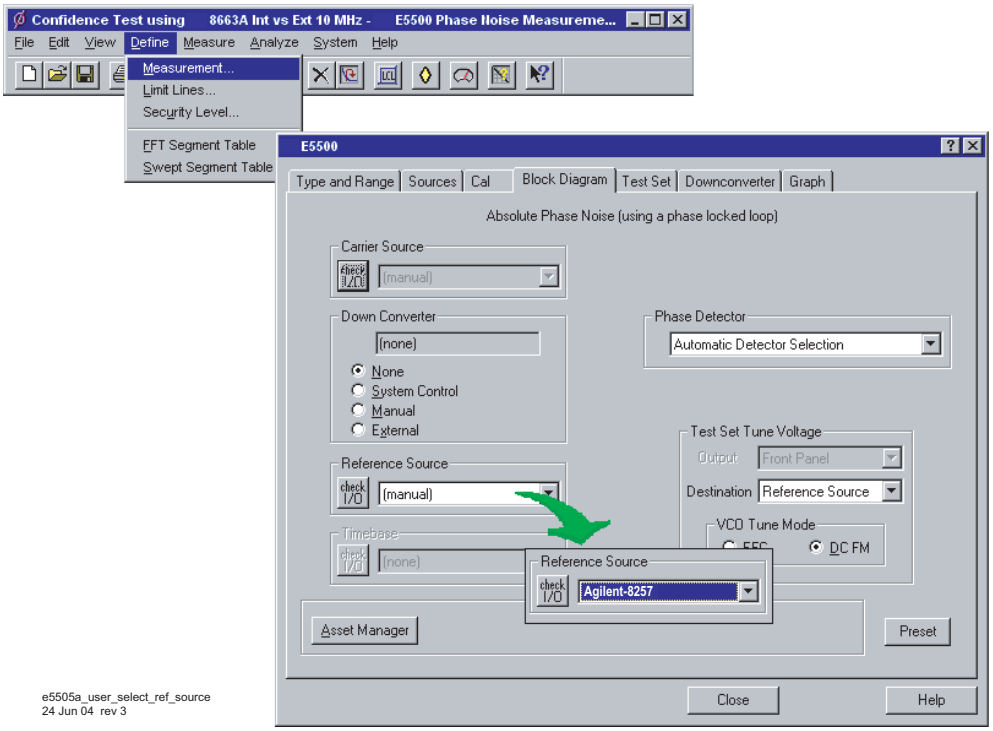

Figure 37 Selecting a reference source

Selecting loop suppression verification

1 Using Figure 38 as a guide, navigate to the **Cal** tab.

2 Check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph.**

3 When you have completed these operations, click the **Close** button.

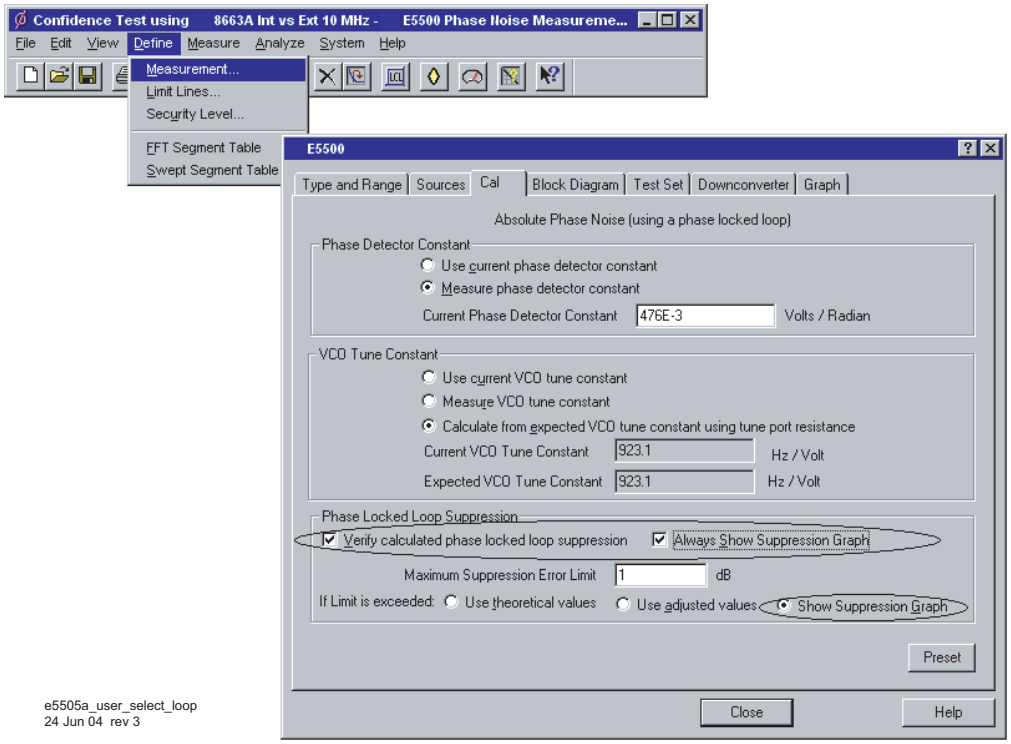

Figure 38 Selecting loop suppression verification

Setting up for the 8663A 10 MHz measurement

The signal amplitude at the test set's R input (Signal Input) port sets the measurement noise floor level. Use Figure 39 on page 70 and Figure 40 on page 70 to help determine the amplitude required to provide a noise floor level that is below the expected noise floor of your DUT. For more information about this graph, refer to "Reference Graphs and Tables" on page 361.

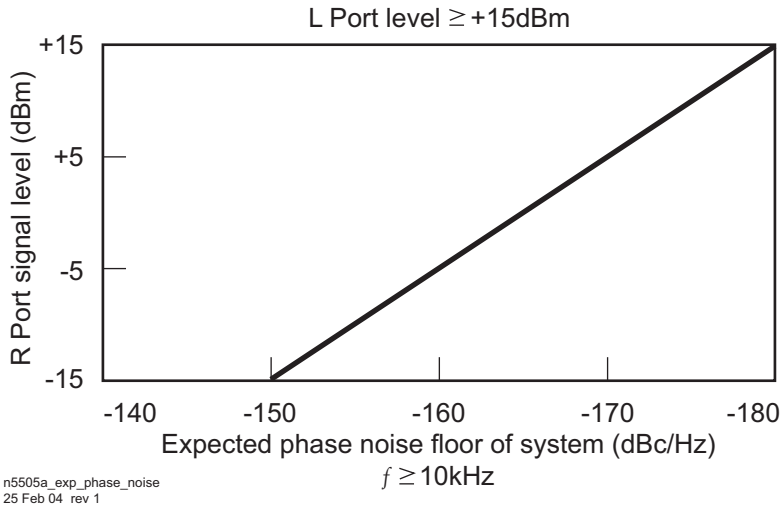

Figure 39 Noise floor for the 8663 10 MHz measurement

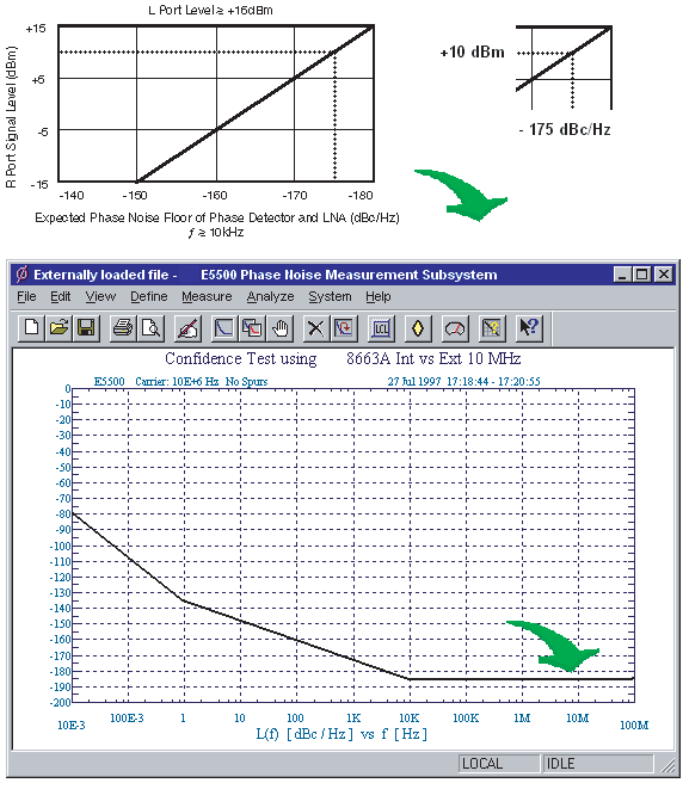

Figure 40 Noise floor example

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it is necessary to insert a low-noise amplifier between the DUT and the test set. Refer to "Inserting a Device" on page 122 for details on determining the effect the amplifiers noise will have on the measured noise floor.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement. See** Figure 41**.**

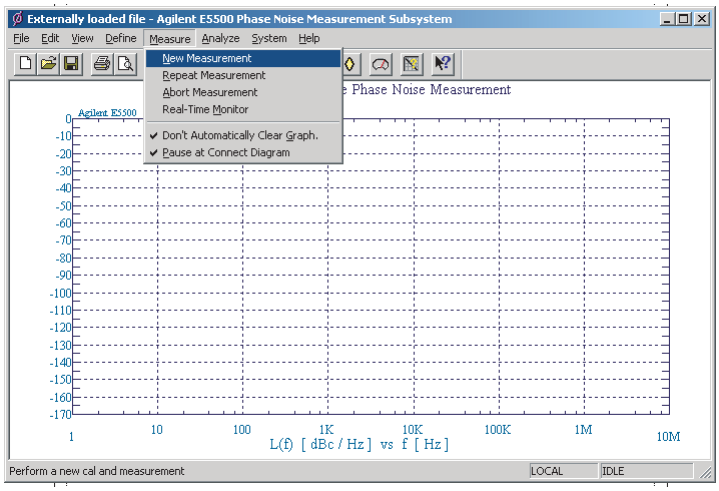

Figure 41 Selecting new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes.**

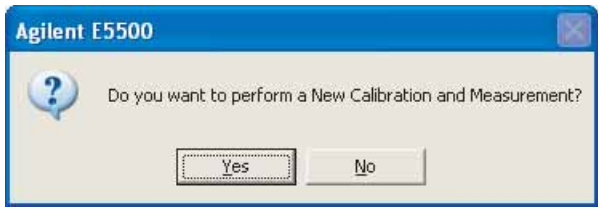

Figure 42 Confirm new measurement

3 When the **Connect Diagram** dialog box appears, click on the hardware pull-down arrow and select your hardware configuration from the list. See Figure 43 on page 72.

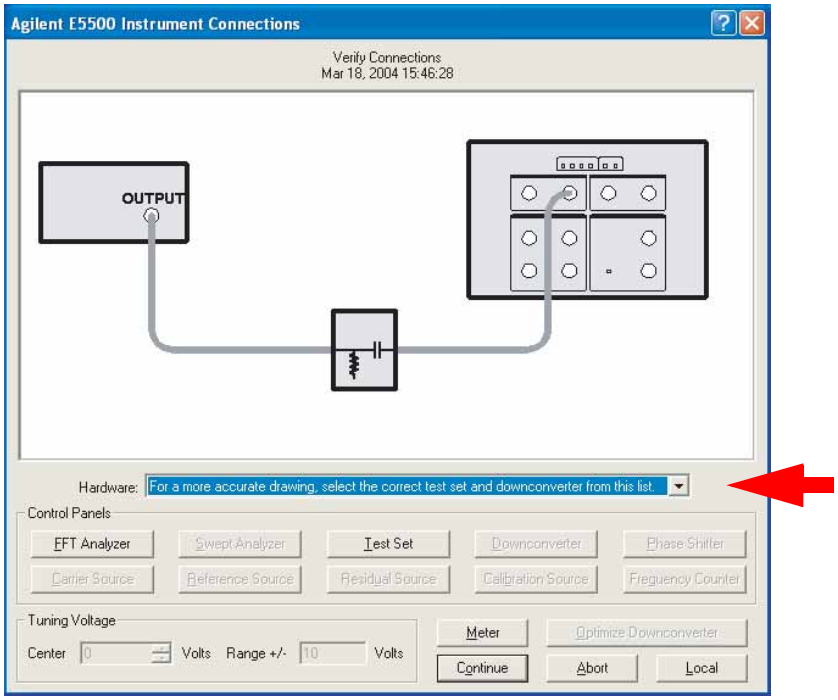

Figure 43 Connection diagram

4 Connect your DUT and reference sources to the test set at this time and confirm your connections as shown in the appropriate connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics contained in Table 6 on page 73.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which occurs at the connection diagram.

5 Press Continue.

- As the system performs the calibration routines, various status messages appear on the display. When the last message—**Measuring PLL suppression**—appears, you can choose to continue the routine or stop it.

6 Press **Continue using Adjusted Loop Suppression** to continue making the noise measurement, or press **Abort** to stop the measurement. (For descriptions of the messages, see **"Status messages"** on page 74**.** You have time to read through the descriptions while the system completes the routines**.)**

:

Table 6 Test set signal input limits and characteristics

Limits	
Frequency	50 kHz to 26.5 GHz
Maximum Signal Input Power	+30 dBm (with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm
• Microwave Phase Detectors	0 to +5 dBm
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• N5502A/70422A	+5 to +15 dBm
• N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

NOTE

Refer to the following system connect diagram examples in Chapter 18, “System Interconnections” for more information about system interconnections.

- Figure 307, “E5505A system connections with standard test set,” on page 403
- Figure 308, “E5505A system connections with test set option 001,” on page 404
- Figure 309, “E5505A system connections with test set option 201,” on page 405

Status messages

This section describes the status messages that appear on the display as the system performs its calibration routines.

Determining Presence of Beat Note... An initial check is made to verify that a beatnote is present within the system's detection range.

Verifying Zero-Beat... The frequency of the beatnote is measured to see if it is within 5% of the estimated Peak Tuning Range of the system. The system's Peak Tuning Range is the portion of the voltage-controlled-oscillator (VCO) source's tuning range being used for the measurement.

When the system measures the phase noise of a signal source using the Phase Lock Loop technique (the technique being used in this example) it requires that one of the two sources used in the setup is a VCO. As you will see later in this demonstration, you are required to estimate the tuning range of the VCO source you are using when you set up your own Phase Lock Loop measurements.

Zero beating sources... The center frequencies of the sources are now adjusted, if necessary, to position the beatnote within the 5% range. The adjustment is made with the tune voltage applied to the VCO source set at its nominal or center position.

Measuring the VCO Tuning Constant... The tuning sensitivity (Hz/V) of the VCO source is now precisely determined by measuring the beatnote frequency at four tune voltage settings across the tuning range of the VCO source. Linearity across the tuning range is also verified

Measuring the Phase Detector Constant... The transfer characteristics (V/rad) of the test set's phase detector are now determined for the specific center frequency and power level of the sources being measured.

Measuring PLL suppression... The required correction data is created to compensate for the phase noise suppression which occurs within the bandwidth of the phase lock loop created for this measurement. The computer displays the PLL suppression curve and associated measurement values.

Sweep segments

When the system begins measuring noise, it places the noise graph on its display. As you watch the graph, you see the system plot its measurement results in frequency segments.

The system measures the noise level across its frequency offset range by averaging the noise within smaller frequency segments. This technique enables the system to optimize measurement speed while providing you with the measurement resolution needed for most test applications.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results for help in evaluating your measurement results. (If the test system has problems completing the measurement, it informs you by placing a message on the computer display.

Checking the beatnote

While the Connect Diagram is still displayed, Agilent recommends that you use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your DUT. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system.

The phase lock loop (PLL) Capture Range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO. Refer to Chapter 14, “Evaluating Your Measurement Results” if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.)

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system is not able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote is very close to 0 Hz.

Searching for the beatnote requires that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display. See Figure 44 on page 76.

If incrementing the frequency of one of the sources does not produce a beatnote, you need to verify the presence of an output signal from each source before proceeding.

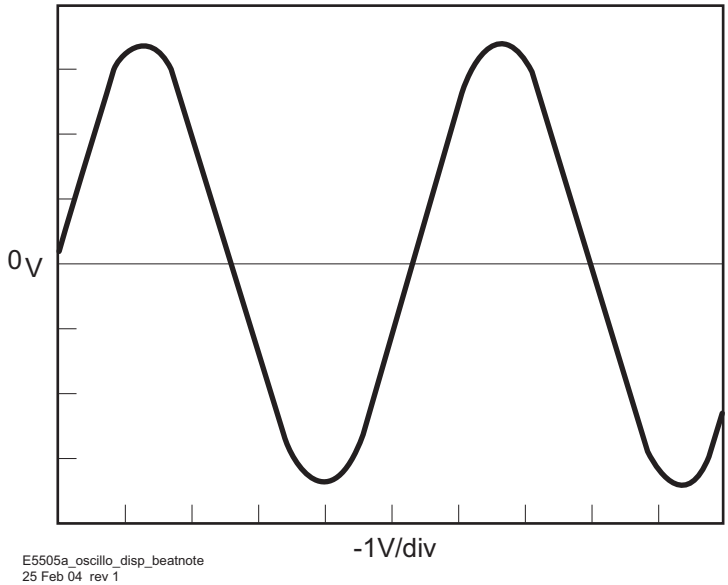

Figure 44 Oscilloscope display of beatnote from test set monitor port

Making the measurement

1. Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.
2. When the PLL Suppression Curve dialog box appears, check View Measured Loop Suppression, View Smoothed Loop Suppression, and View Adjusted Loop Suppression in the lower right of the dialog box.
   See **Figure 45** on page 77.

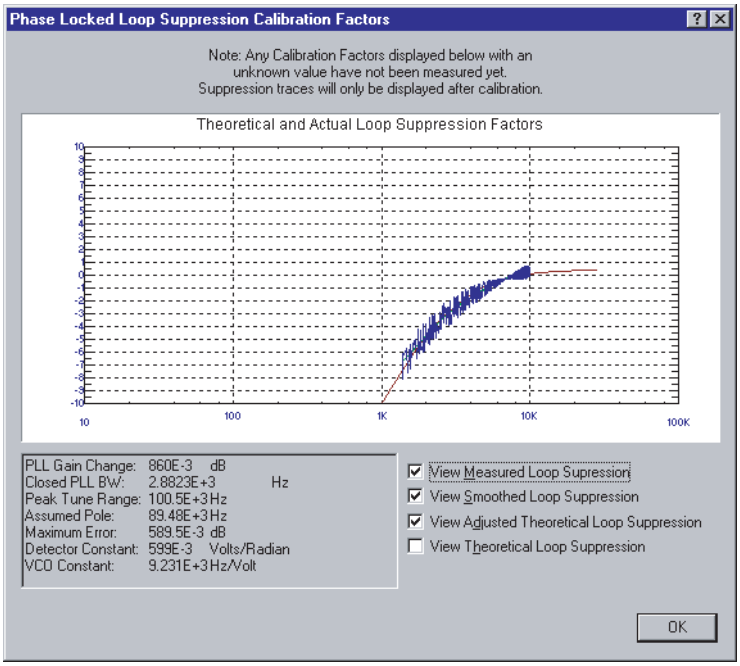

Figure 45 Selecting suppression

There are four different curves for the this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features”).

- “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.
- “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.
- “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, and others).
- “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results for help in evaluating your measurement results.

Figure 46 on page 78 shows a typical phase noise curve for an RF Synthesizer.

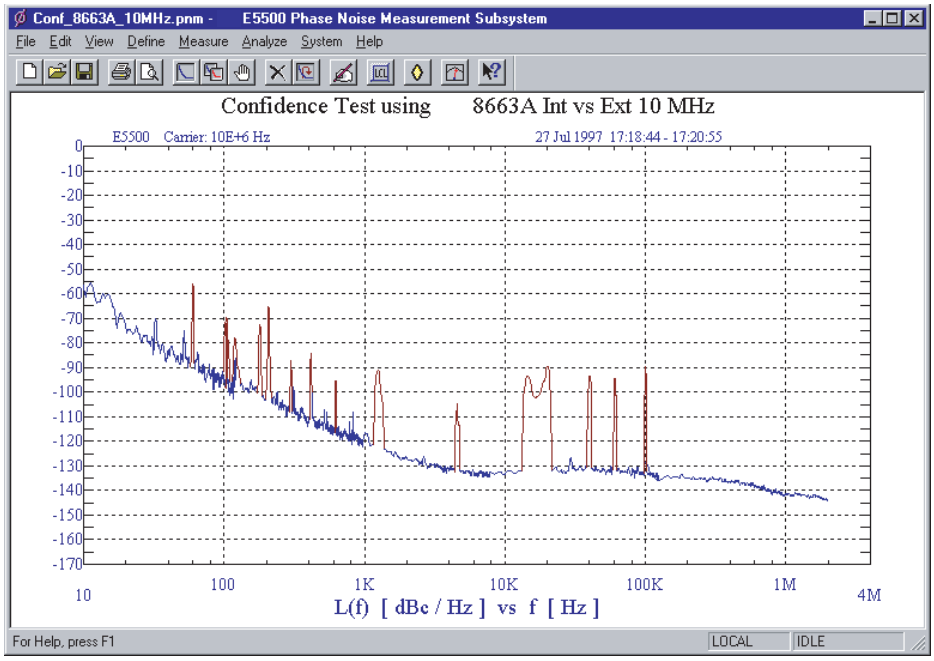

Figure 46 Typical phase noise curve for an 8663A 10 MHz measurement

Table 7 on page 79 contains the data stored in the parameter definitions file.

Table 7 Parameter data for the 8663A 10 MHz measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	• Measurement Type	• Absolute Phase Noise (with phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 2 E + 6 Hz[1]
	• Minimum Number of Averages	• 4
	• FFT Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 10 E + 6 Hz
	• Power	• 7 dBm
	• Carrier Source Output connected to	• Test Set
		• 10 E +6 Hz
	• Detector Input Frequency	• 10 E +6 Hz (same as Carrier Source Frequency)
	• Reference Source Frequency	
	• Reference Source Power	• 16 dBm
	• VCO Tuning Parameters:	
	• Nominal Tune Constant	• 1 E +3 Hz/V
	• Tune Range ±	• ± 10 Volts
	• Center Voltage	• 0 Volts
	• Input Resistance	• 600 ohms
3	**Cal Tab**	
	• Phase Detector Constant	• Measure Phase Detector Constant
	• VCO Tune Constant	• Calculate from expected VCO Tune Constant
	• Phase Lock Loop Suppression	• Verify calculated phase locked loop suppression
	• If Limit is exceeded	• Show Suppression Graph
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Downconverter	• None
	• Reference Source	• Agilent 8663A
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination	• Reference Source
	• VCO Tune Mode	• DCFM
5	**Test Set Tab**	
	• Input Attenuation	• 0 dB
	• LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm

Table 7 Parameter data for the 8663A 10 MHz measurement (continued)

Step	Parameters	Data
6	**Dowconverter Tab**	The downconverter parameters do not apply to this measurement example.
7	**Graph Tab**	
	• Title	• Confidence Test using Agilent 8663A Int vs Ext 10 MHz
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 4 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –170 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

1 The Stop Frequency depends on the analyzers configured in your phase noise system.

Testing the 8644B Internal/External 10 MHz

This measurement example helps you measure the absolute phase noise of an RF synthesizer.

CAUTION To prevent damage to the test set's hardware components, *do not* apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 8 on page 83. Apply the input signal when the connection diagram appears.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Required equipment

This measurement requires an Agilent 8644B in addition to the phase noise test system and your DUT. You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

Defining the measurement

1 From the file menu of the E5505A User Interface, choose **Open**. If necessary, choose the drive or directory where the file you want is stored.

2 In the **File Name** box, choose "**Conf_8644B_10MHz.pnm.**" See Figure 41.

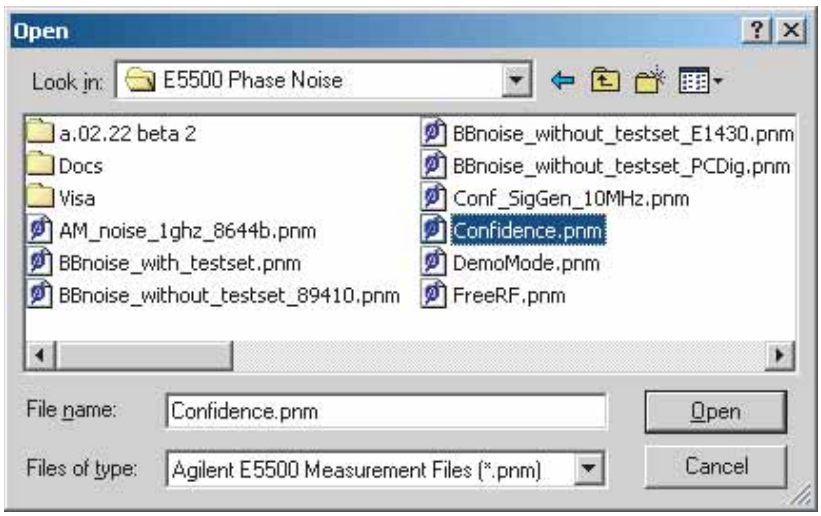

Figure 47 Select the parameters definition file

3 Click the **Open** button.

- The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 10 on page 94 lists the parameter data that has been entered for the RF Synthesizer using a DCFM measurement example.

NOTE

The source parameters shown in Table 10 on page 94 may not be appropriate for the reference source you are using. To change these values, refer toTable 8, “Tuning characteristics for various sources,” on page 83, then continue with step 4 below. Otherwise, go to “Beginning the measurement" on page 87.

4 Using Figure 48 on page 82 as a guide, navigate to the **Sources** tab

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz); enter the same frequency for the detector input frequency.

b Enter the VCO (Nominal) Tuning Constant (see Table 8 on page 83).

c Enter the Tune Range of VCO (see Table 8 on page 83).

d Enter the Center Voltage of VCO (see Table 8 on page 83).

e Enter the Input Resistance of VCO (see Table 8 on page 83)

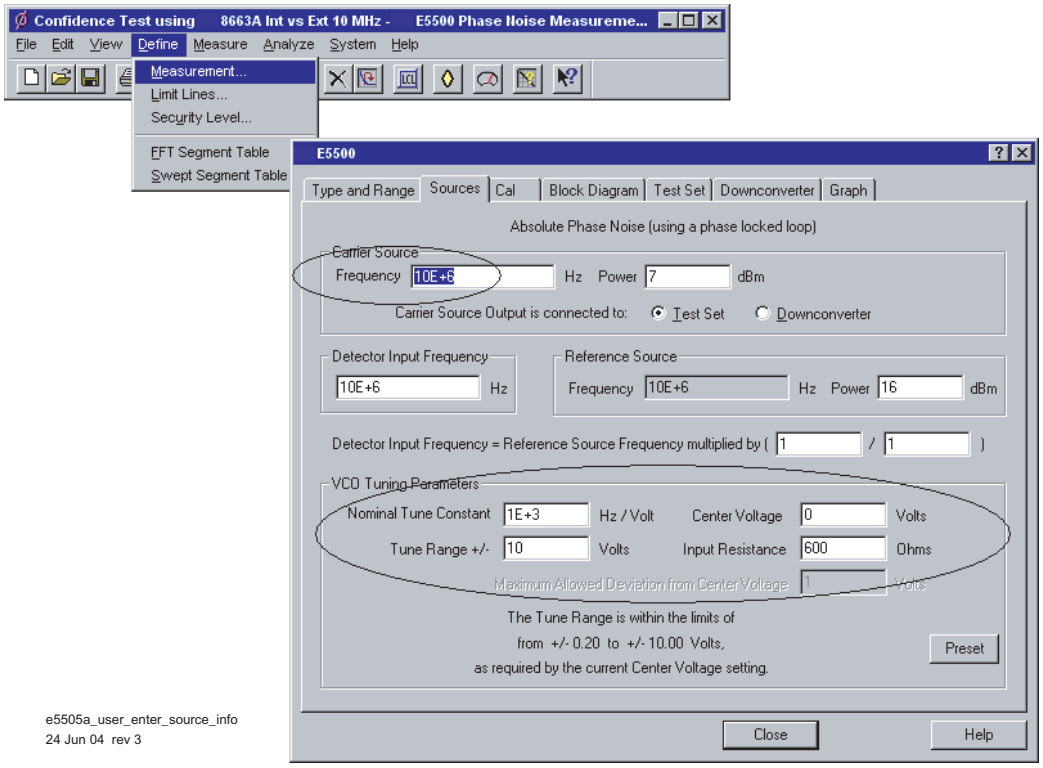

Figure 48 Sources tab in define measurement window

Table 8 Tuning characteristics for various sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (± V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A						
EFC	υ_0	5 E – 9 x υ_0	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662) 600 (8663)	Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1. From the **Define** menu, choose **Measurement;** then choose the **Block Diagram** tab from the **Define Measurement** window. See Figure 49.
2. From the **Reference Source** pull-down list, select **8644**.

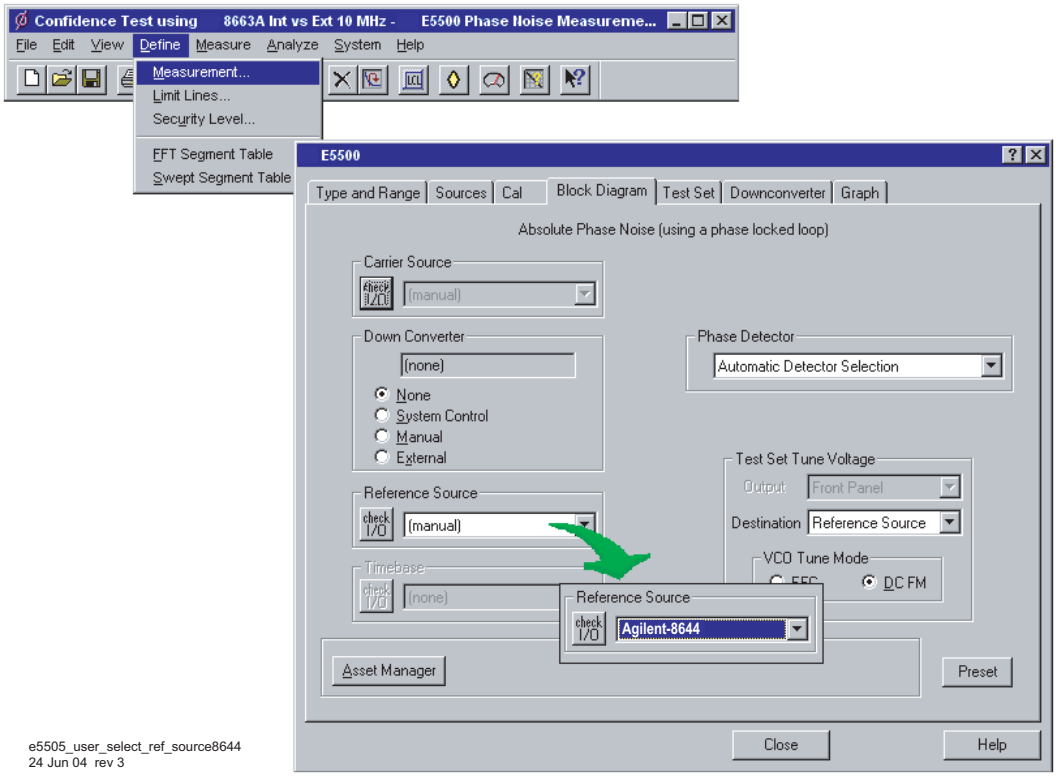

Figure 49 Selecting a reference source

3 When you have completed these operations, click the **Close** button.

Selecting loop suppression verification

1 From the **Define** menu, choose **Measurement;** then choose the **Cal** tab from the **Define Measurement** window.

2 In the **Cal** dialog box, check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph**. See Figure 50 on page 85.

3 When you have completed these operations, click the **Close** button.

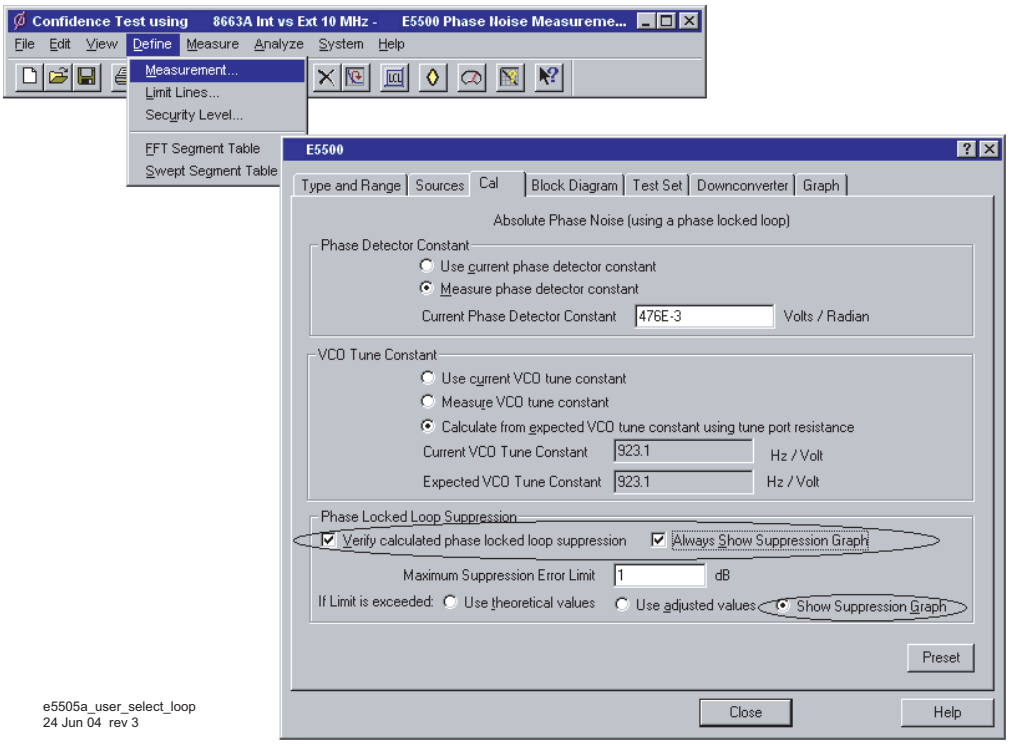

Figure 50 Selecting loop suppression verification

Setting up the 8663A 10 MHz measurement

The signal amplitude at the R input (Signal Input) port on the test set sets the measurement noise floor level. Use the graph in Figure 51 and the example in Figure 52 on page 86 to determine the amplitude. For more information, refer to Chapter 16, “Reference Graphs and Tables.”

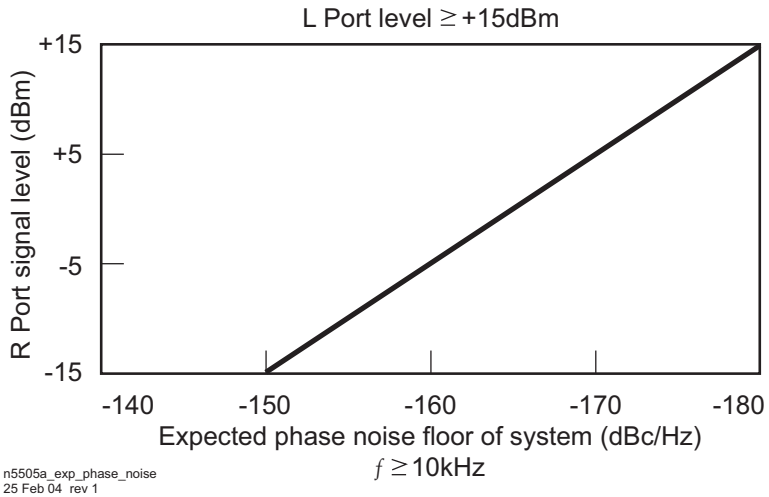

Figure 51 Noise floor for the 8644B 10 MHz measurement

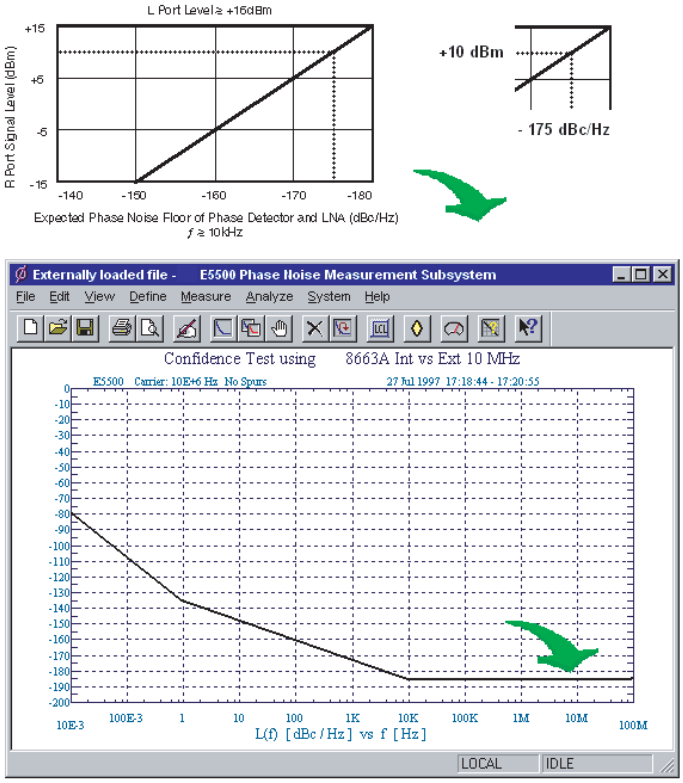

Figure 52 Noise floor example

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it is necessary to insert a low-noise amplifier between the DUT and the test set. Refer to the section "Inserting a Device" on page 122 for details on determining the effect the amplifier's noise will have on the measured noise floor.

Beginning the measurement

CAUTION To prevent damage to the test set's hardware components, *do not* apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 9 on page 89. Apply the input signals when the connection diagram appears, as in step 3 below.

1 From the **Measurement** menu, choose **New Measurement. See Figure 53.**

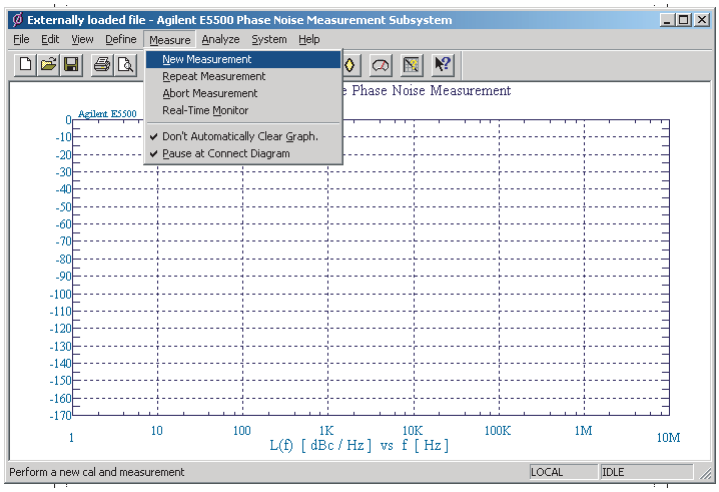

Figure 53 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

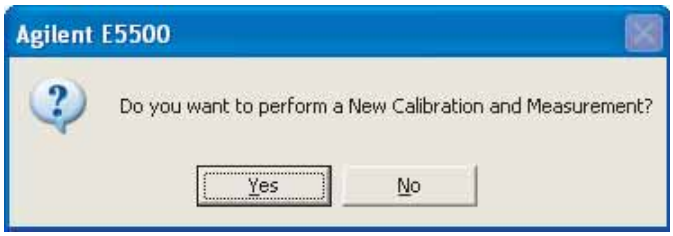

Figure 54 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select your hardware configuration from the list. See Figure 55 on page 88.

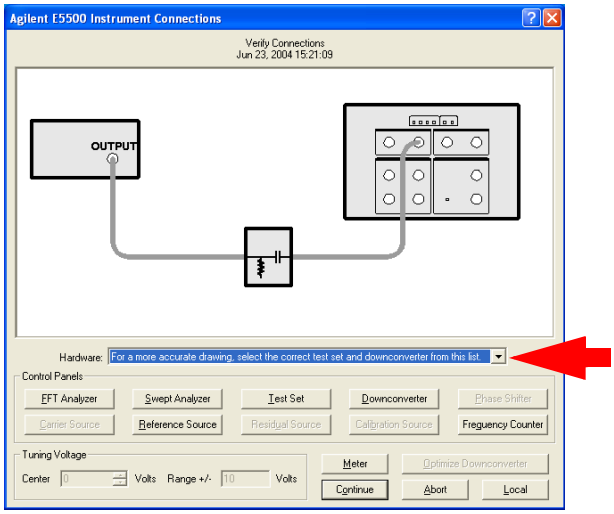

Figure 55 Connect diagram dialog box

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the Connect Diagram (Figure 55).

- The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics in Table 9 on page 89.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which occurs when the connection diagram appears.

5 Press **Continue**.

- As the system performs the calibration routines, various status messages appear on the display. When the last message–**Measuring PLL suppression**–appears, you can choose to continue the routine or stop it.

6 Press **Continue using Adjusted Loop Suppression** to continue making the noise measurement, or press **Abort** to stop the measurement. (For descriptions of the messages, see **"Status messages"** on page 74**.** You have time to read through the descriptions while the system completes the routines**.)**

Table 9 Test set signal input limits and characteristics

Limits	
Frequency	50 kHz to 26.5 GHz
Maximum Signal Input Power	+30 dBm (with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm
• Microwave Phase Detectors	0 to +5 dBm
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

NOTE

Refer to the following system connect diagram examples in Chapter 18, “System Interconnections,” for more information about system interconnections.

- Figure 307, “E5505A system connections with standard test set,” on page 403
- Figure 308, “E5505A system connections with test set option 001,” on page 404
- Figure 309, “E5505A system connections with test set option 201,” on page 405

Status messages

This section describes the status messages that appear on the display as the system performs the calibration routines.

Determining Presence of Beat Note... An initial check is made to verify that a beatnote is present within the system’s detection range.

Verifying zero-beat... The frequency of the beatnote is measured to see if it is within 5% of the estimated Peak Tuning Range of the system. The system’s Peak Tuning Range is the portion of the voltage-controlled-oscillator (VCO) source’s tuning range being used for the measurement.

When the system measures the phase noise of a signal source using the Phase Lock Loop technique (the technique being used in this example) it requires that one of the two sources used in the setup is a VCO. As you see later in this demonstration, you are required to estimate the tuning range of the VCO source you are using when you set up your own Phase Lock Loop measurements.

Zero beating sources... The center frequencies of the sources are now adjusted, if necessary, to position the beatnote within the 5% range. The adjustment is made with the tune voltage applied to the VCO source set at its nominal or center position.

Measuring the VCO Tuning Constant... The tuning sensitivity (Hz/V) of the VCO source is now precisely determined by measuring the beatnote frequency at four tune voltage settings across the tuning range of the VCO source. Linearity across the tuning range is also verified

Measuring the Phase Detector Constant... The transfer characteristics (V/rad) of the test set's phase detector are now determined for the specific center frequency and power level of the sources being measured.

Measuring PLL suppression... The required correction data is created to compensate for the phase noise suppression which occurs within the bandwidth of the phase lock loop created for this measurement. The computer displays the PLL suppression curve and associated measurement values.

Sweep segments

When the system begins measuring noise, it places the noise graph on its display. As you watch the graph, you see the system plot its measurement results in frequency segments.

The system measures the noise level across its frequency offset range by averaging the noise within smaller frequency segments. This technique enables the system to optimize measurement speed while providing you with the measurement resolution needed for most test applications.

When the measurement is complete, refer to Chapter 14, "Evaluating Your Measurement Results" for help in evaluating your measurement results. (If the test system has problems completing the measurement, it informs you by a message on the computer display.

Checking the beatnote

While the Connect Diagram is still displayed, Agilent recommends that you use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your DUT. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system.

The phase lock loop (PLL) Capture Range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO.

Refer to Chapter 14, “Evaluating Your Measurement Results” if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.)

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system is not able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote is very close to 0 Hz.

Searching for the beatnote requires that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display. See Figure 56.

If incrementing the frequency of one of the sources does not produce a beatnote, you need to verify the presence of an output signal from each source before proceeding.

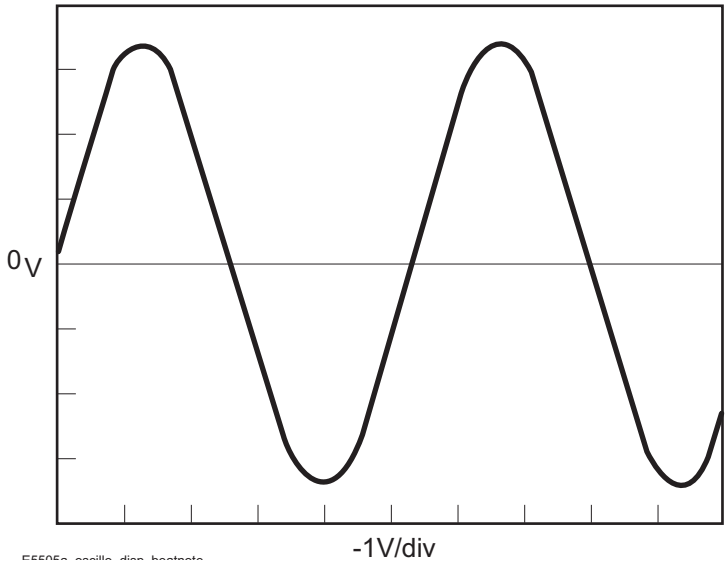

Figure 56 Oscilloscope display of beatnote from test set monitor port

Making the measurement

1 Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.

2 When the PLL Suppression Curve dialog box appears, select **View Measured Loop Suppression**, **View Smoothed Loop Suppression**, and **View Adjusted Loop Suppression. See** **Figure 57** on page 92**.**

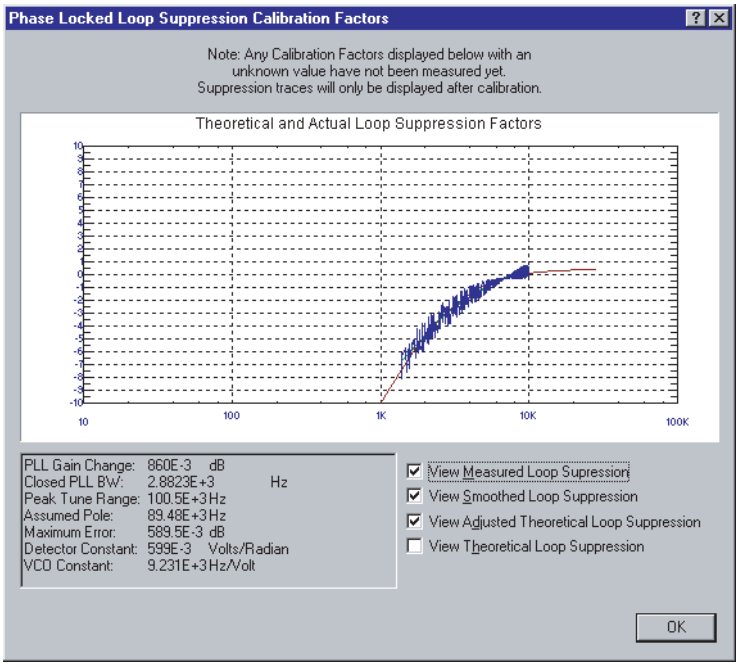

Figure 57 Suppression selections

- There are four different curves for this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features.”)

  a “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.

  b “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.

  c “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, and others).

  d “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 58 on page 93 shows a typical phase noise curve for an RF Synthesizer.

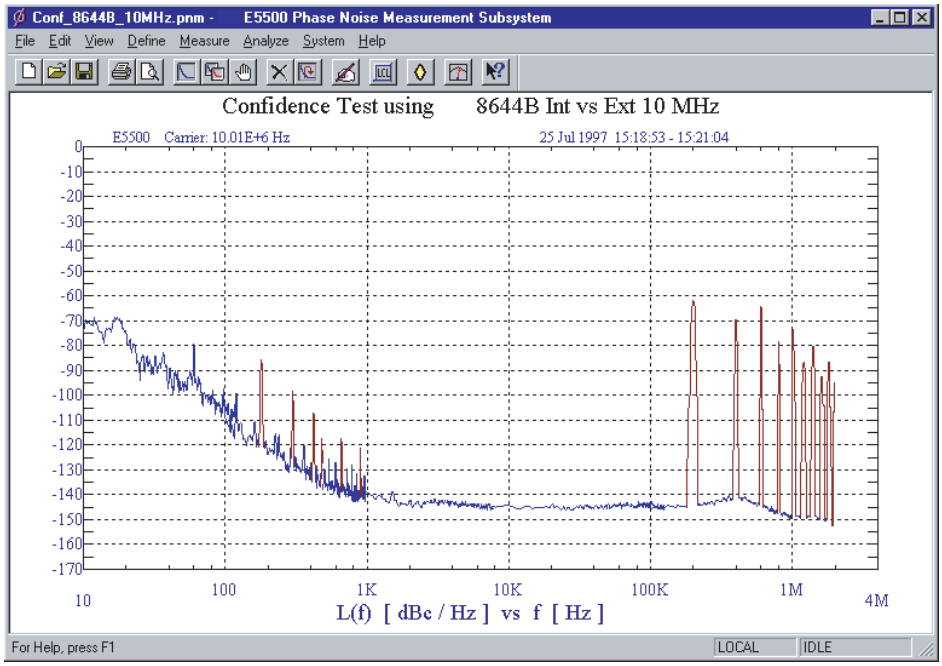

Figure 58 Typical phase noise curve for an 8644B 10 MHz measurement.

Table 10 on page 94 contains the data stored in the parameter definitions file.

Table 10 Parameter data for the **8644B 10** MHz measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	• Measurement Type	• Absolute Phase Noise (using a phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 2 E + 6 Hz[1]
	• Minimum Number of Averages	• 4
	• FFT Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 10 E + 6 Hz
	• Power	• 7 dBm
	• Carrier Source Output is connected to:	• Test Set
	Detector Input	
	• Frequency	• 10 E +6 Hz
	Reference Source	
	• Frequency	• 10 E +6 Hz (same as Carrier Source Frequency)
	• Reference Source Power	• 16 dBm
	VCO Tuning Parameters	
	• Nominal Tune Constant	• 1 E +3 Hz/V
	• Tune Range ±	• ± 10 Volts
	• Center Voltage	• 0 Volts
	• Input Resistance	• 600 ohms
3	**Cal Tab**	
	• Phase Detector Constant	• Measure Phase Detector Constant
	• VCO Tune Constant	• Calculate from expected VCO Tune Constant
	• Phase Lock Loop Suppression	• Verify calculated phase locked loop suppression
	• If Limit is exceeded	• Show Suppression Graph
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Downconverter	• None
	• Reference Source	• Agilent 8644B
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination	• Reference Source
	• VCO Tune Mode	• DCFM
5	**Test Set Tab**	
	• Input Attenuation	• 0 dB
	• LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm

Table 10 Parameter data for the **8644B 10** MHz measurement (continued)

Step	Parameters	Data
6	**Dowconverter Tab**	The downconverter parameters do not apply to this measurement example.
7	**Graph Tab**	
	• Title	• Confidence Test using Agilent 8644B Int vs Ext 10 MHz
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 4 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• - 170 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

1 The stop frequency depends on the analyzers configured in your phase noise system.

Viewing Markers

The marker function allows you to display the exact frequency and amplitude of any point on the results graph.

- To access the marker function, on the **View** menu, click **Markers.** See Figure 59. In the dialog box containing Marker buttons, up to nine markers may be added. To remove a highlighted marker, click the **Delete** button. See Figure 60

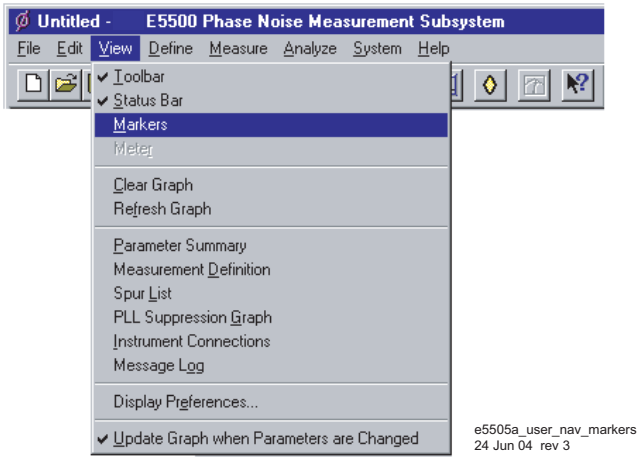

Figure 59 Navigate to markers

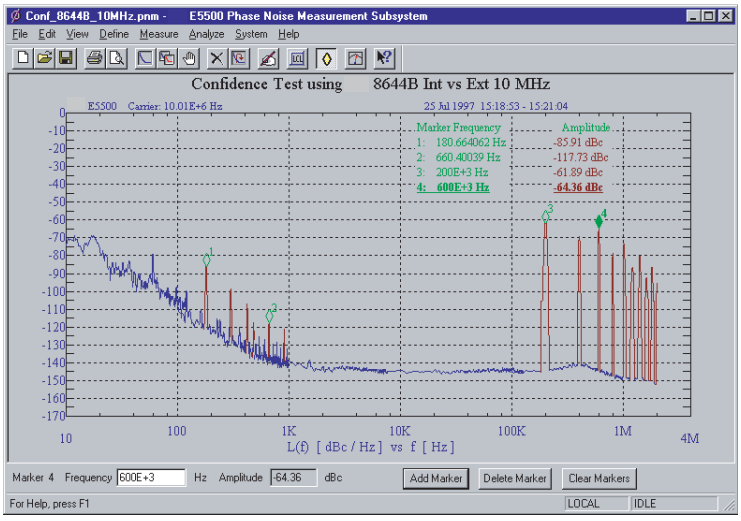

Figure 60 Adding and deleting markers

Omitting Spurs

The Omit Spurs function plots the currently loaded results without displaying any spurs that may be present.

1 On the **View** menu, click **Display Preferences.** See Figure 61.

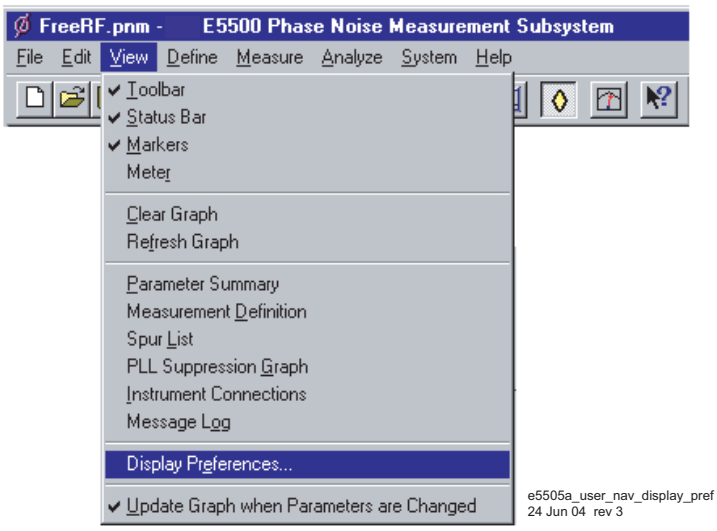

Figure 61 Navigate to display preferences

2 In the **Display Preferences** dialog box, uncheck **Spurs** and click **OK**. See Figure 62.

- The graph is displayed without spurs. See Figure 63 on page 98.

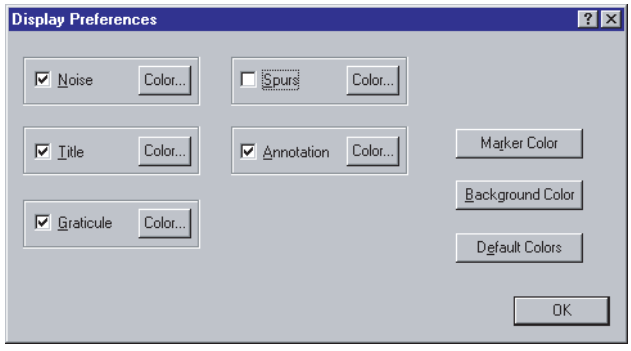

Figure 62 Uncheck spurs

3 To re-display the spurs, check **Spurs** in the **Display Preferences** dialog box.

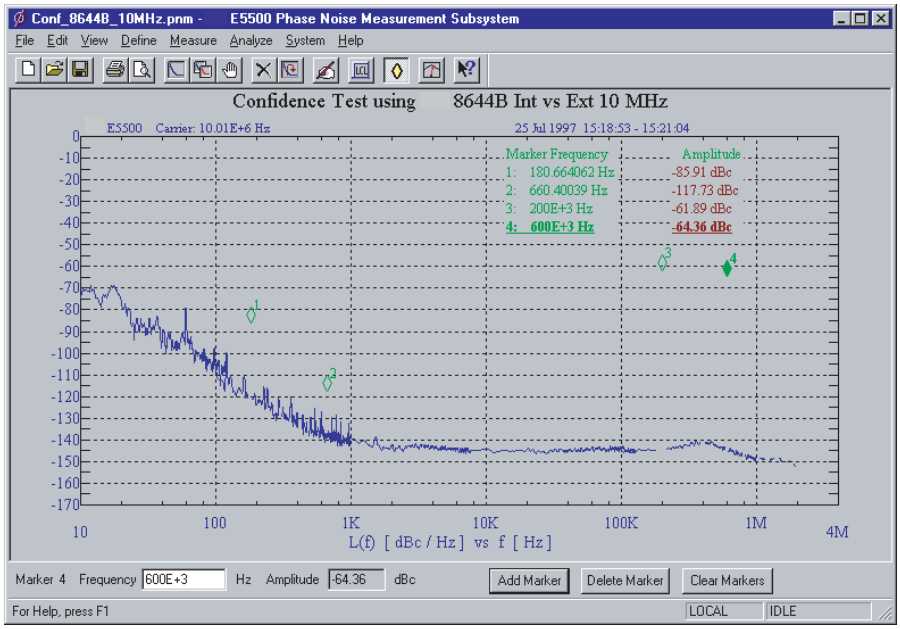

Figure 63 Graph displayed without spurs

Displaying the Parameter Summary

The Parameter Summary function allows you to quickly review the measurement parameter entries that were used for this measurement. The parameter summary data is included when you print the graph.

1 On the **View** menu, click **Parameter Summary.** See Figure 64.

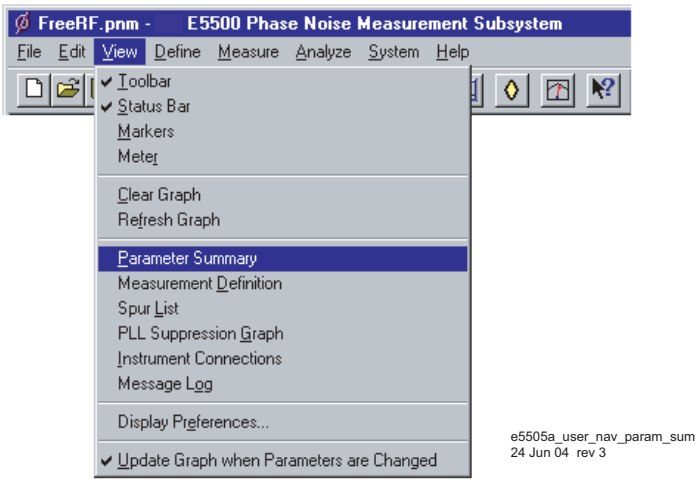

Figure 64 Navigate to parameter summary

2 The **Parameter Summary Notepad** dialog box appears. The data can be printed or changed using standard Notepad functionality. See Figure 65 on page 100.

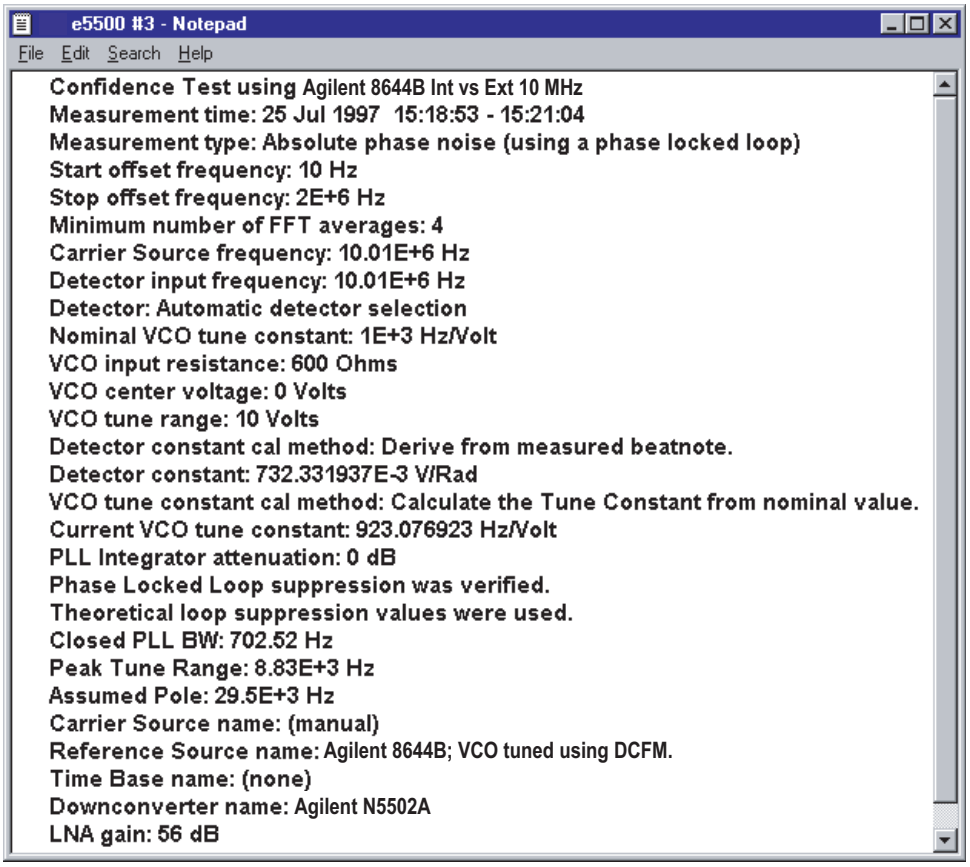

Figure 65 Parameter summary

Exporting Measurement Results

The Export Measurement Results function exports data in one of three types:

- Exporting Trace Data
- Exporting Spur Data
- Exporting X-Y Data

1 To export measurement results, on the **File** menu, point to **Export Results,** then click on either **Trace Data**, **Spur Data**, or **X-Y Data.** See Figure 66.

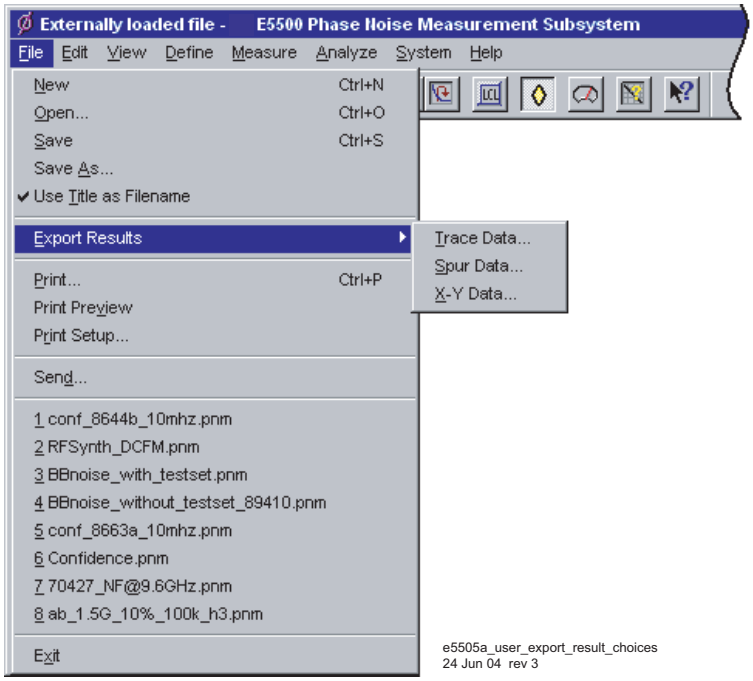

Figure 66 Export results choices

Exporting Trace Data

1 On the **File** menu, point to **Export Results,** then click on **Trace Data.** See Figure 67 on page 102.

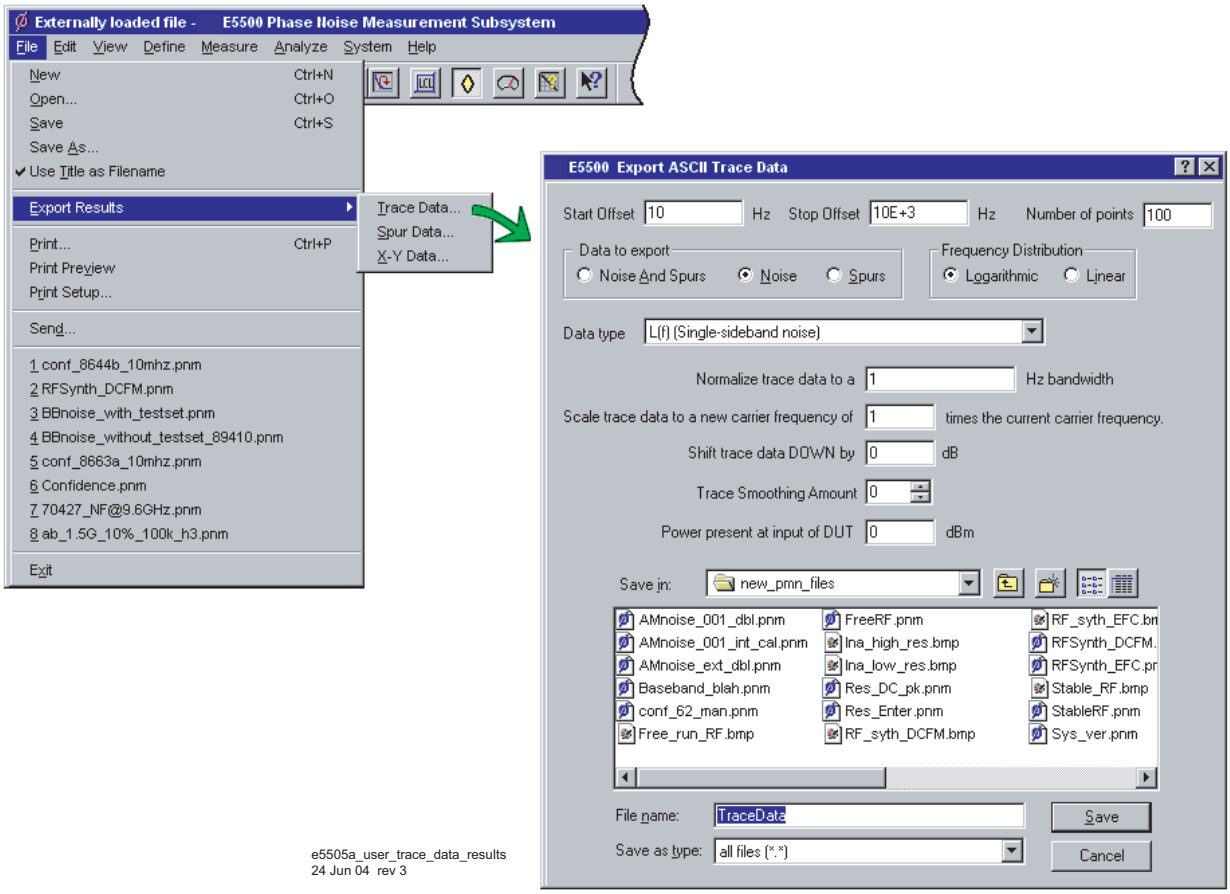

Figure 67 Trace data results

Exporting spur data

1 On the **File** menu, point to **Export Results,** then click on **Spur Data.** See Figure 68.

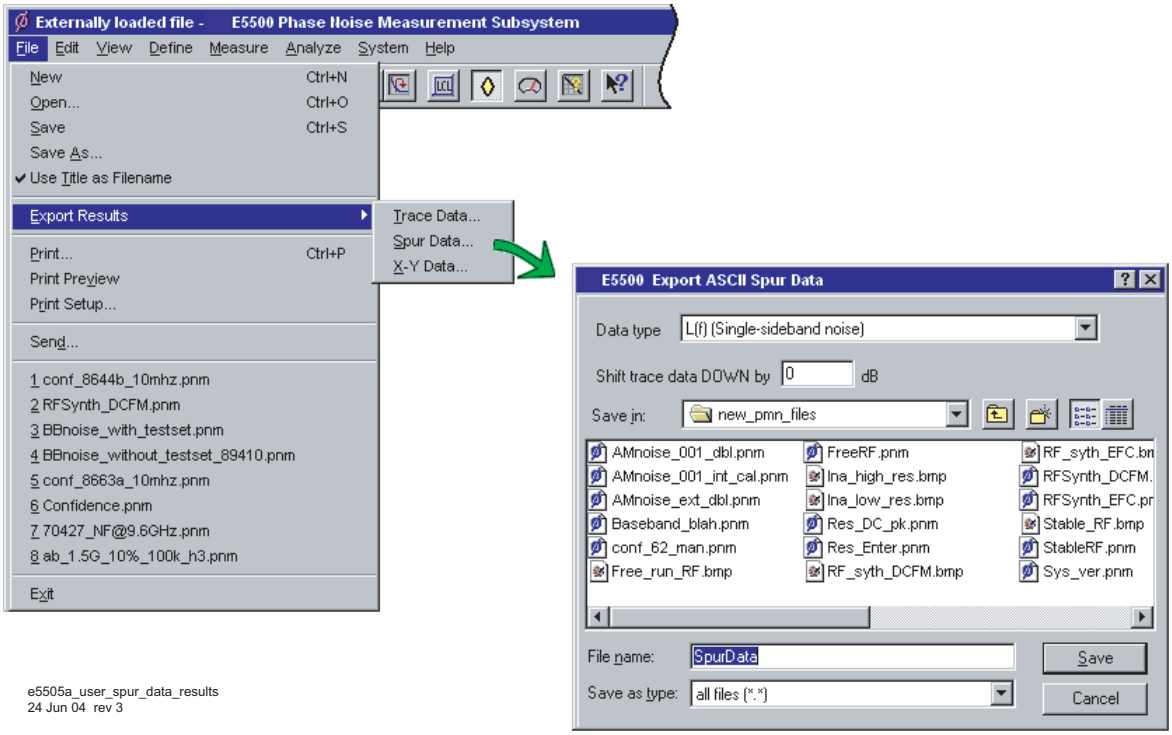

Figure 68 Spur data results

Exporting X-Y data

1 On the **File** menu, point to **Export Results,** then click on **X-Y Data.** See Figure 69.

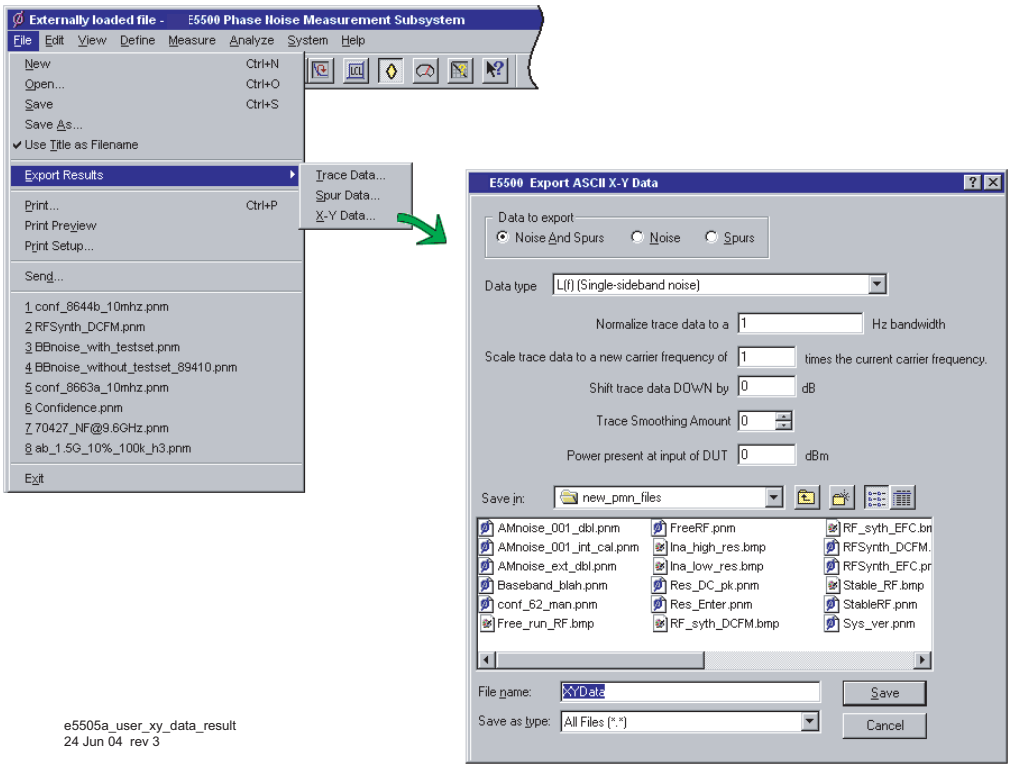

Figure 69 X-Y data results

5 Absolute Measurement Fundamentals

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Selecting a Reference 112
Estimating the Tuning Constant 115
Tracking Frequency Drift 116
Changing the PTR 118
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The Phase-Lock-Loop Technique

The phase lock loop measurement technique requires two signal sources; the source-under-test and a reference source. This measurement type requires that one of the two sources is a voltage-controlled-oscillator (VCO).

You will most likely use the phase lock loop technique since it is the measurement type most commonly used for measuring signal source devices. This chapter focuses on this measurement type for signal source measurements.

Understanding the Phase-Lock-Loop Technique

This measurement technique requires two signal sources set up in a phase locked loop (PLL) configuration. One of the sources is the DUT. The second source serves as the reference against which the DUT is measured. (One of the two sources must be a VCO source capable of being frequency tuned by the System.) Figure 70 shows a simplified diagram of the PLL configuration used for the measurement.

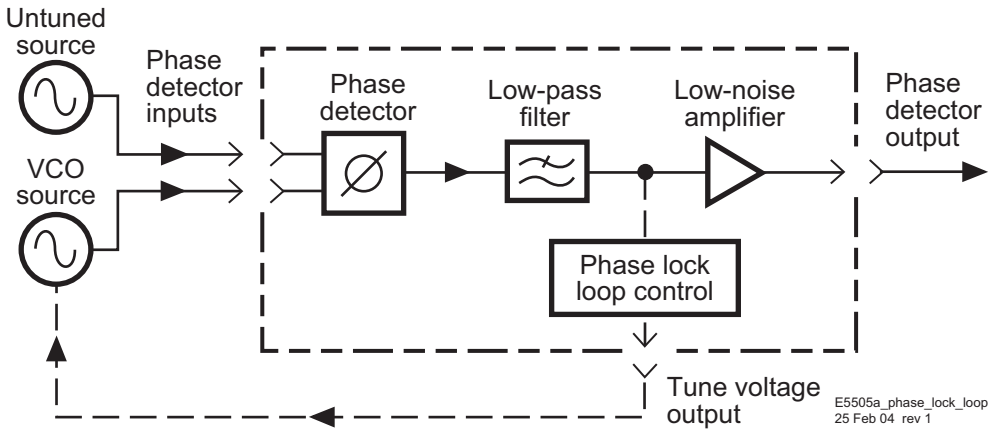


Figure 70 Simplified block diagram of the phase lock loop configuration

The Phase-Lock-Loop Circuit

The Capture and Drift tracking ranges

Like other PLL circuits, the phase lock loop created for the measurement has a Capture Range and a drift tracking range. The Capture Range is equal to 5% of the system's peak tuning range, and the drift tracking range is equal to 24% of the system's peak tuning range.

The system's peak tuning range is derived from the tuning characteristics of the VCO source you are using for the measurement. Figure 71 illustrates the relationship that typically exists between the VCO's peak-to-peak tuning range and the tuning range of the system.

The system's drift tracking range is limited to a small portion of the peak tuning range to minimize the possibility of measurement accuracy degradation caused by non-linearity across the VCO's tuning range.

Peak tune range (PTR)

PTR is determined using two parameters:

- VCO tuning sensitivity (Hz/Volt)
- Total voltage tuning range (Volts)

PTR = (VCO Tuning Sensitivity) X (Total Voltage Tuning Range)

PTR = (100 Hz/V) X (10 V) = 1000 Hz

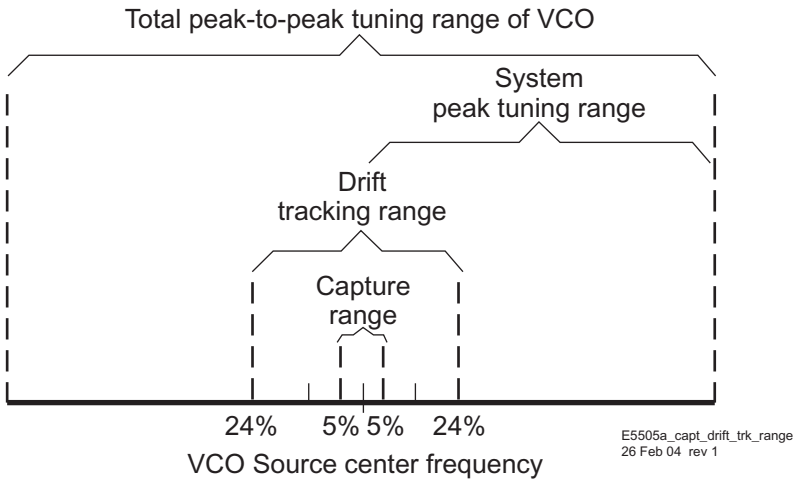


Figure 71 Capture and drift-tracking range with tuning range of VCO

As an Example:

A Peak Tuning Range of 1000 Hz provides the following ranges:

Capture Range = 0.05 X 1000 Hz = 50 Hz

Drift Tracking Range = 0.24 X 1000 Hz = 240 Hz

Tuning requirements

The peak tuning range required for your measurement depends on the frequency stability of the two sources you are using. The signals from the two sources are mixed in the system's phase detector to create a beatnote. In order for the loop to acquire lock, the center frequencies of the sources must be close

enough together to create a beatnote that is within the system's Capture Range. Once the loop is locked, the frequency of the beatnote must remain within the drift tracking range for the duration of the measurement. In Figure 72, the ranges calculated in the previous example are marked to show their relationship to the beatnote frequency.

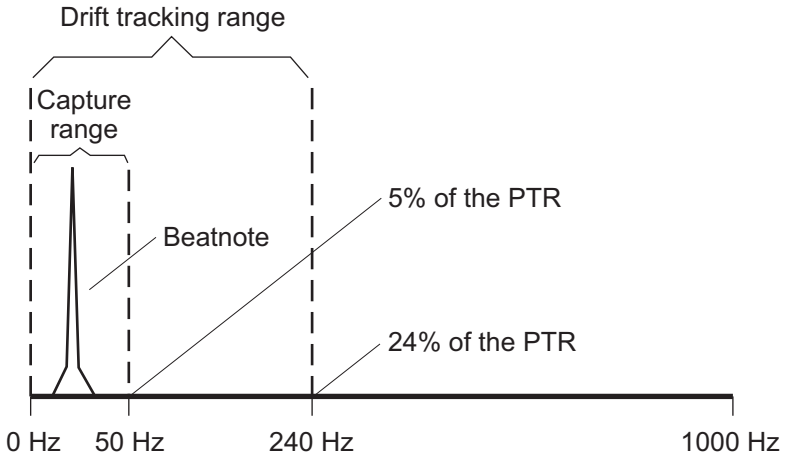


Figure 72 Capture and drift-tracking ranges and beatnote frequency

If the beatnote does not remain within the drift tracking range during the measurement, the out of lock detector is set and the System stops the measurement. If this happens, you need to increase the system's drift tracking range by increasing the system's peak tuning range (if possible) or by selecting a VCO source with a greater tuning range.

Selecting the VCO source

Although you must select a VCO source that provides a sufficient tuning range to permit the system to track the beatnote, keep in mind that a wide tuning range typically means a higher noise level on the VCO source signal. When the VCO source for your measurement is also the reference source, this trade-off can make reference source selection the most critical aspect of your measurement setup.

Specifying your VCO source

When you set up your PLL measurement, you need to know four things about the tuning characteristics of the VCO source you are using. The System determines the VCO source's peak tuning range from these four parameters.

- Tuning Constant, estimated tuning sensitivity (Hz/V)
- Center Voltage of Tuning Range, (V)
- Tune Range of VCO, (±V)

- Input Resistance of Tuning Port, (ohms) if the tuning constant is not to be measured.

The measurement examples in the next chapter that recommend a specific VCO source provides you with the tuning parameters for the specified source.

What Sets the Measurement Noise Floor?

The noise floor for your measurement is set by two things:

- The noise floor of the phase detector and low-noise amplifier (LNA)
- The noise level of the reference source you are using

The System Noise Floor

The noise floor of the system is directly related to the amplitude of the input signal at the R input port of the system's phase detector. Table 11 shows the amplitude ranges for the L and R ports.

Table 11 Amplitude ranges for L and R ports

Phase Detector				
50 kHz to 1.6 GHz		**1.2 to 26.5 GHz[1]**		**50 kHz to 26.5 GHz[2]**
Ref Input (L Port)	**Signal Input (R Port)**	**Ref Input (L Port)**	**Signal Input (R Port)**	**AM Noise**
+ 15 dBm to + 23 dBM	0 dBm to + 23 dBM	+ 7 dBm to + 10 dBM	0 dBm to + 5 dBM	0 dBm to 20 dBM

1 Phase noise test set Options 001 and 201 with no attenuation.

2 Phase noise test set Option 001 with no attenuation.

If the L port (Reference Input) signal is within the amplitude range shown in Table 11, the signal level at the R (Signal Input) port sets the noise floor for the system.

Figure 73 shows the relationship between the R (signal) input level and the system noise floor.

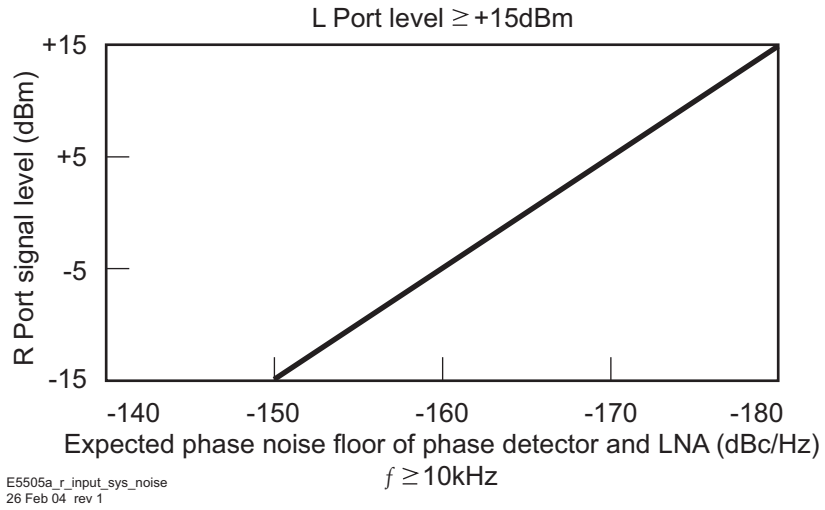


Figure 73 Relationship between the R input level and system noise floor

The Noise Level of the Reference Source

Unless it is below the system's noise floor, the noise level of the source you are using as the reference source sets the noise floor for the measurement. When you set up your measurement, you want to use a reference source with a noise level that is at or below the level of the source you are going to measure.

Figure 74 demonstrates that as the noise level of the reference source approaches the noise level of the DUT, the level measured by the System (which is the sum of all noise sources affecting the system) is increased above the actual noise level of the DUT.

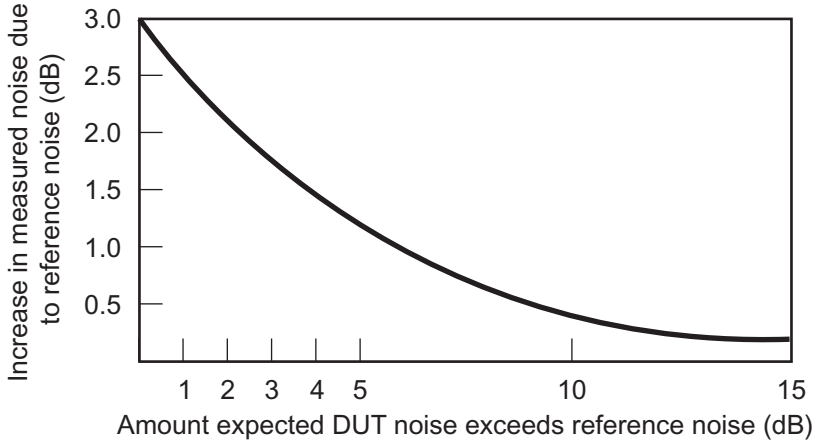


Figure 74 Reference source noise approaches DUT noise

Selecting a Reference

Selecting an appropriate reference source is critical when you are making a phase noise measurement using the phase lock loop technique. The key to selecting a reference source is to compare the noise level of the reference with the expected noise level of the DUT. In general, the lower the reference source's noise level is below the expected noise level of the DUT the better. (Keep in mind that you only need to be concerned about the reference source's noise level within the frequency offset range over which you plan to measure the DUT.)

As shown by the graph in Figure 75, the further the reference source's noise level is below the noise level of the DUT, the less the reference source's noise contributes to the measurement results.

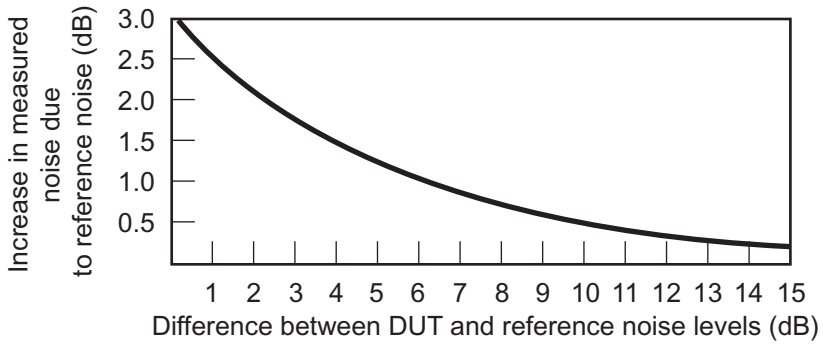


Figure 75 DUT noise approaches reference noise

Using a Similar Device

The test system performs best when you are able to use a device similar to the DUT as the reference source for your PLL measurement. Of course one of the devices must be capable of being voltage tuned by the system to do this.

To select a similar device for use as the reference source, you must establish that the noise level of the reference source device is adequate to measure your DUT. The Three Source Comparison technique enables you to establish the actual noise levels of three comparable devices when two devices are available in addition to the DUT.

If only one device is available in addition to the DUT, you can perform the Phase Noise Using a Phase Locked Loop Measurement using these two devices and know that the noise level of each of the devices is at least as good as the measured results. (The measured results represent the sum of the noise of both devices.)

Using a Signal Generator

When using a signal generator as a reference source, it is important that the generator's noise characteristics are adequate for measuring your device.

Tuning Requirements

Often the reference source you select also serves as the VCO source for the PLL measurement. (The VCO source can be either the DUT or the reference source.) To configure a PLL measurement, you need to know the following tuning information about the VCO source you are using.

- Tuning Constant (Hz/V) (within a factor of 2)
- Tuning Voltage Range (V)
- Center Voltage of Tuning Range (V)
- Input Resistance of Tuning Port (Ω)

The primary consideration when evaluating a potential VCO source for your measurement is whether it provides the test system with sufficient capture and drift tracking ranges to maintain lock throughout the measurement. To make this determination, you must estimate what the drift range of the sources you are using will be over the measurement period (thirty minutes maximum). (Details on the relationship between the capture and drift tracking ranges and the tuning range of the VCO source are provided in Table 12. This information helps you evaluate your VCO source based on the estimated drift of your sources.)

Table 12 lists the tuning parameters for several VCO options.

Table 12 Tuning Characteristics of Various VCO Source Options

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (± V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A						
EFC	υ_0	5 E – 9 x υ_0	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 k (8662) 600 (8663)	Calculate Calculate
Agilent 8642A/B		FM Deviation	0	10	600	Calculate
Agilent 8644B		FM Deviation	0	10	600	Calculate

Table 12 Tuning Characteristics of Various VCO Source Options (continued)

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (± V)	Input Resistance (Ω)	Tuning Calibration Method
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Calculate
Other User VCO Source		Estimated within a factor of 2	–10 to +10	See Figure 76	1 E + 6	Measure

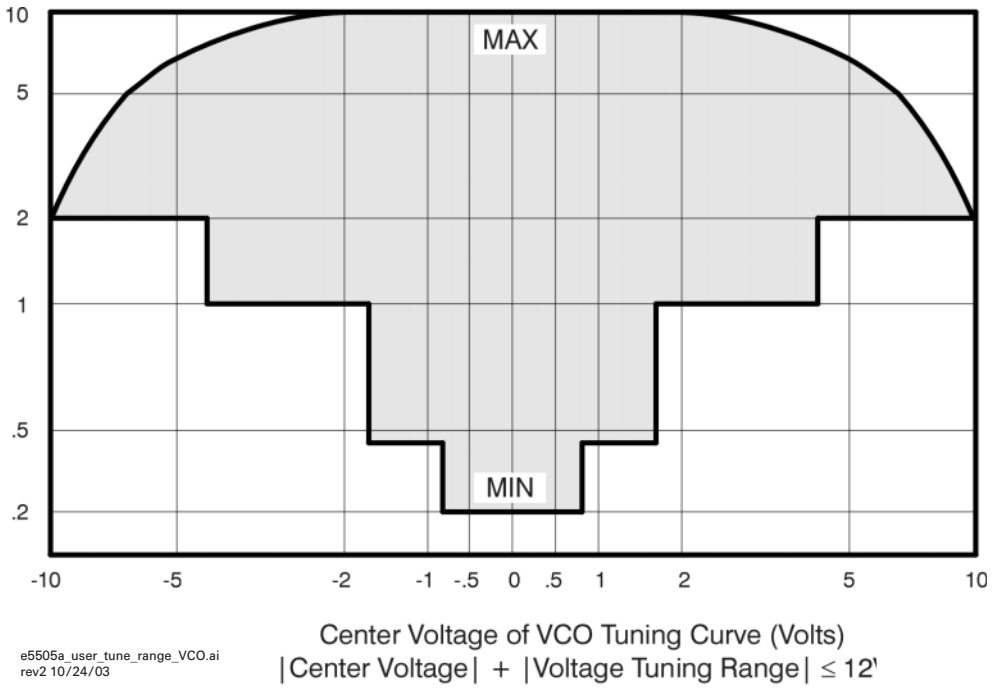


Figure 76 Voltage tuning range limits relative to center voltage of the VCO tuning curve

Estimating the Tuning Constant

The VCO tuning constant is the tuning sensitivity of the VCO source in Hz/V. The required accuracy of the entered tuning constant value depends on the VCO tuning constant calibration method specified for the measurement. The calibration method is selected in the Calibration Process menu. Table 13 lists the calibration method choices and the tuning constant accuracy required for each.

Table 13 VCO tuning constant calibration method

VCO Tuning Constant Calibration Method (selected in calibration screen)	Required Tuning Constant Accuracy (entered in parameter screen)
Use the current tuning constant (must be accurate from a previous measurement of the same source).	Within a factor of 2 of actual value. (Enter 1 E + 6 for Input Resistance.)
Measure the VCO tuning constant	Within a factor of 2 of actual value. (Enter 1 E + 6 for Input Resistance.)

Tracking Frequency Drift

The system's frequency drift tracking capability for the phase lock loop measurement is directly related to the tuning range of the VCO source being used. The system's drift tracking range is approximately 24% of the peak tuning range (PTR) of the VCO.

PTR= VCO Tuning Constant X Voltage Tuning Range

This is the frequency range within which the beatnote signal created by the test set's phase detector must remain throughout the measurement period. In addition, the beatnote signal must remain within the system's Capture Range (5% of the PTR) during the time it takes the system to calibrate and lock the phase lock loop.

The stability of the beatnote is a function of the combined frequency stability of the sources being used for the measurement. If beatnote drift prevents the beatnote from remaining within the Capture Range long enough for the system to attain phase lock, the computer informs you by displaying a message. If the beatnote drifts beyond the drift tracking range during the measurement, the computer stops the measurement and inform you that the system has lost lock.

Evaluating beatnote drift

The Checking the Beatnote section included in each phase lock loop measurement example in this chapter provides a procedure for adjusting the beatnote to within the Capture Range set for the measurement. If you have not done so already, verify that the beatnote signal can be tuned to within the Capture Range and that it will remain within the range.

Continue to observe the beatnote and verify that it will not drift beyond the drift tracking range (24% of the PTR) during the measurement period. The length of the measurement period is primarily a function of the frequency offset range specified for the measurement (Start to Stop Frequency).

Action

If beatnote drift exceeds the limits of the Capture or drift tracking ranges set for your measurement, the system is not able to complete the measurement. You have two possible alternatives.

1 Minimize beatnote drift.

- By Allowing sources to warm-up sufficiently.
- By Selecting a different reference source with less drift.

2 Increase the capture and drift tracking Ranges.

- By Selecting a measurement example in this chapter that specifies a drift rate compatible with the beatnote drift rate you have observed.
- By Increasing the peak tuning range for the measurement. (Further information about increasing the PTR is provided in Changing the PTR.)

Changing the PTR

The peak tuning range (PTR) for the phase lock loop measurement is set by the tune range entered for the VCO and the VCO's tuning constant. (If the calibration technique is set to measure the VCO tuning constant, the measured value is used to determine the system's PTR.)

PTR= VCO Tuning Constant X Voltage Tuning Range

From the PTR, the phase noise software derives the capture and drift tracking Ranges for the measurement. These ranges set the frequency stability requirements for the sources being used.

The PTR also determines the phase lock loop (PLL) bandwidth for the measurement. An important attribute of the PLL bandwidth is that it suppresses the close-in noise which would otherwise prevent the system from locking the loop.

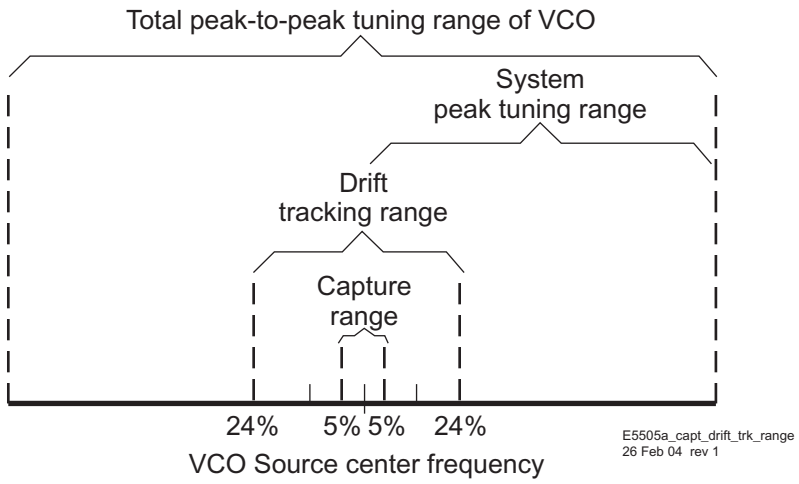


Figure 77 Peak tuning range

The Tuning Qualifications

Changing the PTR is accomplished by changing the tune range of VCO value or the VCO tuning constant value or both. There are several ways this can be done. However, when considering these or any other options for changing the PTR, it is important to remember that the VCO source must always meet the following tuning qualifications.

- The tuning response of the VCO source must always remain monotonic.
- The VCO source's output level must remain constant across its tuning range.

As long as these qualifications are met, and the software does not indicate any difficulty in establishing its calibration criteria, an increase in PTR will not degrade the system's measurement accuracy.

The following methods may be considered for increasing or decreasing the PTR.

Voltage controlled oscillators

1 Select a different VCO source that has the tuning capabilities needed for the measurement.

2 Increase the tune range of the VCO source.

CAUTION Be careful not to exceed the input voltage limitations of the Tune Port on the VCO source

NOTE Increasing the tune range of the VCO is only valid as long as the VCO source is able to continuously meet the previously mentioned tuning qualifications.

Signal generators

1 If you are using a signal generator with a calibrated 1 Vpk DC FM Input (such as the Agilent 8640B, 8642A/B, 8656B, or 8662/3), the Voltage tuning Range can be increased to 10 V as long as you select Computed from the expected T. Constant in the Calibration Process display. These signal generators continue to meet all of the previously mentioned tuning qualifications across a 10 V tuning range.

2 Increase the signal generator's frequency deviation setting and set the software to measure the new tuning constant or enter the increased deviation if it is known. (Note that increasing the deviation setting often increases the source's noise level as well.)

3 If you are using a synthesizer with Electronic-Frequency-Control (EFC) capability such as the Agilent 8662A or Agilent 8663A, it is possible to increase the tuning range of these sources using a VCO as an external time base. When a compatible VCO source is connected to the EXT INPUT on the 8662/3, the tuning capability of the VCO source is transferred to the synthesizer.

Minimizing Injection Locking

Injection locking occurs when a signal feeds back into an oscillator through its output path. This can cause the oscillator to become locked to the injected signal rather than to the reference signal for the phase locked loop.

Injection locking is possible whenever the buffering at the output of an oscillator is not sufficient to prevent a signal from entering. If the injection locking occurs at an offset frequency that is not well within the PLL bandwidth set for the measurement, it can cause the system to lose phase lock.

Adding Isolation

The best way to prevent injection locking is to isolate the output of the source being injection locked (typically the DUT) by increasing the buffering at its output. This can be accomplished by inserting a low noise amplifier and/or an attenuator between the output of the source being injection locked and the test set. (For information on determining the effect that the amplifier noise will have on the measurement noise floor, refer to Inserting a Device in this section.)

Increasing the PLL Bandwidth

If the injection locking bandwidth is less or equal to the PLL bandwidth, it may be possible to increase the PLL bandwidth sufficiently to complete the measurement. The PLL bandwidth is increased by increasing the peak tuning range (PTR) for the measurement.

NOTE The PTR for the measurement is set by the tuning characteristics of the VCO source you are using. Figure 78 on page 121 shows that increasing the PLL bandwidth can require a substantially larger increase in the PTR. For information on the limitations of increasing the PTR, refer to Changing the PTR in this section.

To estimate the PTR needed to prevent injection locking from causing the system to lose lock:

1. Determine the injection locking bandwidth. Tune the beatnote toward 0 Hz using the procedure described in the Checking the Beatnote section of each phase lock loop measurement example in this chapter. When the injection locking occurs, the beatnote disappears. The injection locking bandwidth is the frequency of the beatnote just prior to where the injection locking occurs as the beatnote is tuned toward 0 Hz.
2. Multiply the injection locking bandwidth by 2 to determine the minimum PLL bandwidth required to prevent the injection locking from causing the system to lose lock. (To prevent accuracy degradation, it may be necessary to increase the PLL bandwidth to 4 X the injection locking bandwidth. The

computer informs you during the measurement if the possibility of accuracy degradation exists.)

3 Locate the required PLL bandwidth in Figure 78 to determine the PTR required for the measurement. (For details on increasing the PTR, refer to Changing the PTR in this section.

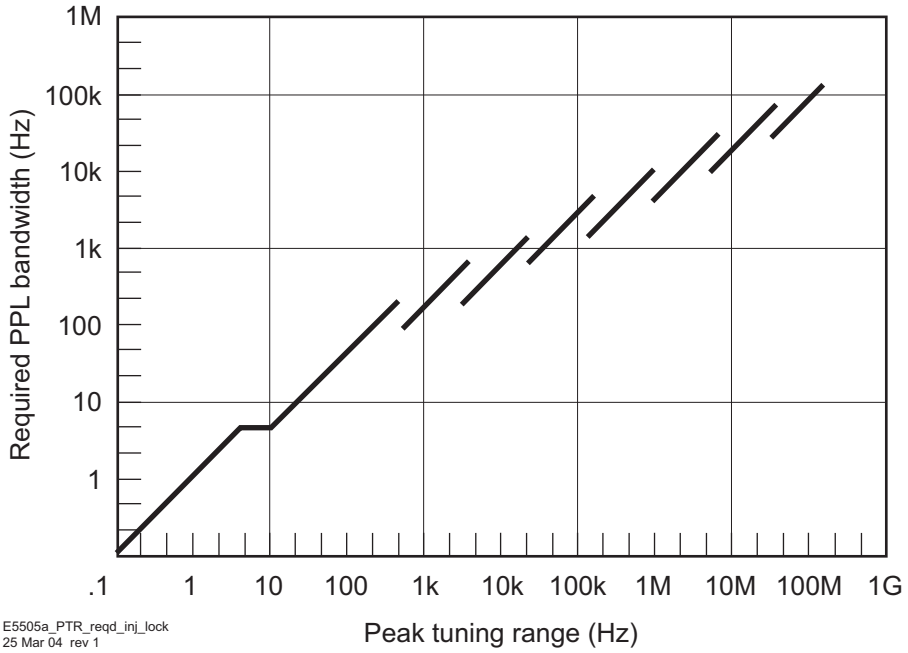


Figure 78 Peak tuning range (PTR) Required by injection locking.

Inserting a Device

An attenuator

You may find that some of your measurement setups require an in-line device such as an attenuator in one of the signal source paths. (For example, you may find it necessary to insert an attenuator at the output of a DUT to prevent it from being injection-locked to the reference source.) The primary consideration when inserting an attenuator is that the signal source has sufficient output amplitude to maintain the required signal level at the test set's phase detector input port. The signal level required for the measurement depends on the noise floor level needed to measure the DUT.

Figure 79 shows the relationship between the signal level at the R port and the measurement noise floor.

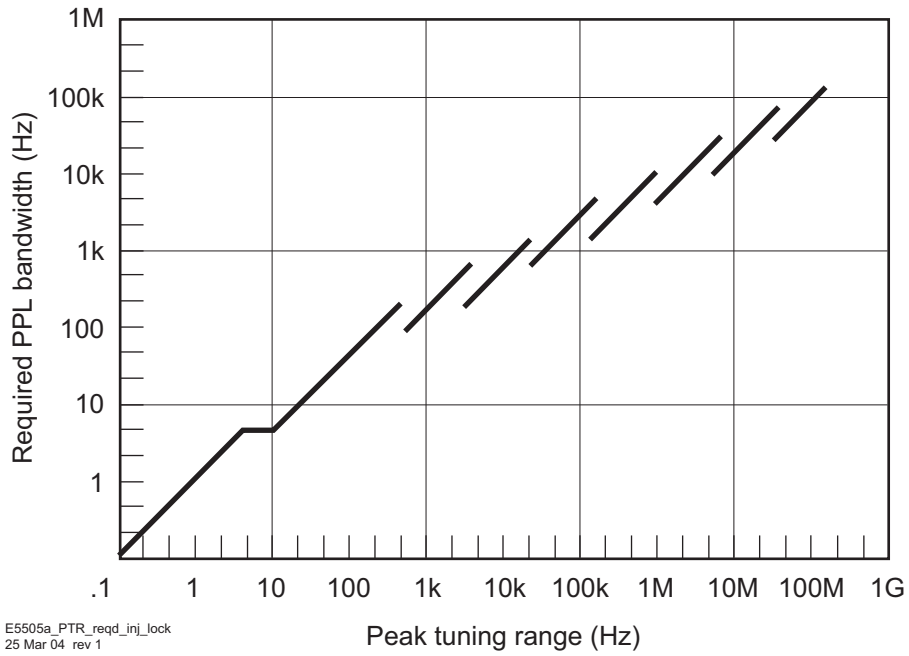


Figure 79 Measurement noise floor relative to R-Port signal level

An amplifier

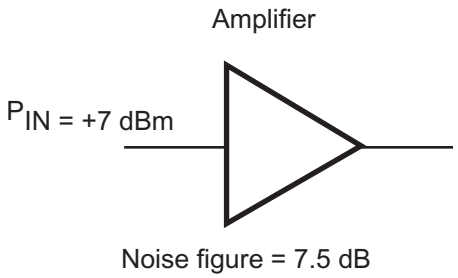
If a source is not able to provide a sufficient output level, or if additional isolation is needed at the output, it may be necessary to insert a low phase-noise RF amplifier at the output of the source.

Note, however, that the noise of the inserted amplifier is also summed into the measured noise level along with the noise of the source.

The Agilent N5507A Option K22 dual RF amplifier was designed specifically for this purpose. This instrument is the preferred solution for tests requiring an external amplifier.

Use the following equation to estimate what the measurement noise floor is as a result of the added noise of an inserted amplifier: Figure 80 shows an example.

L(f) out = –174 dB + Amplifier Noise Figure – Power into Amplifier – 3dB



$\mathcal{L}(f)$ = -174 dBm + 7.5dB - (+7 dBm) - 3 dB

$\mathcal{L}(f)$ = -176.5 dBc/Hz

Figure 80 Measurement noise floor as a result of an added attenuator

Evaluating Noise Above the Small Angle Line

If the average noise level on the input signals exceeds approximately 0.1 radians RMS integrated outside of the Phase Lock Loop (PLL) bandwidth, it can prevent the system from attaining phase lock.

The following procedure allows you to evaluate the beatnote created between the two sources being measured. The intent is to verify that the PLL bandwidth is adequate to prevent the noise on the two sources from causing the system to lose lock.

If the computer is displaying the hardware Connect Diagram you are ready to begin this procedure. (If it is not, begin a New Measurement and proceed until the hardware Connect Diagram appears on the display.)

Determining the Phase-Lock-Loop bandwidth

1 Determine the Peak Tuning Range (PTR) of your VCO by multiplying the VCO Tuning Constant by the Tune Range of VCO value entered. (If the phase noise software has measured the VCO Tuning Constant, use the measured value.)

$$PTR = VCO\ Tuning\ Constant\ X\ Voltage\ Tuning$$

For Example:

$$PTR = 100\frac{Hz}{V} X\, 10V = 1\, kHz$$

2 Estimate the Phase Lock Loop (PLL) bandwidth for the measurement using the PTR of your VCO and the graph in Figure 81.

Observing the beatnote

If the beatnote frequency is below 100 kHz it appears on the Agilent E4411A RF analyzer's display in both the frequency domain and the time domain. If the beatnote does not appear on the RF analyzer, then the beatnote is either greater than 100 kHz or it does not exist.

If incrementing the frequency of one of the sources does not produce a beatnote within 100 kHz, you need to verify the presence of an output signal from each source before proceeding.

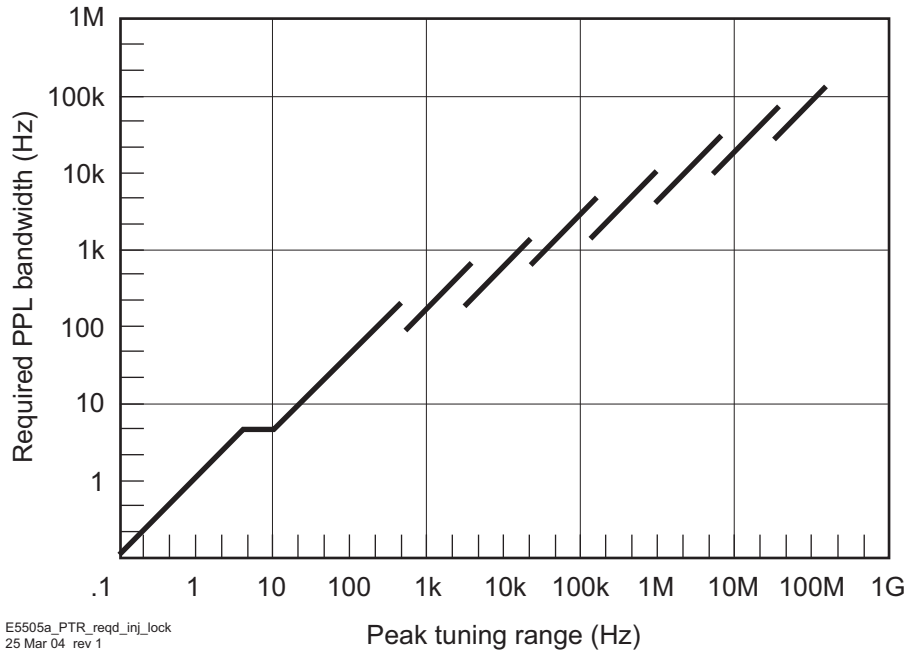


Figure 81 Phase lock loop bandwidth provided by the peak tuning range

1 Once the beatnote is displayed;
   a press the press [[RANGE]]
   b press [[AUTO RANGE OFF]]
   c and press [[SINGLE AUTO RANGE]] on the RF analyzer
2 Set the span width on the RF analyzer to approximately 4 x PLL bandwidth. Adjust the BITNET to position it near the center of the display.

NOTE

If you are not able to tune the beatnote to 2 X PLL bandwidth (center of display) due to frequency drift, refer to Tracking Frequency Drift in this section for information about measuring drifting signals. If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, then your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to"Minimizing Injection Locking" on page 120 for recommended actions.

   a Press the [[AVG]] key, and then the RMS key.

   Wait for the trace to return and then press;

   b [[MKR]] and MKR to Peak.
3 Press [[REL MKR]], and MKR REF.

4 Press the [[DEFINE TRACE]]

   a press the [[and the MATH FUNCTION keys.

   Using the --> key on the RF analyzer, offset the marker by the PLL bandwidth. Read the offset frequency and noise level indicated at the bottom of the display. (If the noise level falls below the bottom of the display, the marker reading is still correct.)

5 To increase the vertical scale

   a press [[VERT SCALE]]

   b press [[, DEFINE DB/DIV]], and enter 20 dB.

6 Compare the average noise level at the PLL bandwidth offset to the small angle criterion level shown on the graph in Figure 82. The average noise level of the signal must remain below the small angle line at all offset frequencies beyond the PLL bandwidth. (The small angle line applies only to the level of the average noise. Spur levels that exceed the small angle line do not degrade measurement accuracy provided they do not exceed —40 dBc.)

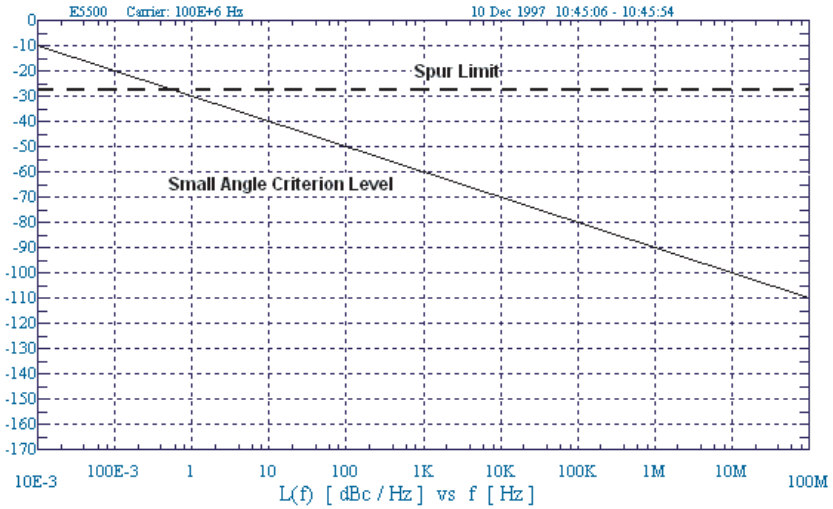


Figure 82 Graph of small angle line and spur limit

7 Continue moving the marker to the right to verify that the average noise level remains below the small angle line.

8 Increase the span by a factor of ten by selecting FREQ and DEFINE SPAN. Continue comparing the noise level to the graph.

9 Continue to increase the span width and compare the noise level out to 100 kHz. (If the noise level exceeds the small angle line at any offset frequency beyond the PLL bandwidth, note the offset frequency and level of the noise. Use the graph in Figure 83 on page 127 to determine the Peak

Tuning Range (PTR) necessary to provide a sufficient PLL bandwidth to make the measurement.

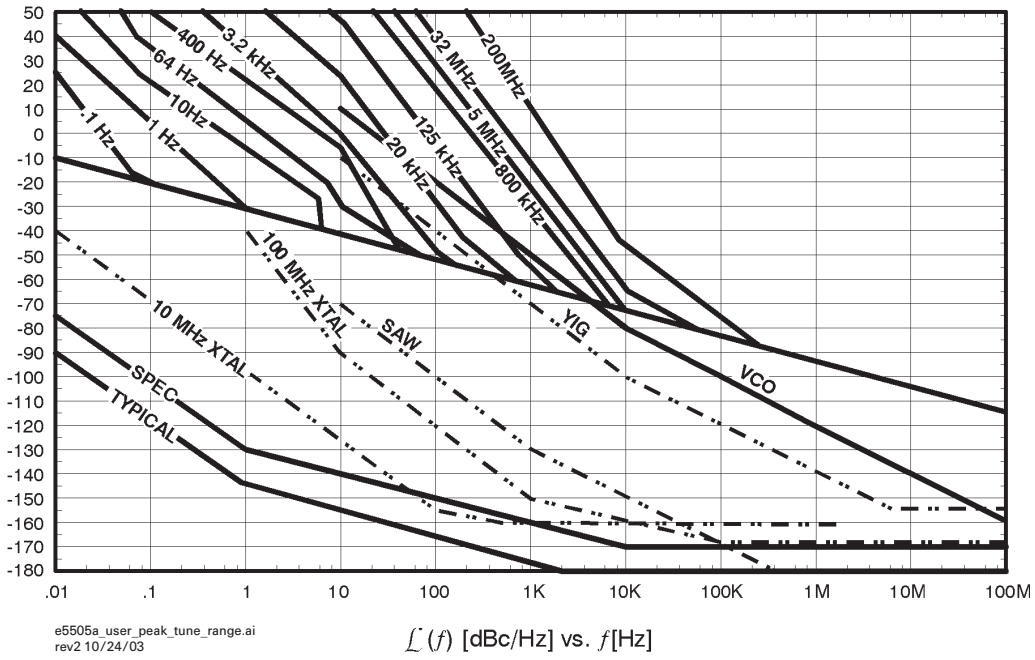


Figure 83 Requirements for noise exceeding small angle limit

Measurement options

If the observed level exceeded the small angle line at any point beyond the PLL bandwidth set for the measurement, you need to consider one of the following measurement options.

1. Evaluate your source using the noise data provided by the RF analyzer in the procedure you just performed.
2. Increase the PTR if possible, to provide a sufficient PLL bandwidth to suppress the noise. (For information on increasing the PTR, refer to Changing the PTR in this section.)
3. Reduce the noise level of the signal sources.
4. Use the Discriminator technique to measure the phase noise level of your source.

5 Absolute Measurement Fundamentals

6
Absolute Measurement Examples

Stable RF Oscillator 130
Free-Running RF Oscillator 145
RF Synthesizer Using DCFM 160
RF Synthesizer Using EFC 174
Microwave Source 188

Stable RF Oscillator

This measurement example will help you measure the phase noise of a stable RF oscillator with frequency drift of <20 ppm over a period of thirty minutes.

CAUTION To prevent damage to the test set's components, *do not* apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 15 on page 138. Apply the input signal when the connection diagram appears.

Required equipment

This measurement requires a VCO reference source, in addition to the phase noise test system and your DUT. (For more information, see "Selecting a reference source" on page 132.) You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the measurement

1. From the **File** menu of the E5500 User Interface, choose **Open**.
2. If necessary, choose the drive or directory where the file you want is stored.
3. In the file name box, choose **"StableRF.pnm"**. See Figure 84.

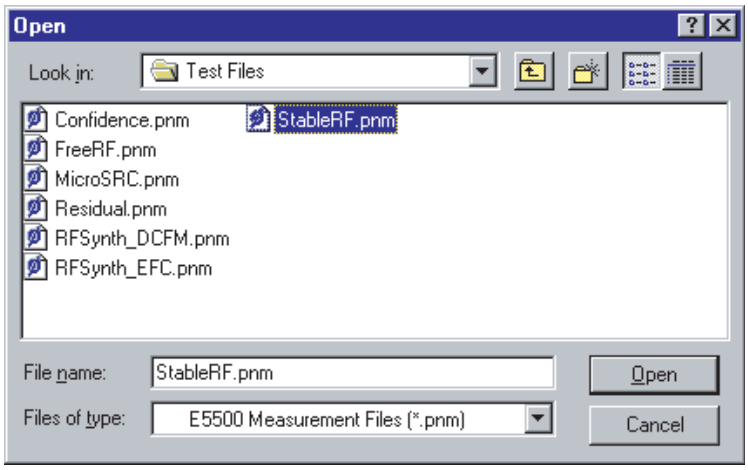


Figure 84 Select the parameters definition file

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 16 on page 143 lists the parameter data that has been entered for the Stable RF Source measurement example.

NOTE

Note that the source parameters entered for step 2 in Table 16 on page 143 may not be appropriate for the reference source you are using. To change these values, refer to Table 14, “Tuning characteristics for various sources,” on page 132, then continue with step 5 below. Otherwise, go to “Beginning the measurement" on page 136:

5 Using Figure 85 on page 131 as a guide, navigate to the **Sources** tab.

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.

b Enter the VCO (nominal) Tuning Constant. (For values, see Table 14 on page 132).

c Enter the Tune Range of VCO (see Table 14).

d Enter the Center Voltage of VCO (see Table 14).

e Enter the Input Resistance of VCO (see Table 14).

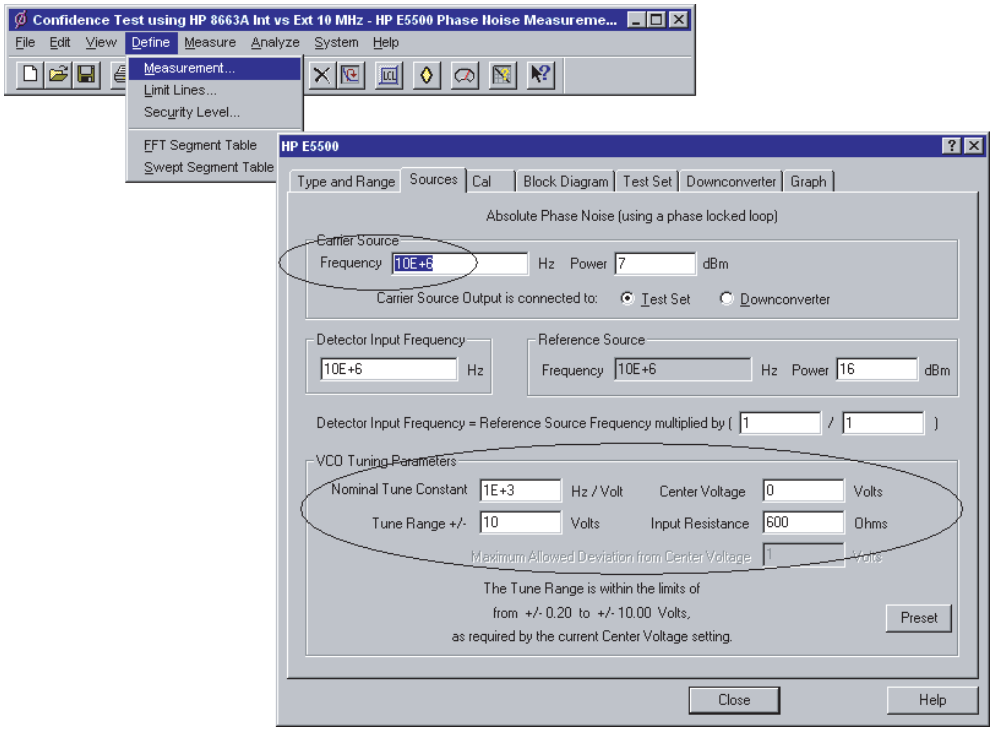


Figure 85 Enter source information

Table 14 Tuning characteristics for various sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (±V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A						
EFC	υ_0	5 E – 9 x υ_0	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662) 600 (8663)	Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1. Using Figure 86 on page 133 as a guide, navigate to the **Block Diagram** tab.
2. From the **Reference Source** pull-down list, select your source.

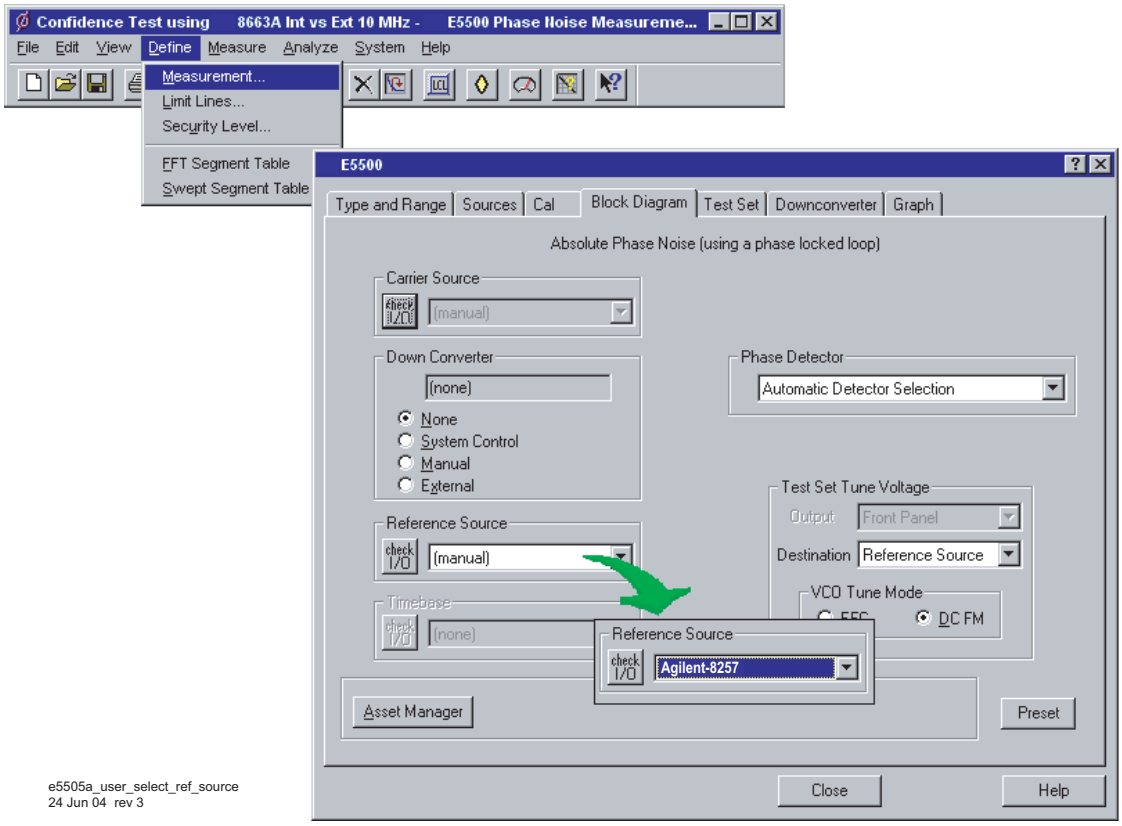


Figure 86 Selecting a reference source

3 When you have completed these operations, click the **Close** button.

Selecting Loop Suppression Verification

1 Using Figure 87 on page 134 as a guide, navigate to the **Cal** tab.

2 In the **Cal** dialog box, check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph**.

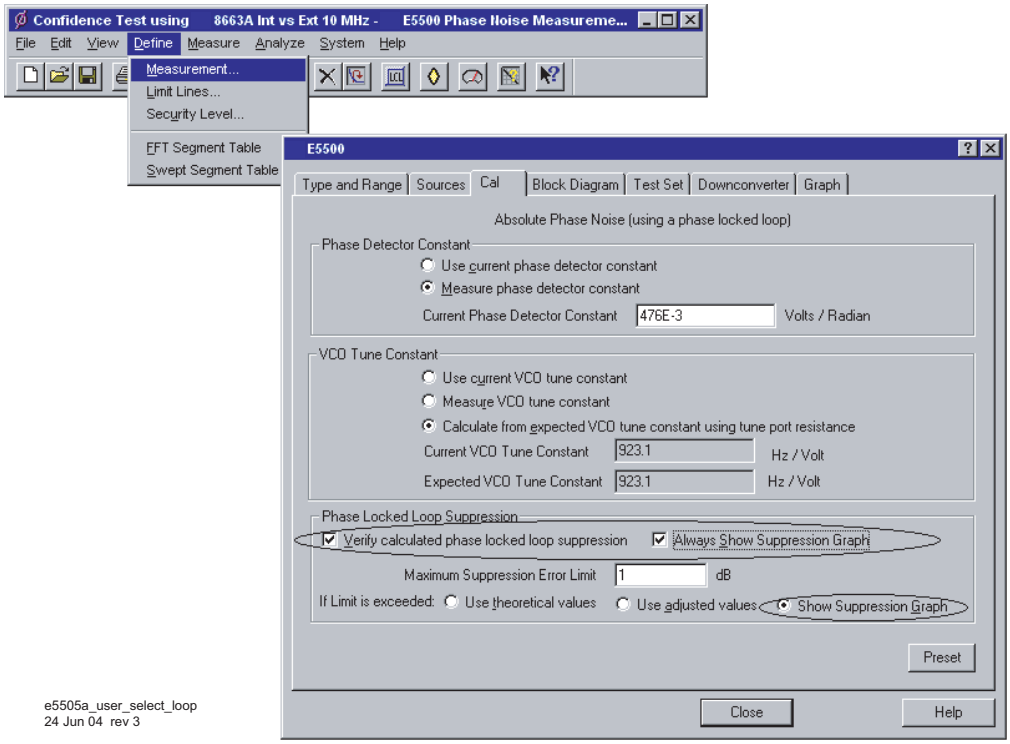


Figure 87 Selecting loop suppression verification

3 When you have completed these operations, click the **Close** button.

Setup considerations for stable RF oscillator measurement

Measurement noise floor

The signal amplitude at the test set's R input (Signal Input) port sets the measurement noise floor level. Use Figure 88 on page 135 and Figure 89 on page 135 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your DUT. (The Checking the Beatnote procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your DUT will provide.)

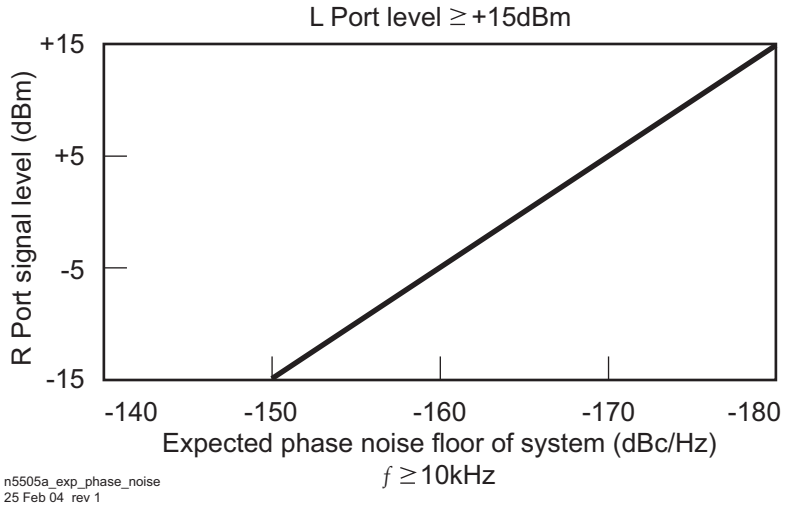


Figure 88 Noise floor for the stable RF oscillator measurement

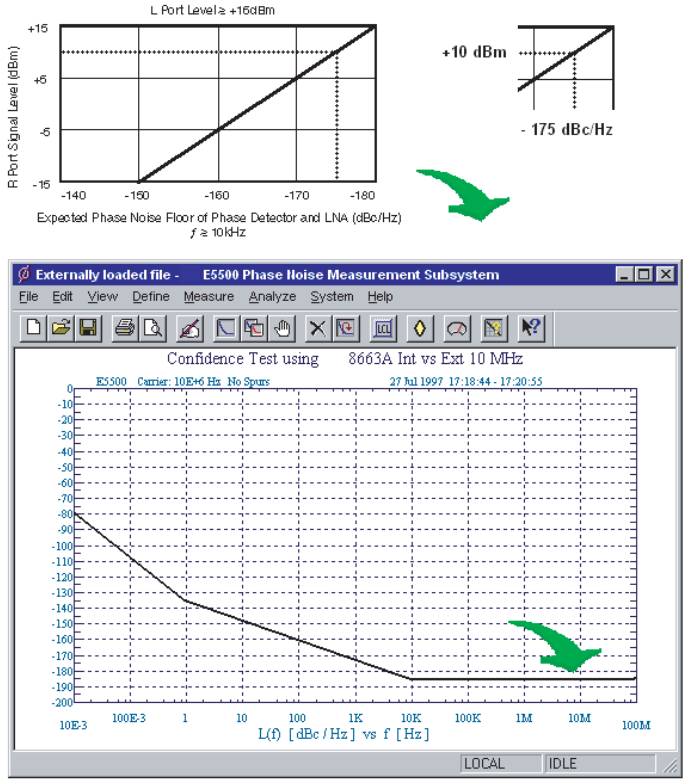


Figure 89 Noise floor calculation example

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it is necessary to insert a low-noise amplifier between the DUT and the test set. Refer to "Inserting a Device" on page 122 for details on determining the amplifier noise effect on the measured noise floor.

VCO reference source

This setup calls for a second signal source that is similar in type to the DUT. The second source is used as the reference source. In order for the noise measurement results to accurately represent the noise of the DUT, the noise level of the reference source should be below the expected noise level of the DUT. (For additional help in selecting an appropriate reference source, refer to Chapter 6, “Absolute Measurement Examples.)

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement**. See Figure 90.

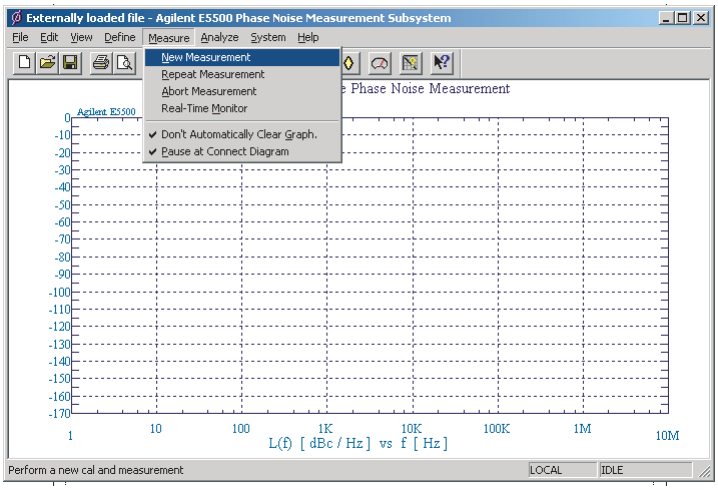


Figure 90 Selecting a new measurement

2 When the Do you want to **Perform a** New Calibration and Measurement? dialog box appears, click **Yes.** See Figure 91.

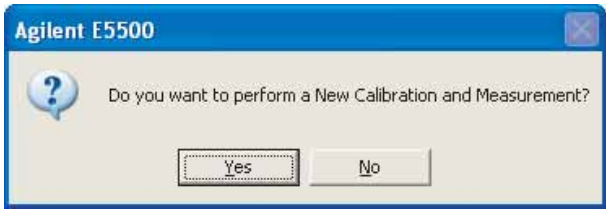


Figure 91 Confirm new measurement

3 When the **Connect Diagram** dialog box appears, click on the hardware pull-down arrow and select your hardware configuration from the list.

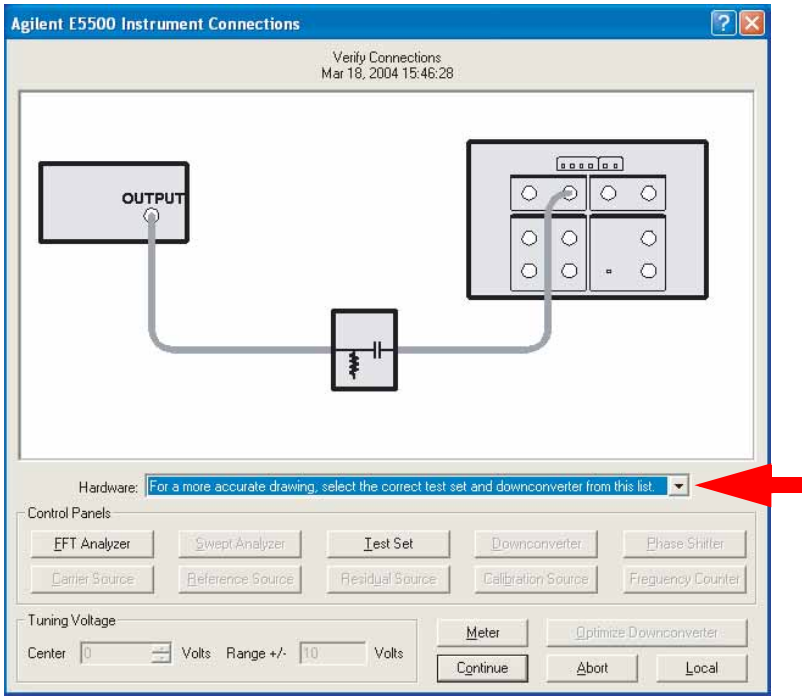


Figure 92 Connect diagram for the stable RF oscillator measurement

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION The test set's signal input is subject to the limits and characteristics in Table 15 on page 138.

Table 15 Test set signal input limits and characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm (+30 dBm with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

CAUTION To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which occurs at the connection diagram.

NOTE Refer to the following system connect diagram examples in Chapter 18, "System Interconnections" for more information about system interconnections.

- Figure 307, "E5505A system connections with standard test set," on page 403
- Figure 308, "E5505A system connections with test set option 001," on page 404
- Figure 309, "E5505A system connections with test set option 201," on page 405

Checking the beatnote

While the connect diagram is still displayed, use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your DUT. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the capture range of the system.

The phase lock loop (PLL) capture range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO. Refer to Chapter 14, “Evaluating Your Measurement Results” if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system will not be able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz.

Searching for the beatnote will require that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display.

If incrementing the frequency of one of the sources does not produce a beatnote, you will need to verify the presence of an output signal from each source before proceeding.

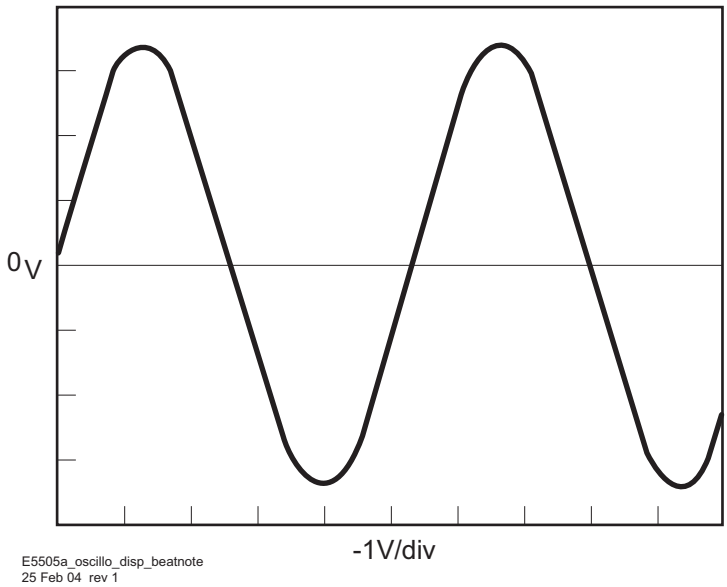


Figure 93 Oscilloscope display of beatnote from test set Monitor port

Making the measurement

1. Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.
2. When the PLL Suppression Curve dialog box appears, select View Measured Loop Suppression, View Smoothed Loop Suppression, and View Adjusted Loop Suppression See Figure 94 on page 141.

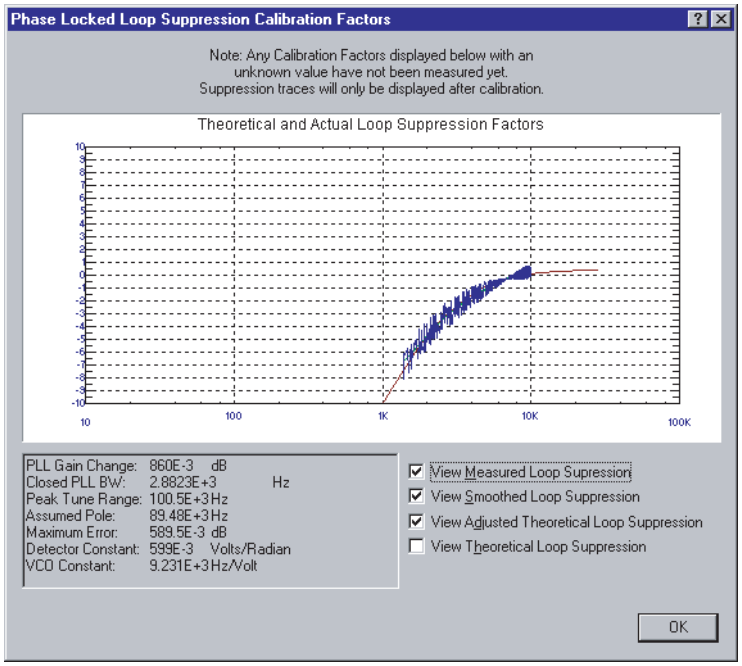


Figure 94 Selecting suppressions

Four different curves are available for this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features.)

- **a** “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.
- **b** “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.
- **c** “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, etc).
- **d** “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results for help in evaluating your measurement results.

Figure 95 on page 142 shows a typical phase noise curve for a stable RF Oscillator.

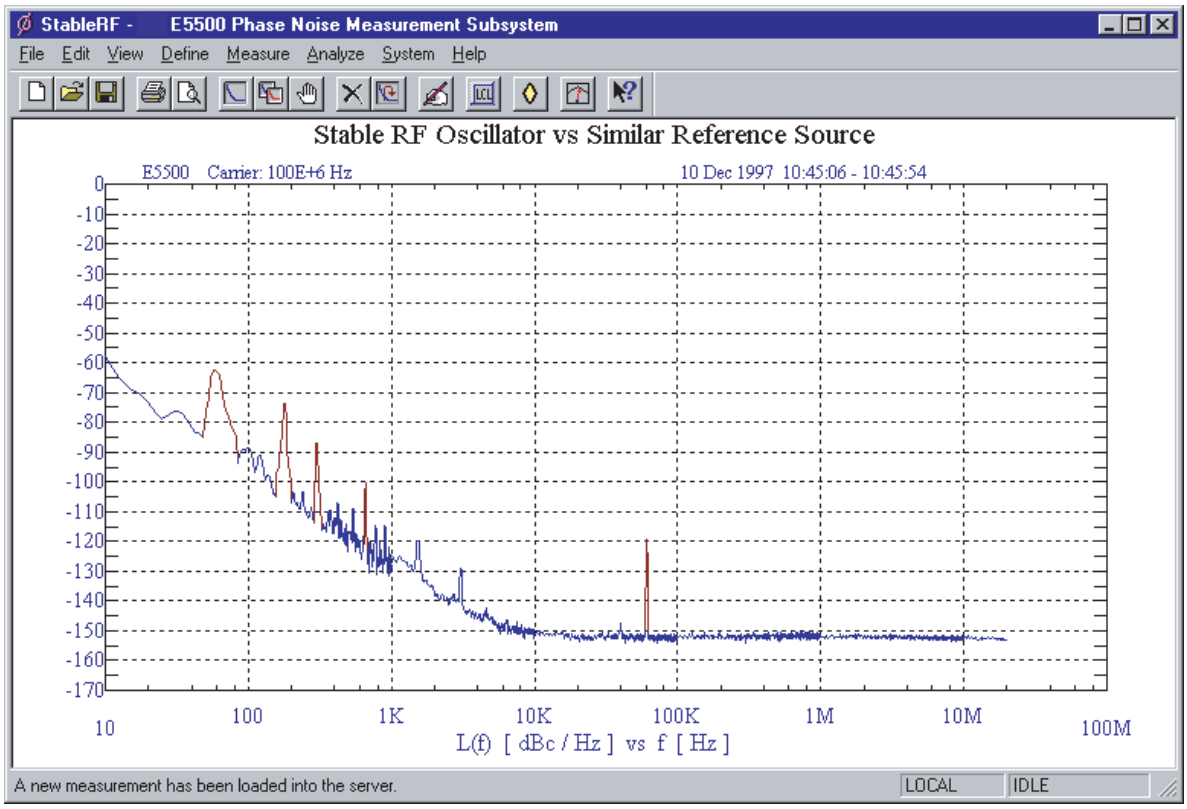


Figure 95 Typical phase noise curve for a stable RF oscillator

Table 16 Parameter data for the stable RF oscillator measurement

Step	Parameters	Data
1	Type and Range Tab • Measurement Type • Start Frequency • Stop Frequency • Averages • Quality • FFT Analyzer Measurement Mode	 • Absolute Phase Noise (using a phase locked loop) • 1 Hz • 100 E + 6 Hz • 4 • Normal • Use Multiple Time Segments
2	Sources Tab • Carrier Source Frequency • Carrier Source Power Carrier Source Output connected to: • Detector Input Frequency • Reference Source Frequency • Reference Source Power • Nominal Tune Constant • Tune Range ± • Center Voltage • Input Resistance	 • 100 E + 6 Hz • 8 dBm • Test Set • 100 E +6 Hz • 100 E +6 Hz (same as Carrier Source Frequency) • 16 dBm • 40 E +3 Hz/V • ± 10 Volts • 0 Volts • 1 E + 6 Ω 1 Volts
3	Cal Tab • Phase Detector Constant • VCO Tune Constant • Phase Lock Loop Suppression	 • Measure Phase Detector Constant • Calculate VCO Tune Constant • Verify calculated phase locked loop suppression
4	Block Diagram Tab • Carrier Source • Downconverter • Reference Source • Timebase • Phase Detector • Test Set Tune Voltage Output • Test Set Tune Voltage Destination • VCO Tune Mode	 • None • None • Agilent 8662A • None • Automatic Detector Selection • Front Panel • Reference Source • DCFM

Table 16 Parameter data for the stable RF oscillator measurement (continued)

Step	Parameters	Data
5	Test Set Tab	
	• Input Attenuation	• Auto checked
	• LNA Low Pass Filter	• Auto checked
	• LNA Gain	• Auto Gain
	Detector Maximum Input Levels	
	• Microwave Phase Detector	• 0 dBm
	• RF Phase Detector	• 0 dBm
	• AM Detector	• 0 dBm
	• Ignore out-of-lock conditions	• Not checked
	• Pulsed Carrier	• Not checked
	• DC Block	• Not checked
	• Analyzer View	• Baseband
	• PLL Integrator Attenuation	• 0 dBm
6	Downconverter Tab	The downconverter parameters do not apply to this measurement example.
7	Graph Tab	
	• Title	• Stable RF Oscillator vs Similar Reference Source
	• Graph Type	• Single-sideband Noise
	• X Scale Minimum	• 1 Hz
	• X Scale Maximum	• 10 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –170 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

Free-Running RF Oscillator

This measurement example will help you measure the phase noise of a free-running RF oscillator with frequency drift >20 ppm over a period of thirty minutes.

CAUTION To prevent damage to the test set's components, *do not* apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 18 on page 152. Apply the input signal when the connection diagram appears.

Required equipment

This measurement requires an 8644B reference source in addition to the E5505A system and your DUT. (For more information, see the section "Selecting a reference source" on page 132.) You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement

Defining the measurement

1. From the **File** menu of the E5500 User Interface, choose **Open**.
2. If necessary, choose the drive or directory where the file you want is stored.
3. In the **File Name** box, choose "**FreeRF.pnm**". See Figure 96.

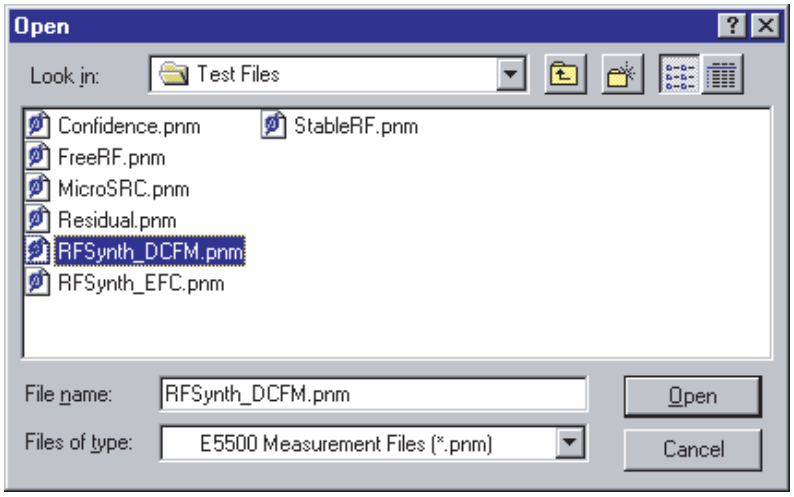


Figure 96 Select the parameters definition file

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 16 on page 143 lists the parameter data that has been entered for the Free-Running RF Source measurement example.)

NOTE

Note that the source parameters entered for step 2 in Table 16 on page 143 may not be appropriate for the reference source you are using. To change these values, refer to Table 17 on page 147, then continue with step 5 below. Otherwise, go to "Beginning the measurement" on page 151.

5 Using Figure 84 as a guide, navigate to the **Sources** tab.

e Enter the carrier (center) frequency of your DUT(5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.

f Enter the VCO (Nominal) Tuning Constant (see Table 17 on page 147).

g Enter the Tune Range of VCO (see Table 17).

h Enter the Center Voltage of VCO (see Table 17).

i Enter the Input Resistance of VCO (see Table 17).

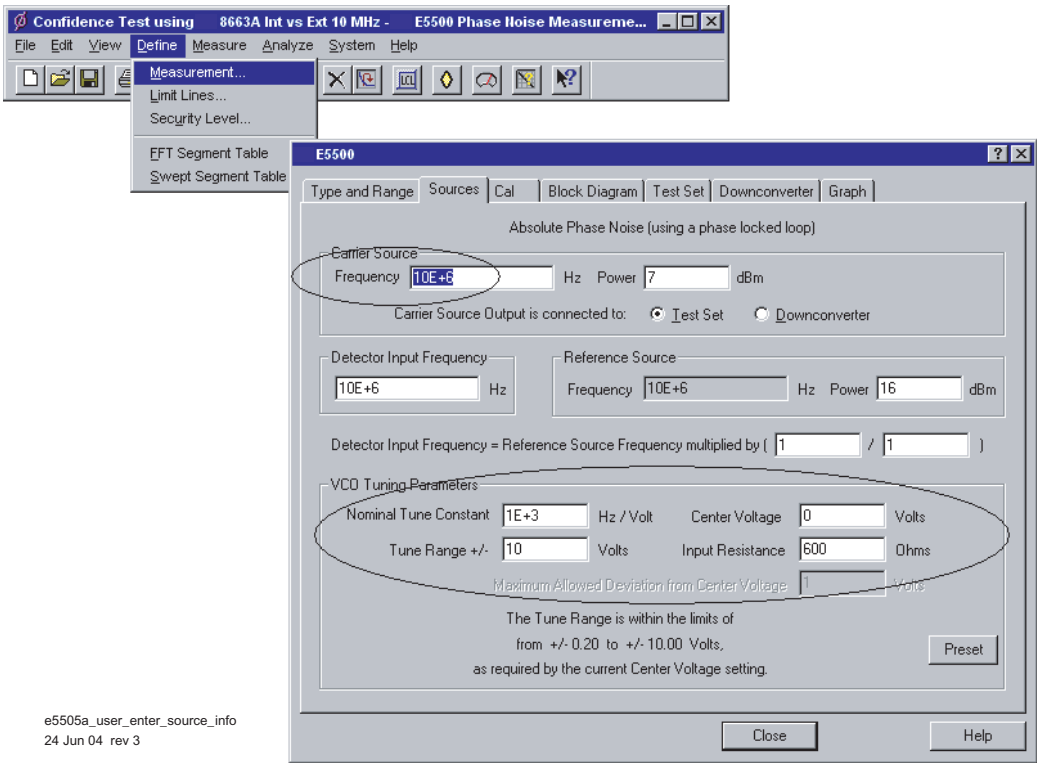


Figure 97 Enter source information

Table 17 Tuning characteristics for various sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (±V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A EFC DCFM	υ_0	5 E – 9 x υ_0 FM Deviation	0 0	10 10	1E + 6 1 K (8662) 600 (8663)	Measure Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1 Using Figure 98 as a guide, navigate to the **Block Diagram** tab.

2 From the **Reference Source** pull-down list, select **your source.**

3 When you have completed these operations, click the **Close** button.

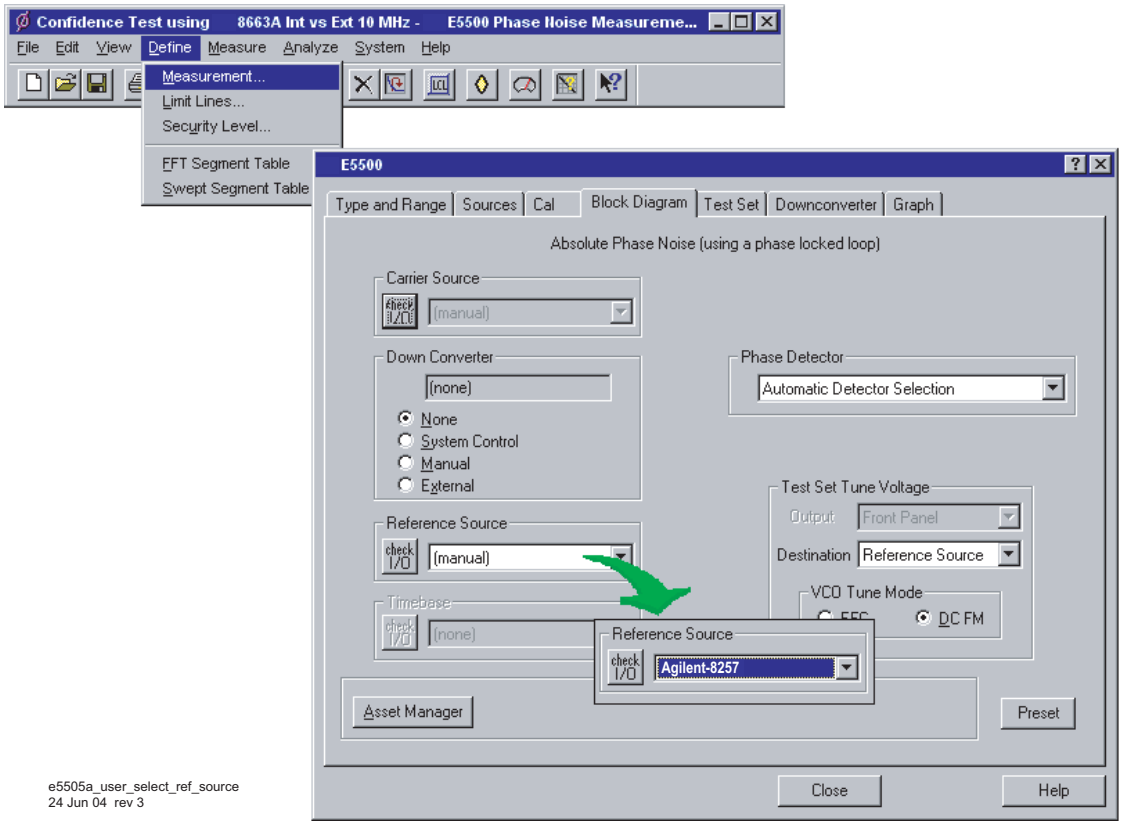


Figure 98 Selecting a reference source

Selecting Loop Suppression Verification

1 Using Figure 99 on page 149 as a guide, navigate to the **Cal** tab.

2 In the **Cal** dialog box, check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph**.

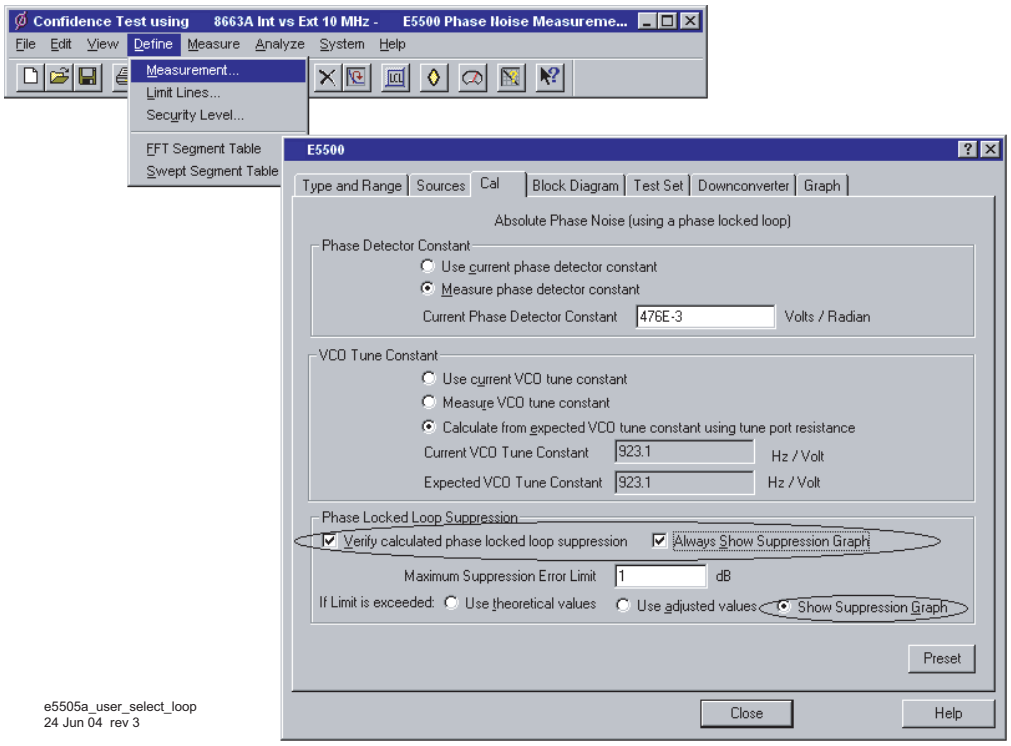


Figure 99 Selecting loop suppression verification

3 When you have completed these operations, click the **Close** button.

Setup considerations for the free-running RF oscillator measurement

Measurement noise floor

The signal amplitude at the test set's R input (Signal Input) port sets the measurement noise floor level. Use Figure 100 on page 150 and Figure 101 on page 150 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your DUT. (The Checking the Beatnote procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your DUT will provide.)

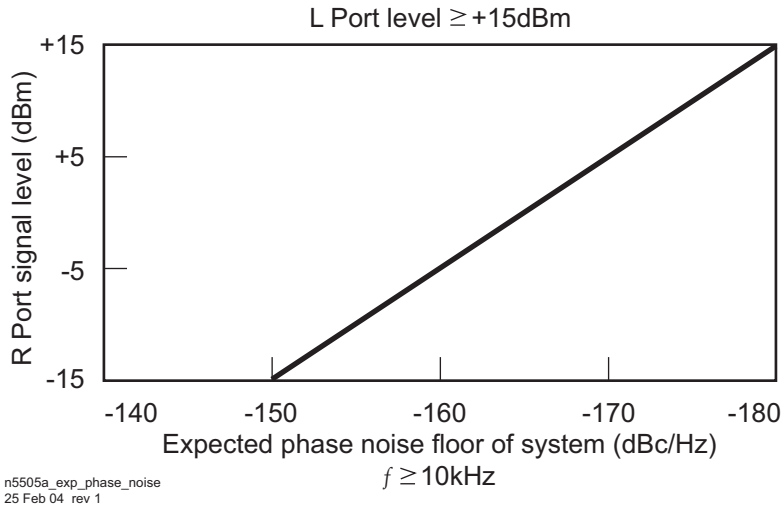


Figure 100 Noise floor for the free-running RF oscillator measurement

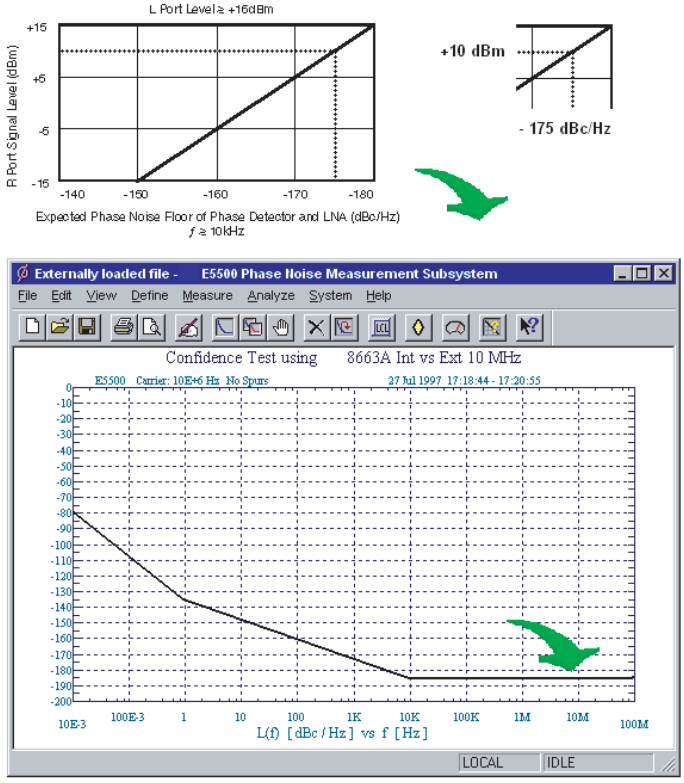


Figure 101 Noise floor calculation example

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low-noise amplifier between the DUT and the test set. Refer to “Inserting an Device” in Chapter 5, “Absolute Measurement Fundamentals for details on determining the effect the amplifiers noise will have on the measured noise floor.

VCO reference

In order for the noise measurement results to accurately represent the noise of the DUT, the noise level of the reference source should be below the expected noise level of the DUT.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement. See Figure 102.**

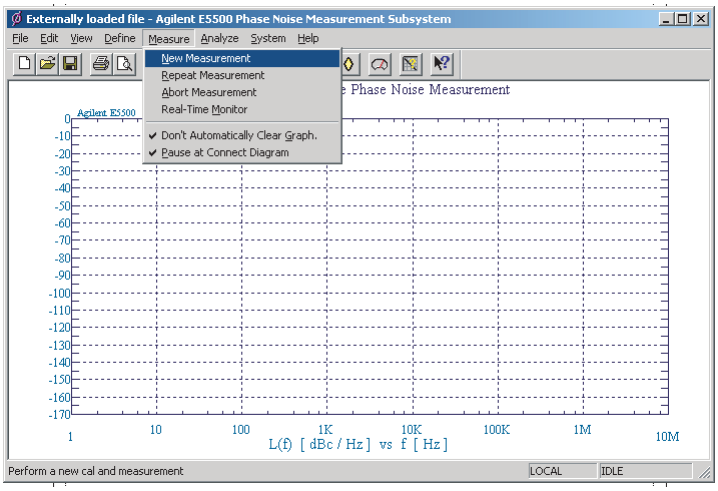


Figure 102 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

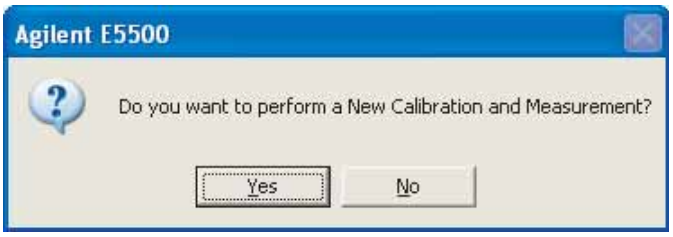


Figure 103 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select your hardware configuration from the list. See Figure 104.

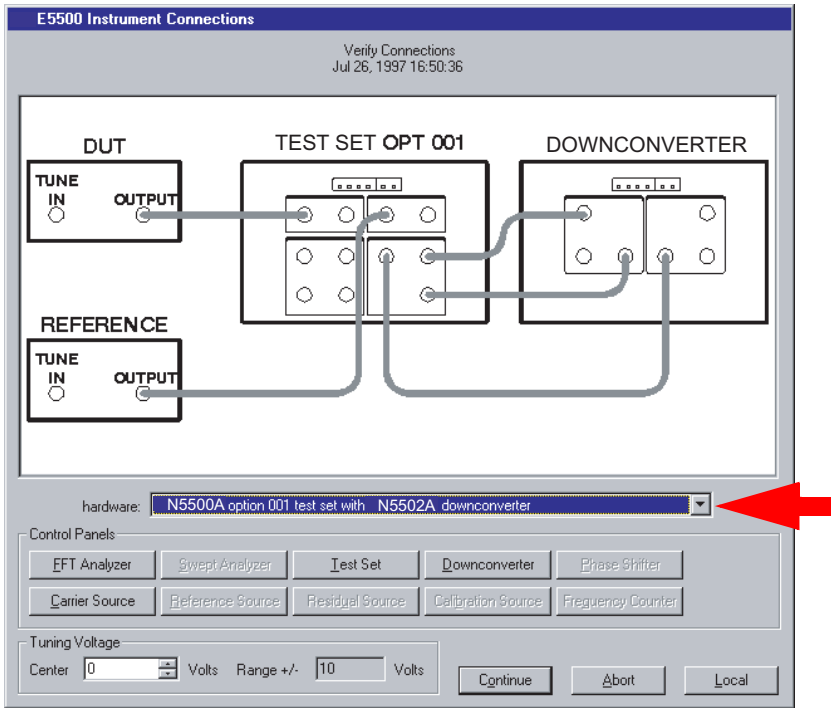


Figure 104 Connect diagram for the free-running RF oscillator measurement

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics in Table 18 on page 152.

To prevent damage to the test set's components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which will occur when the connection diagram appears.

Table 18 Test set signal input limits and characteristics

Limits

Table 18 Test set signal input limits and characteristics

Frequency	• 50 kHz to 1.6 GHz (Std) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm (+30 dBm with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

NOTE

Refer to the following system connect diagram examples in Chapter 18, “System Interconnections,” for more information about system interconnections.

- Figure 307, “E5505A system connections with standard test set,” on page 403
- Figure 308, “E5505A system connections with test set option 001,” on page 404
- Figure 309, “E5505A system connections with test set option 201,” on page 405

Checking the beatnote

While the connect diagram is still displayed, Agilent recommends that you use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your device-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the capture range of the system.

The phase lock loop (PLL) capture range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO.

Refer to Chapter 14, “Evaluating Your Measurement Results if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.)

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system will not be able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote is very close to 0 Hz.

Searching for the beatnote requires you to adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display.

If incrementing the frequency of one of the sources does not produce a beatnote, you need to verify the presence of an output signal from each source before proceeding.

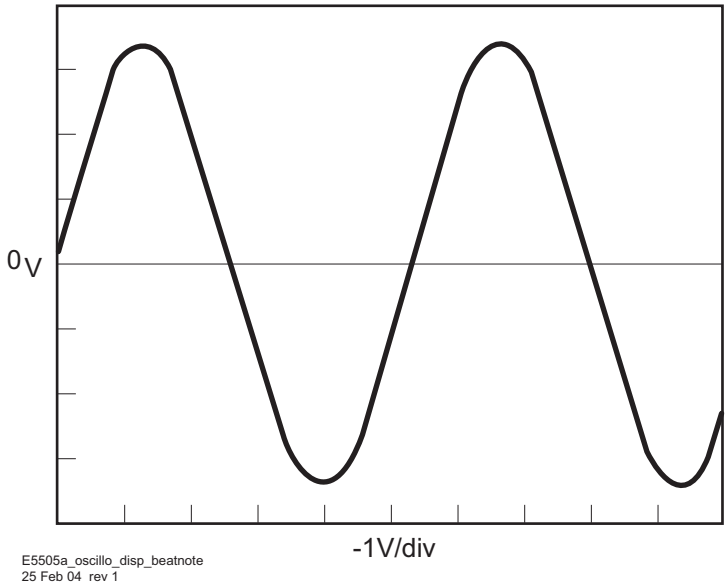


Figure 105 Oscilloscope display of beatnote from test set Monitor port

1 Estimate the system's capture range (using the VCO source parameters entered for this measurement). The estimated VCO tuning constant must be accurate within a factor of 2. A procedure for Estimating the Tuning Constant is located in this chapter.

$$\text{Capture Range (Hz)} = \frac{\text{VCO Tuning Constant (Hz / V) X Tuning Range (V)}}{10}$$

$$\text{Capture Range (Hz)} = \frac{\text{(Hz / V) X} \qquad \text{(V)}}{10} = _____ \text{(Hz)}$$

NOTE If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to Minimizing Injection Locking in the Problem Solving section of this chapter for recommended actions.

NOTE If you are not able to tune the beatnote to within the capture range due to frequency drift, refer to Tracking Frequency Drift in the Problem Solving section of this chapter for information about measuring drifting signals.

Making the measurement

1 Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.

2 When the PLL Suppression Curve dialog box appears, select **View Measured Loop Suppression**, **View Smoothed Loop Suppression**, and **View Adjusted Loop Suppression**. See Figure 106 on page 156.

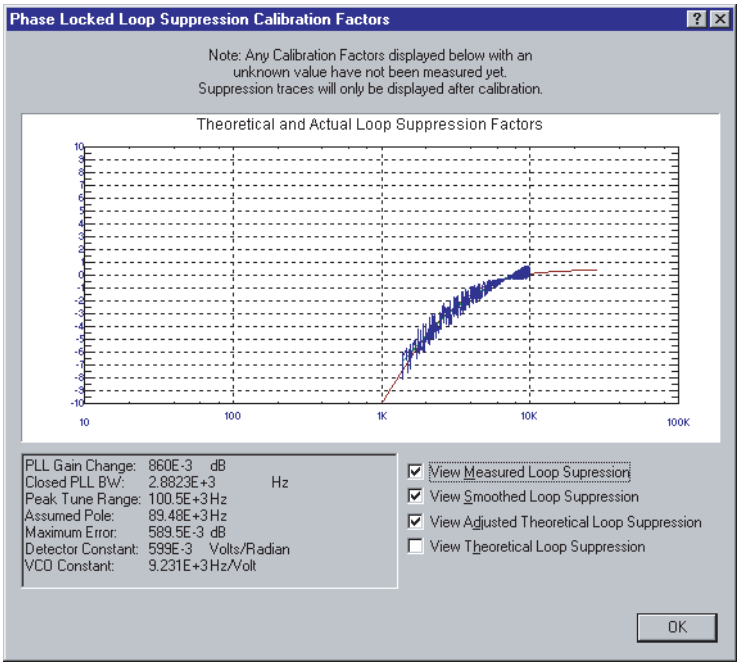


Figure 106 Selecting suppressions

- There are four different curves for this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features.)
  - **a** “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.
  - **b** “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.
  - **c** “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, etc).
  - **d** “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results for help with using the results.

Figure 107 on page 157 shows a typical phase noise curve for a free-running RF Oscillator.

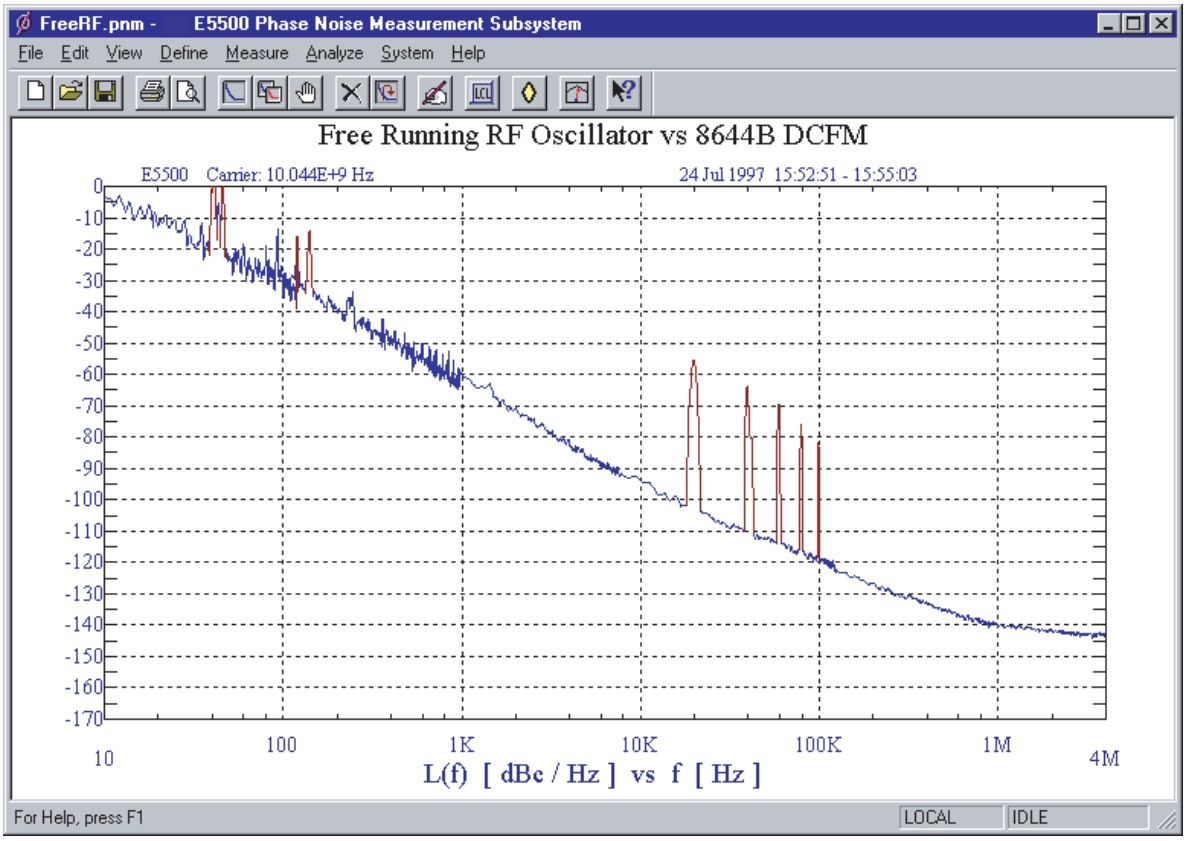


Figure 107 Typical phase noise curve for a free-running RF oscillator

Table 19 Parameter data for the free-running RF oscillator measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Absolute Phase Noise (using a phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 4 E + 6 Hz
	• Minimum Number of Averages	• 4
	FFT Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 10.044 E + 9 Hz
	• Power	• – 4 dBm
	• Carrier Source Output is connected to:	• Test Set
	Detector Input	
	• Frequency	• 444 E +6 Hz
	Reference Source	
	• Frequency	• 444 E +6 Hz (same as Carrier Source Frequency)
	• Reference Source Power	• 16 dBm
	VCO Tuning Parameters	
	• Nominal Tune Constant	• 40 E +3 Hz/V
	• Tune Range ±	• ± 10 Volts
	• Center Voltage	• 0 Volts
	• Input Resistance	• 600 ohms
3	**Cal Tab**	
	• Phase Detector Constant	• Measure Phase Detector Constant
	• VCO Tune Constant	• Calculate from expected VCO Tune Constant
	• Phase Lock Loop Suppression	• Verify calculated phase locked loop suppression
	• If Limit is exceeded	• Show Suppression Graph
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Downconverter	• Agilent N5502A/70422A
	• Reference Source	• Agilent 8644B (System Control)
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination:	• Reference Source
	• VCO Tune Mode	• DCFM

Table 19 Parameter data for the free-running RF oscillator measurement (continued)

5	**Test Set Tab**	
	Input Attenuation	• 0 dB
	LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm
6	**Downconverter Tab**	
	Input Frequency	• 10.044 E + 9
	L.O. Frequency	• Auto
	I.F. Frequency	• 444 E +6
	Millimeter Frequency	• 0
	L.O. Power	• 20 dBM
	Maximum AM Detector Level	• 0 dBm
	Input Attenuation	• 0 dB
	I.F. Gain	• 0 dB
	• Auto	• Checked
	Microwave/Millimeter Band	• Microwave (0 to 26.5 GHz)
	Millimeter Band Mixer Bias	
	• Enable	• Unchecked
	• Current	• 0 mA
	Reference Chain	
	• Reference	• 10 MHz
	• External Tune Enable	• Unchecked
	Tuning Sensitivity	• 0 ppm/v
	• Nominal	• 0 ppm/V
	• 100 MHz PLL Bandwidth	• 126 Hz
	• 600 MHz PLL Bandwidth	• 10000 Hz

RF Synthesizer Using DCFM

This measurement example will help you measure the absolute phase noise of an RF synthesizer using DCFM.

CAUTION To prevent damage to the test set's components, *do not* apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 21 on page 167. Apply the input signal when the connection diagram appears.

Required equipment

This measurement requires an Agilent 8257x with a DCFM Input port, in addition to the phase noise test system and your DUT. (For more information, see "Selecting a reference source" on page 132.) You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the measurement

1. From the **File** menu, choose **Open**.
2. If necessary, choose the drive or directory where the file you want is stored.
3. In the **File Name** box, choose "**RFSynth_DCFM.pnm**". See Figure 108.

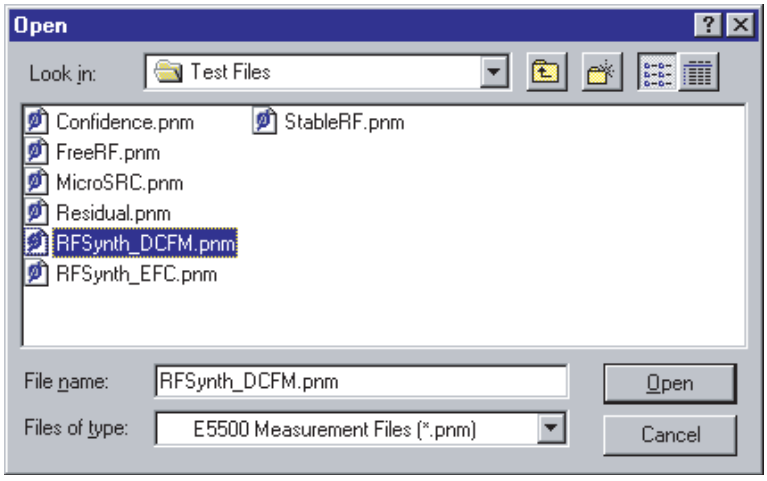


Figure 108 Select the parameters definition file

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 25 on page 186 lists the parameter data that has been entered for the RF Synthesizer using DCFM measurement example.

NOTE

Note that the source parameters entered for step 2 in Table 22 on page 172 may not be appropriate for the reference source you are using. To change these values, refer to Table 20 on page 162, then continue with step 5 below. Otherwise, go to "Beginning the measurement" on page 166

5 Using Figure 92 as a guide, navigate to the **Sources** tab.

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.

b Enter the VCO (Nominal) Tuning Constant (see Table 20 on page 162).

c Enter the Tune Range of VCO (see Table 20).

d Enter the Center Voltage of VCO (see Table 20).

e Enter the Input Resistance of VCO (see Table 20).

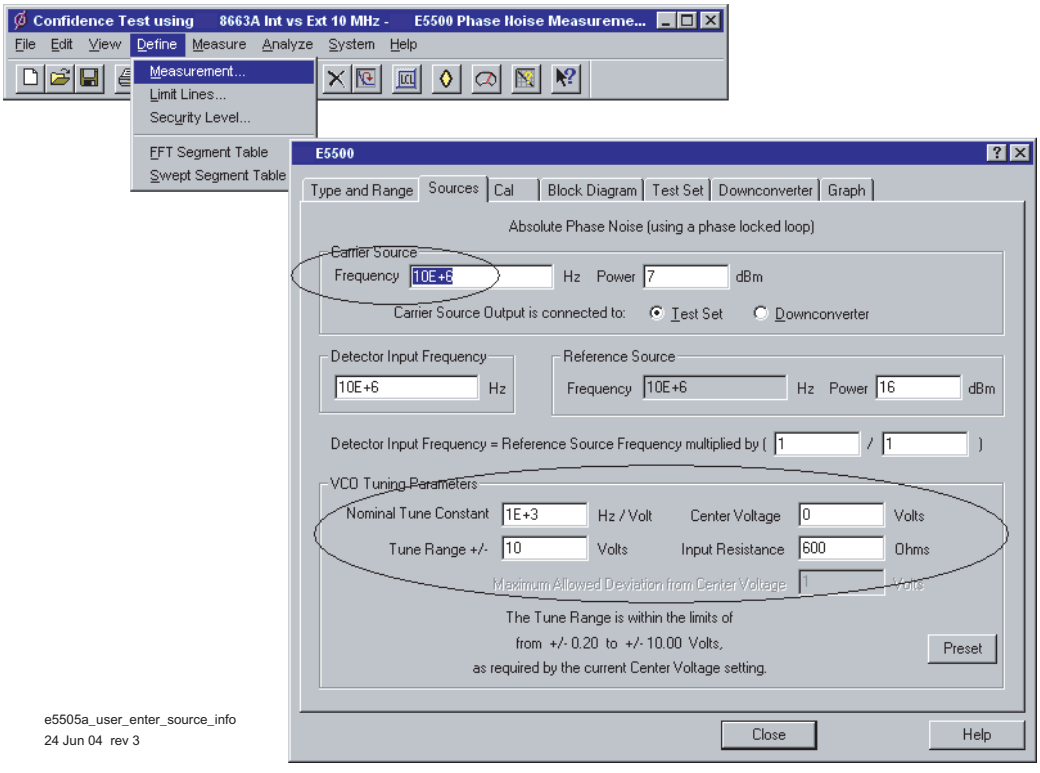


Figure 109 Enter source information

Table 20 Tuning characteristics for various sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (±V)	Input Resistance (Ω)	Calibration Method
Agilent 8662/3A EFC DCFM	υ_0	5 E – 9 x υ_0 FM Deviation	0 0	10 10	1E + 6 1 K (8662) 600 (8663)	Measure Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1 Using Figure 110 as a guide, navigate to the **Block Diagram** tab.

2 From the **Reference Source** pull-down list, select your source.

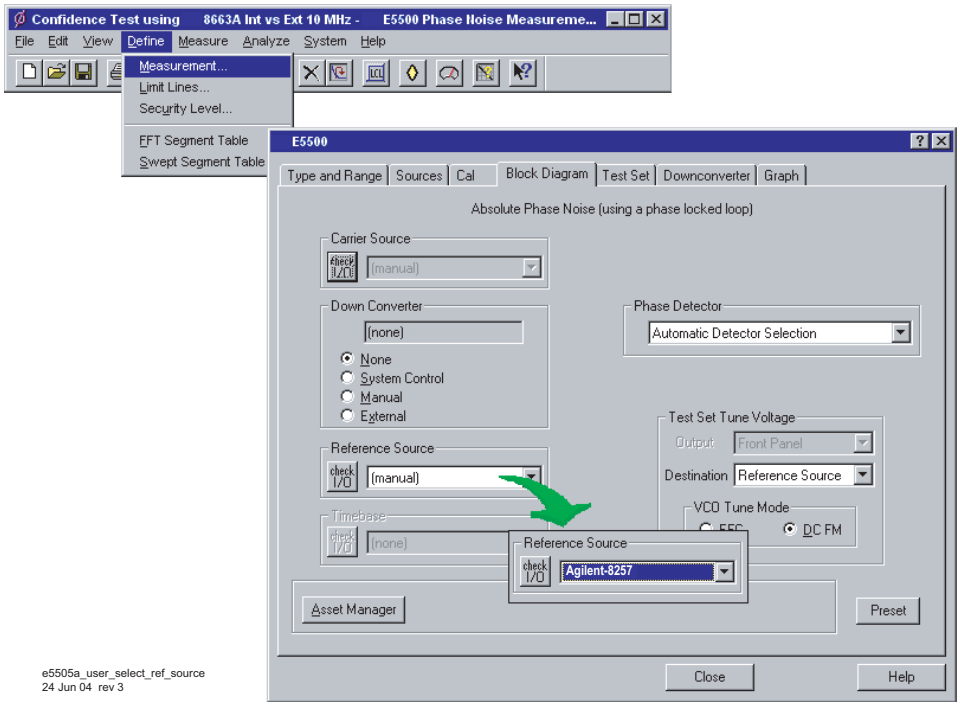


Figure 110 Selecting a reference source

3 When you have completed these operations, click the **Close** button.

Selecting Loop Suppression Verification

1 Using Figure 111 as a guide, navigate to the **Cal** tab.

2 In the **Cal** dialog box, check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph.**

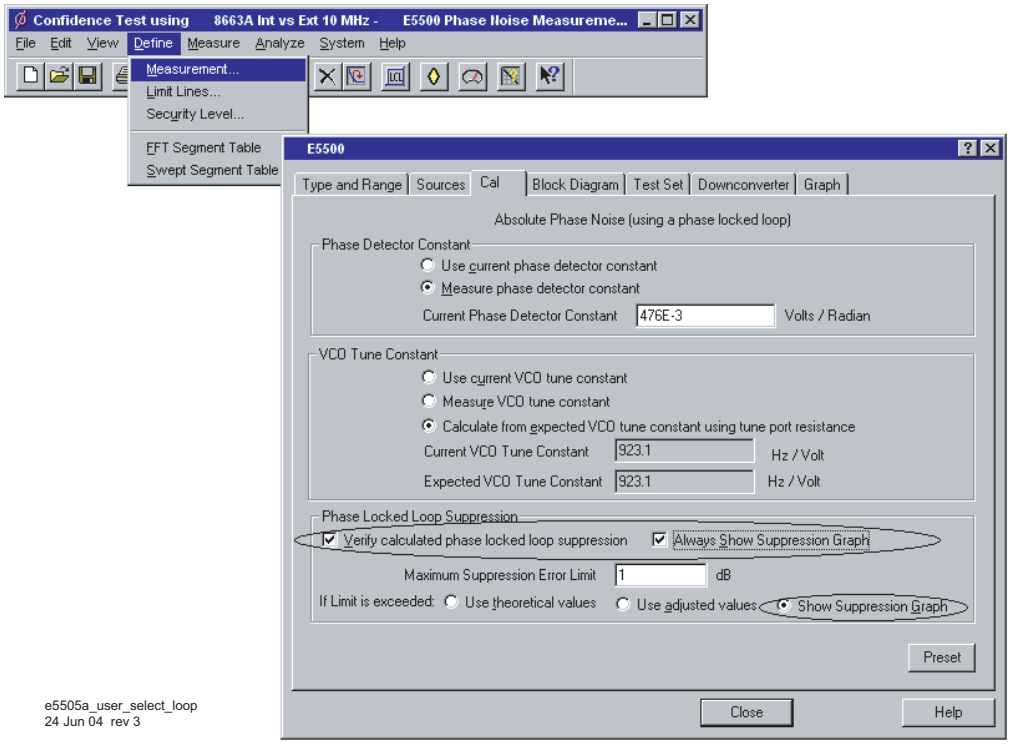


Figure 111 Selecting loop suppression verification

3 When you have completed these operations, click the **Close** button.

Setup considerations for the RF synthesizer using DCFM measurement

Measurement noise floor

The signal amplitude at the test set's R input (Signal Input) port sets the measurement noise floor level. Use Figure 112 and Figure 113 on page 165 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your DUT.

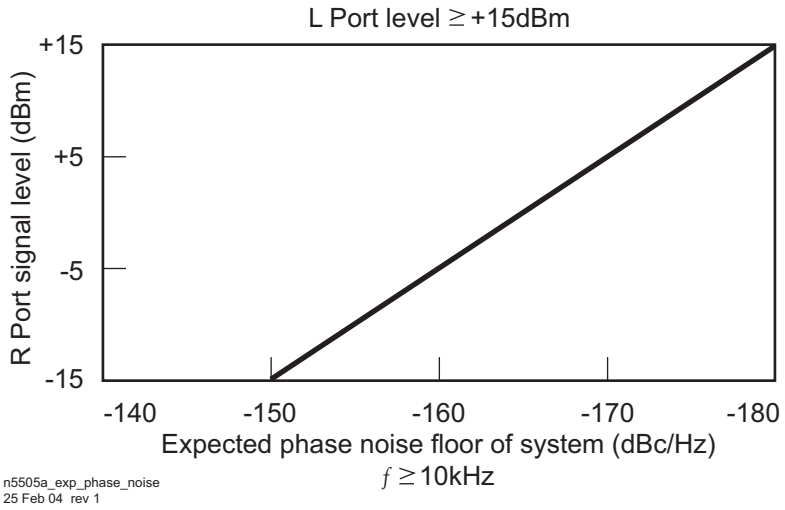


Figure 112 Noise floor for the RF synthesizer (DCFM) measurement

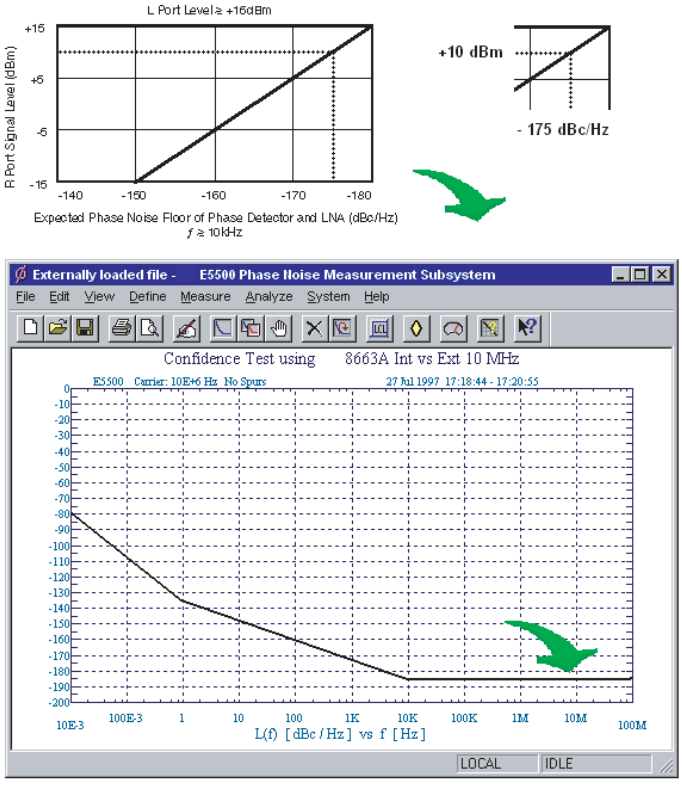


Figure 113 Noise floor calculation example

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT and the test set input. (Refer to the section "Inserting a Device" on page 122 for details on determining the effect that the amplifier's noise will have on the measured noise floor.)

Agilent 8663A VCO reference

This setup uses the 8663A as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the DUT, the noise level of the reference source should be below the expected noise level of the DUT.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement. See Figure 102.**

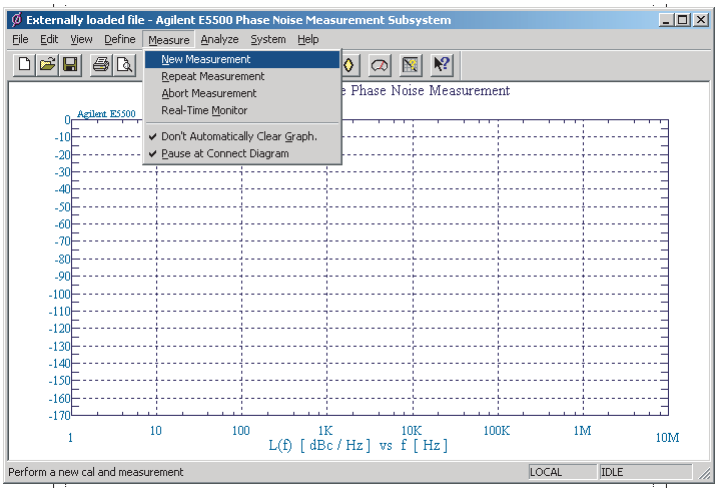


Figure 114 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

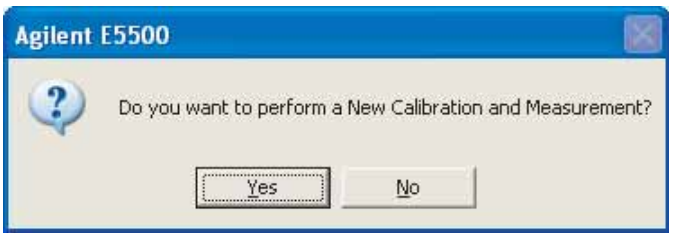


Figure 115 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select your hardware configuration from the list. See Figure 116.

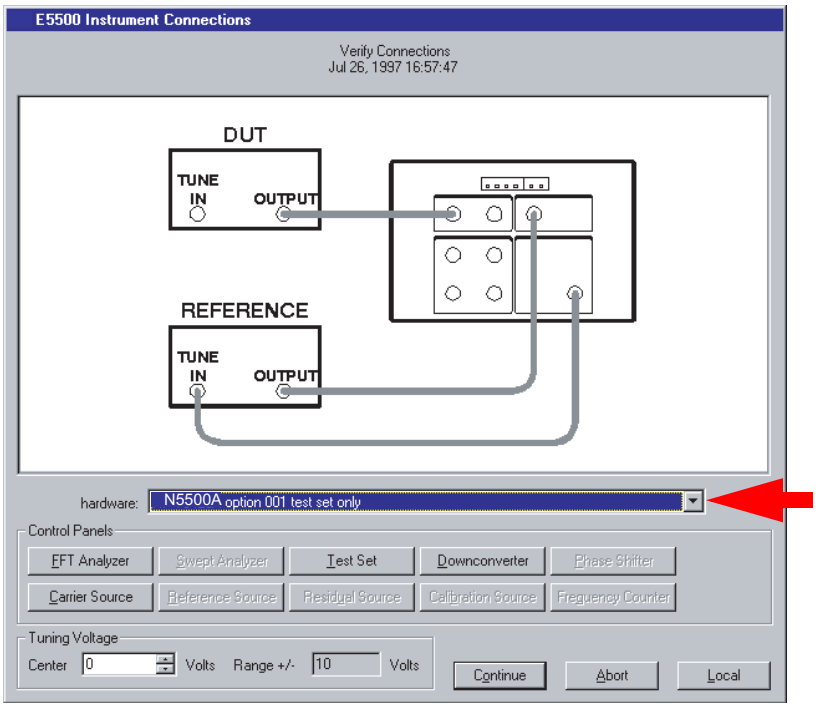


Figure 116 Connect diagram for the RF synthesizer (DCFM) measurement

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics in Table 21 on page 167.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which will occur when the connection diagram appears.

Table 21 Test set signal input limits and characteristics

Limits

Table 21 Test set signal input limits and characteristics (continued)

Frequency	• 50 kHz to 1.6 GHz (Std) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm (+30 with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

NOTE

Refer to the following system connect diagram examples in Chapter 18, “System Interconnections,” for more information about system interconnections.

- Figure 307, “E5505A system connections with standard test set,” on page 403
- Figure 308, “E5505A system connections with test set option 001,” on page 404
- Figure 309, “E5505A system connections with test set option 201,” on page 405

Checking the beatnote

While the connect diagram is still displayed, use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your device-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the capture range of the system.

The phase-lock-loop (PLL) capture range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO.

Refer to Chapter 14, “Evaluating Your Measurement Results” if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.)

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system will not be able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz.

Searching for the beatnote will require that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display.

If incrementing the frequency of one of the sources does not produce a beatnote, you will need to verify the presence of an output signal from each source before proceeding.

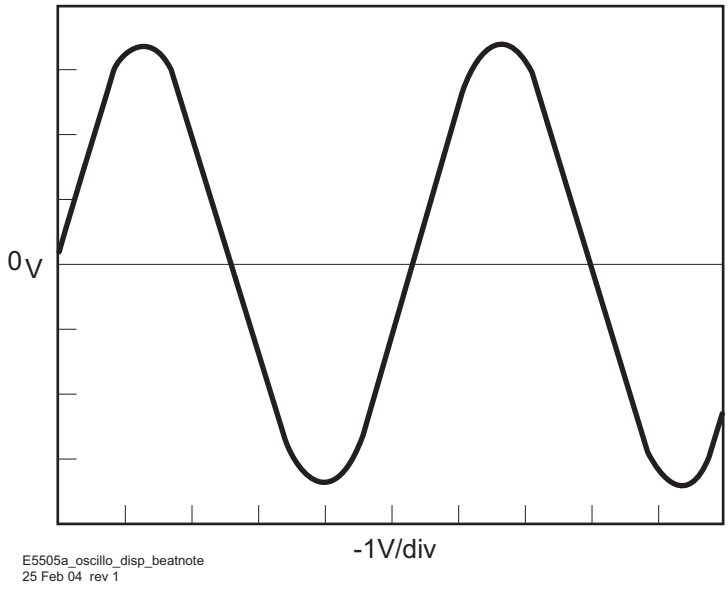


Figure 117 Oscilloscope display of beatnote from the test set Monitor port

Making the measurement

1 Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.

2 When the PLL Suppression Curve dialog box appears, select **View Measured Loop Suppression**, **View Smoothed Loop Suppression**, and **View Adjusted Loop Suppression**. See Figure 118.

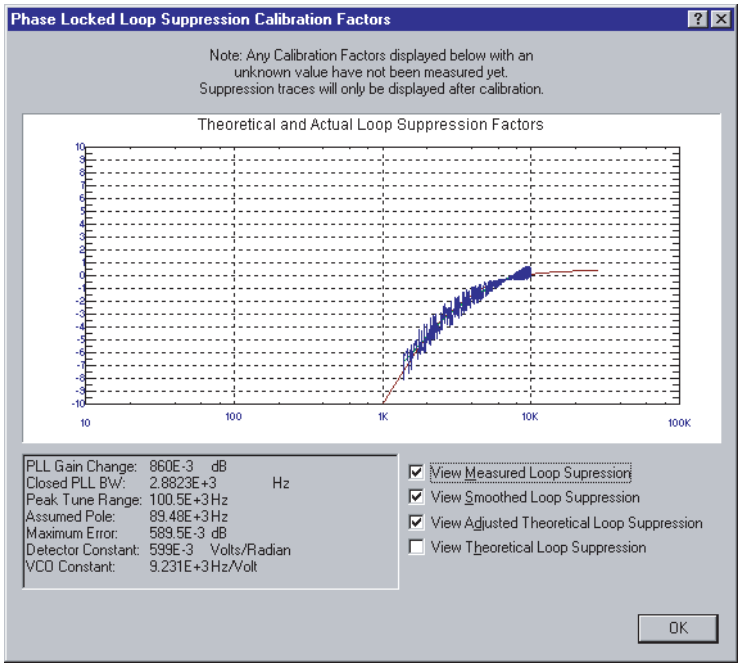


Figure 118 Selecting suppressions

There are four different curves for this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features.”)

a “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.

b “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.

c “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, etc).

d “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results” for help with using the results.

Figure 119 shows a typical phase noise curve for an RF synthesizer using DCFM.

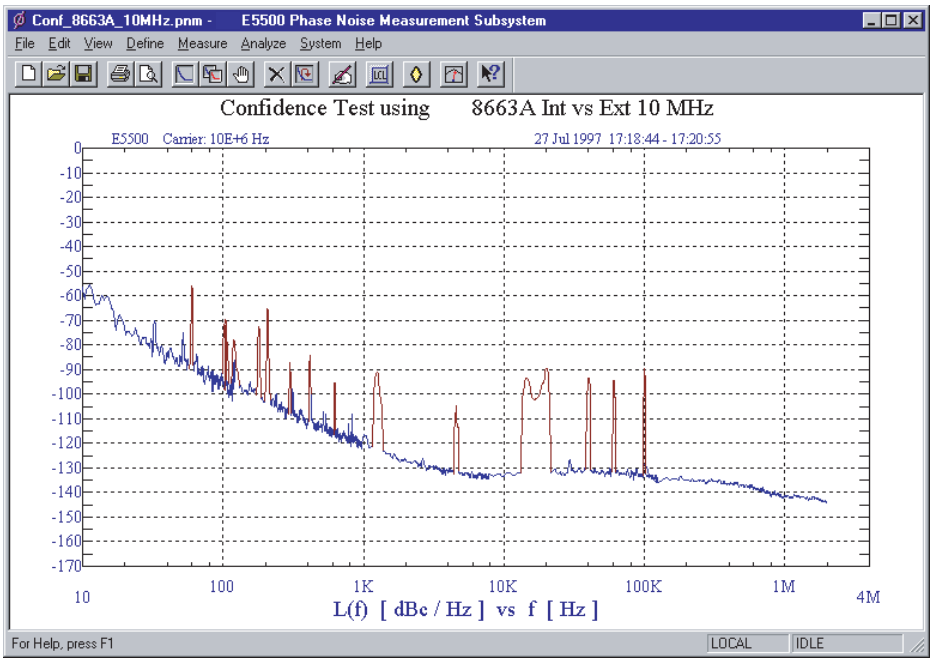


Figure 119 Typical phase noise curve for an RF synthesizer using DCFM

Table 22 Parameter Data for the RF Synthesizer (DCFM) Measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Absolute Phase Noise (using a phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 4 E + 6 Hz
	• Minimum Number of Averages	• 4
	FFT Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 600 E + 6 Hz
	• Power	• 20 dBm
	• Carrier Source Output is connected to:	• Test Set
	Detector Input	
	• Frequency	• 600 E +6 Hz
	Reference Source	
	• Frequency	• 600 E +6 Hz (same as Carrier Source Frequency)
	• Reference Source Power	• 16 dBm
	VCO Tuning Parameters	
	• Nominal Tune Constant	• 40 E +3 Hz/V
	• Tune Range ±	• ± 10 Volts
	• Center Voltage	• 0 Volts
	• Input Resistance	• 600 Ω
3	**Cal Tab**	
	Phase Detector Constant	Measure Phase Detector Constant
	VCO Tune Constant	Calculate from expected VCO Tune Constant
	Phase Lock Loop Suppression	Verify calculated phase locked loop suppression
	If Limit is exceeded	Show Suppression Graph
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Downconverter	• None
	• Reference Source	• Agilent 8663A
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination:	• Reference Source
	• VCO Tune Mode	• DCFM

Table 22 Parameter Data for the RF Synthesizer (DCFM) Measurement (continued)

Step	Parameters	Data
5	**Test Set Tab**	
	• Input Attenuation	• 0 dB
	• LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm
6	**Downconverter Tab**	• The downconverter parameters do not apply to this measurement example.
7	**Graph Tab**	
	• Title	• RF Synthesizer vs Agilent 8663A using DCFM
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 4 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –170 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

RF Synthesizer Using EFC

This measurement example will help you measure the absolute phase noise of an RF synthesizer using EFC.

CAUTION To prevent damage to the test set's components, the input signal *do not* apply the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 31. Apply the input signal when the connection diagram appears

Required equipment

This measurement requires an Agilent 8257x with an EFC Input port, in addition to the phase noise test system and your DUT. (For more information, refer to the section "Selecting a reference source" on page 132.) You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement

Defining the measurement

1 From the **File** menu, choose **Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, choose "**RFSynth_EFC.pnm**". See Figure 120.

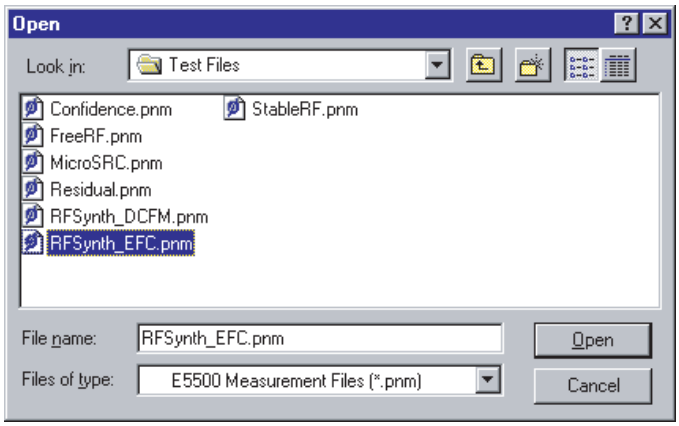


Figure 120 Select the parameters definition file

4 Click the **Open** button.

- The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 28 on page 200 lists the parameter data that has been entered for the RF Synthesizer using EFC measurement example.)

NOTE Note that the source parameters in Table 28 may not be appropriate for the reference source you are using. To change these values, refer to Table 26 on page 190, then continue with step step 5. Otherwise, go to "Beginning the measurement" on page 180.

5 Using Figure 121 on page 176 as a guide, navigate to the **Sources** tab.

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.

b Enter the VCO Tuning Constant (see Table 26 on page 190).

c If you are going to use EFC tuning to tune the 8663A, use the following equation to calculate the appropriate VCO Tuning Constant to enter for the measurement.

- VCO Tuning Constant = T x Carrier Frequency
- Where T= 5E-9 for EFC

For example, to calculate the Tuning Constant value to enter for EFC tuning when the center frequency is 300 MHz:

- (5 E – 9) X (300 E + 6) = (1500 E – 3) = 1.5

d Enter the Tune Range of VCO (Table 26).

e Enter the Center Voltage of VCO (Table 26).

f Enter the Input Resistance of VCO (Table 26)

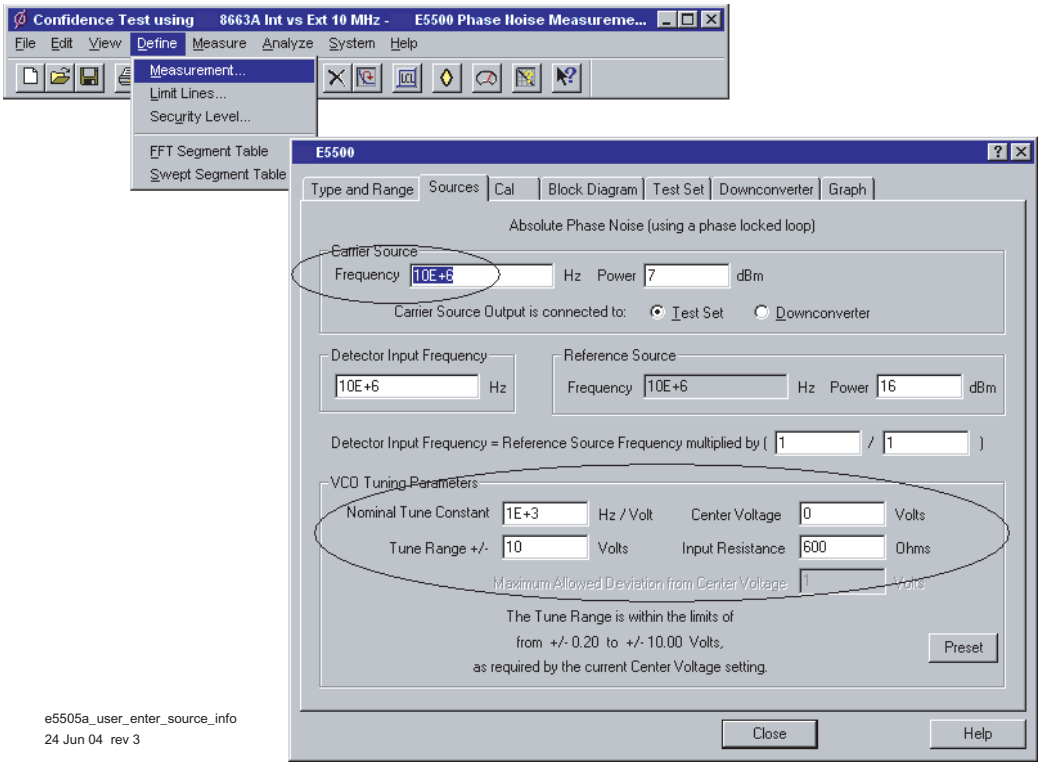


Figure 121 Enter Source Information

Table 23 Tuning Characteristics for Various Sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (±V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A EFC DCFM	υ_0	5 E – 9 x υ_0 FM Deviation	0 0	10 10	1E + 6 1 K (8662) 600 (8663)	Measure Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1 Using Figure 122 as a guide, navigate to the **Block Diagram** tab.

2 From the **Reference Source** pull-down list, select your source.

3 When you have completed these operations, click the **Close** button.

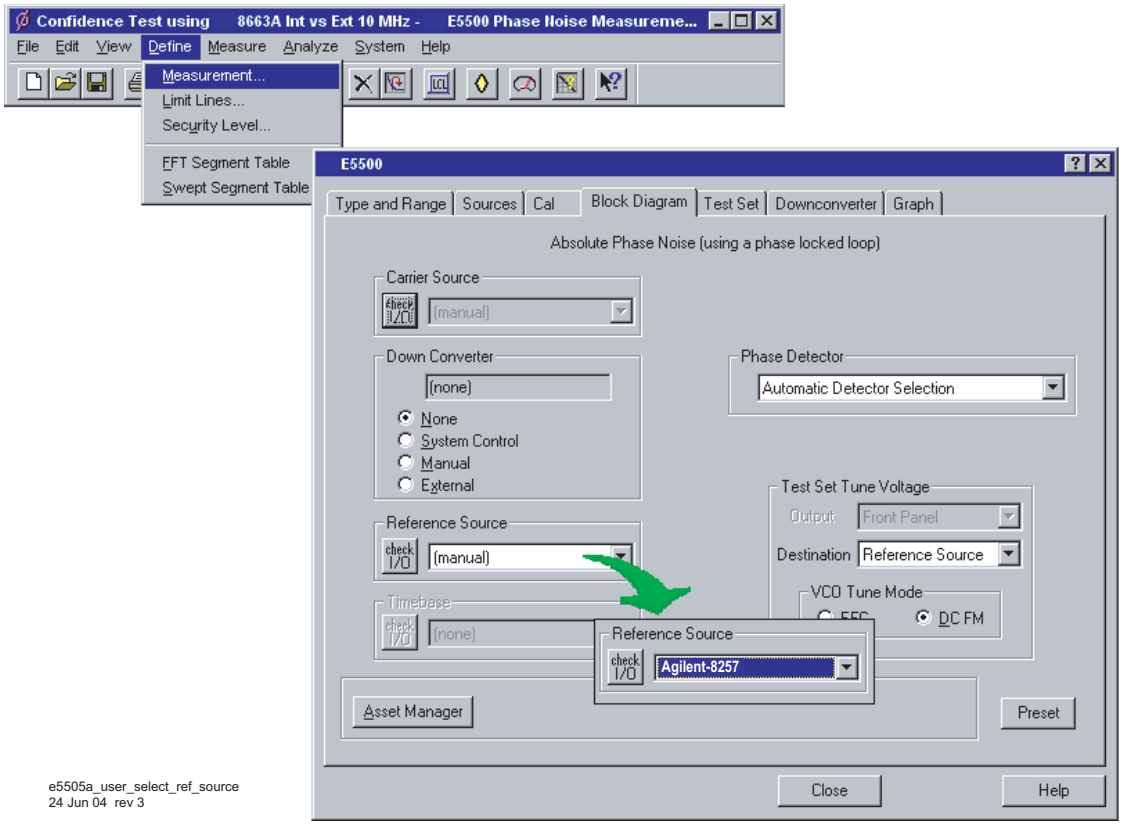


Figure 122 Selecting a reference source

Selecting Loop Suppression Verification

1 Using Figure 123 on page 178 as a guide, navigate to the **Cal** tab.

2 In the **Cal** dialog box, check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph**.

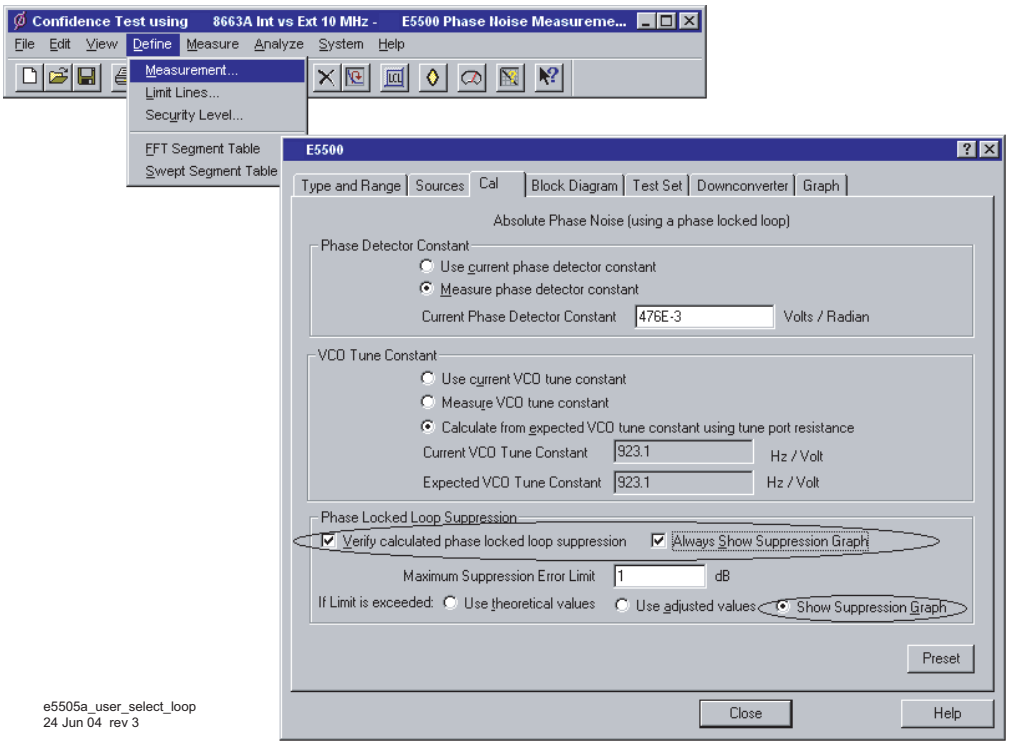


Figure 123 Selecting Loop suppression verification

Setup considerations for the RF synthesizer using EFC measurement

Measurement noise floor

The signal amplitude at the test set's R input (Signal Input) port sets the measurement noise floor level. Use Figure 124 and Figure 125 on page 179 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your DUT.

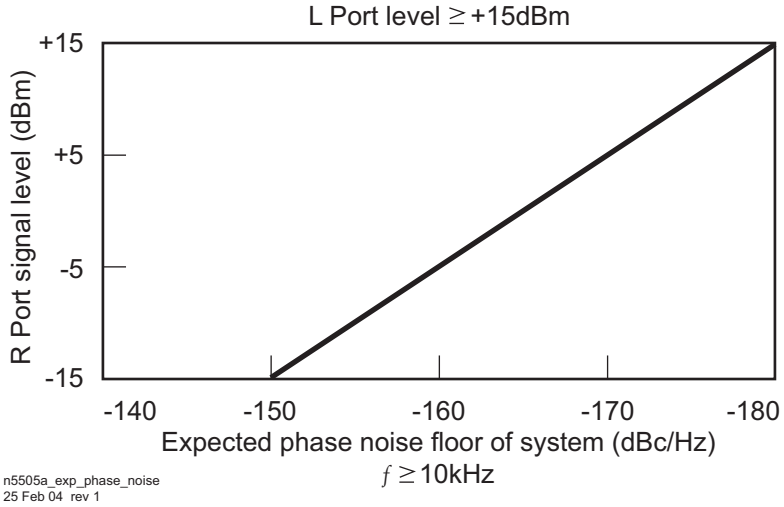


Figure 124 Noise floor for the RF synthesizer (EFC) measurement

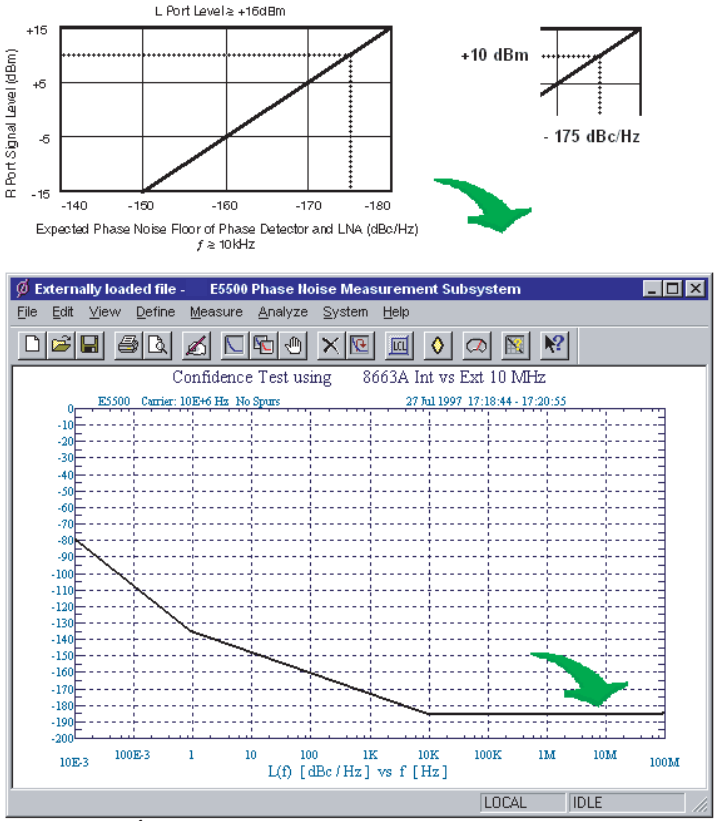


Figure 125 Noise floor calculation example

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT and the test set input. (Refer to the section "Inserting a Device" on page 122 for details on determining the effect that the amplifier's noise will have on the measured noise floor.)

Agilent 8663A VCO reference

This setup uses the 8663A as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the DUT, the noise level of the reference source should be below the expected noise level of the DUT.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement. See Figure 126.**

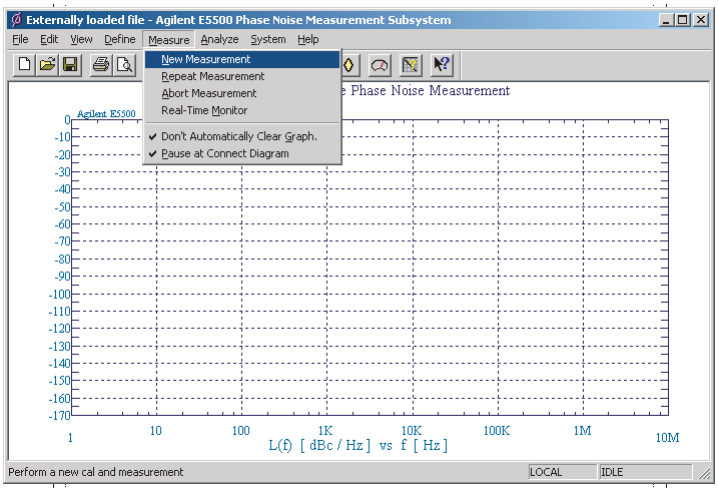


Figure 126 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

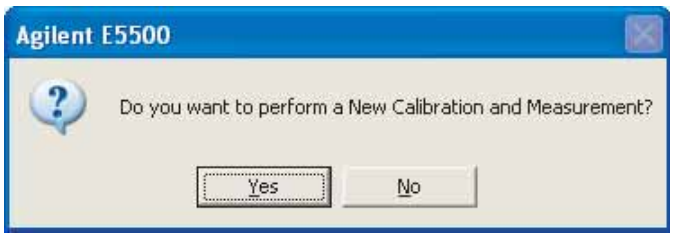


Figure 127 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select your hardware configuration from the list. See Figure 128.

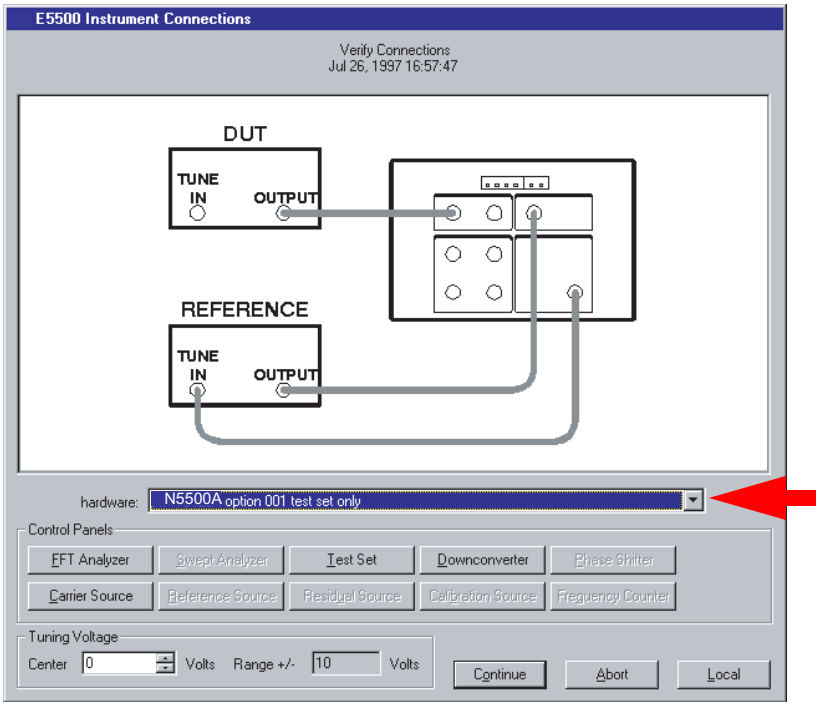


Figure 128 Connect diagram for the RF synthesizer (EFC) measurement

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics in Table 24 on page 182.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which will occur when the connection diagram appears.

Table 24 Test set signal Input Limits and Characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm(+30 with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

NOTE

Refer to the following system connect diagram examples in Chapter 18, “System Interconnections,” for more information about system interconnections.

- Figure 307, “E5505A system connections with standard test set,” on page 403
- Figure 308, “E5505A system connections with test set option 001,” on page 404
- Figure 309, “E5505A system connections with test set option 201,” on page 405

Checking the beatnote

While the connect diagram is still displayed, Agilent recommends that you use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your device-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the capture range of the system.

The phase lock loop (PLL) capture range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO.

Refer to Chapter 14, “Evaluating Your Measurement Results if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.)

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system will not be able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz.

Searching for the beatnote will require that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display.

If incrementing the frequency of one of the sources does not produce a beatnote, you will need to verify the presence of an output signal from each source before proceeding.

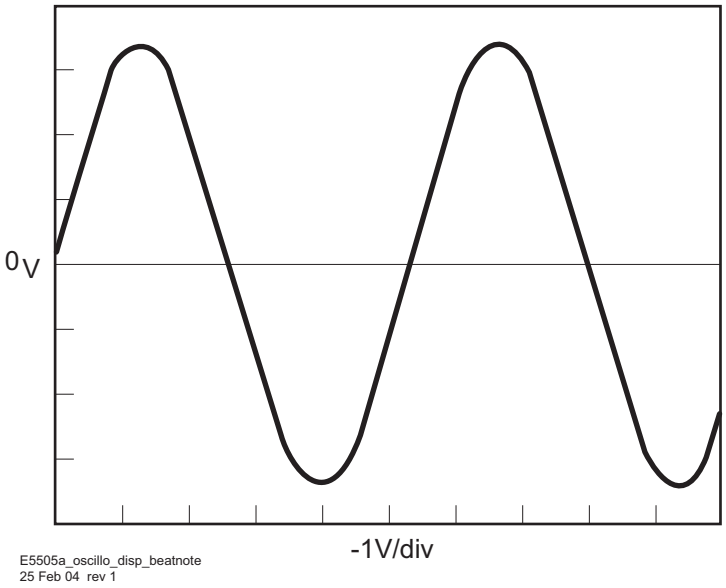


Figure 129 Oscilloscope display of a beatnote from the test set Monitor port

Making the measurement

1. Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.
2. When the PLL Suppression Curve dialog box appears, select **View Measured Loop Suppression**, **View Smoothed Loop Suppression**, and **View Adjusted Loop Suppression**. See Figure 130 on page 184.

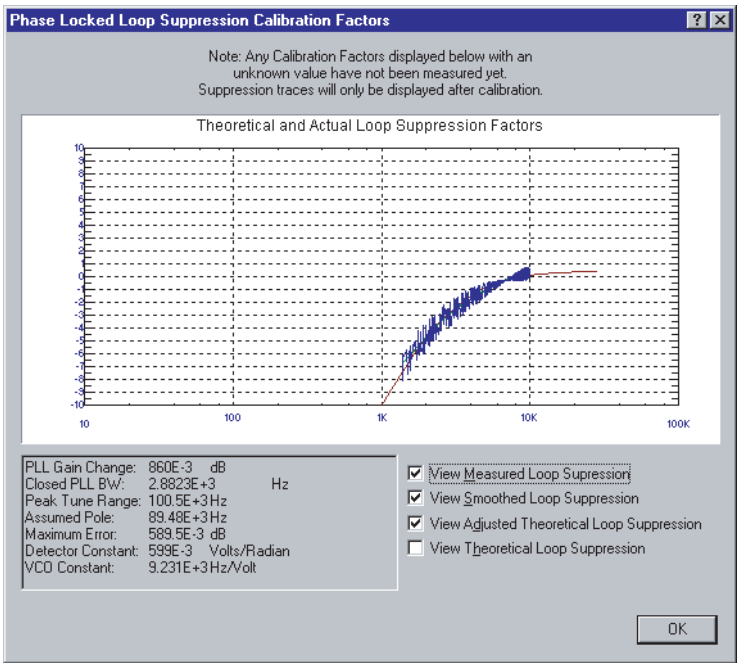


Figure 130 Selecting suppressions

There are four different curves for this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features.”)

- **a** “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.
- **b** “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.
- **c** “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, etc).
- **d** “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results” for help with using the results.

Figure 131 shows a typical phase noise curve for a RF synthesizer using EFC.

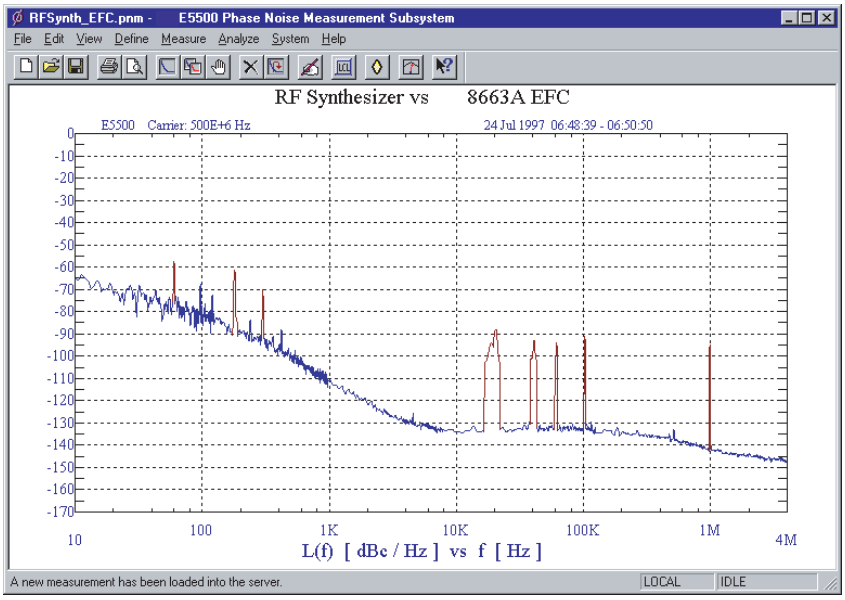


Figure 131 Typical phase noise curve for an RF synthesizer using EFC

Table 25 Parameter data for the RF synthesizer (EFC) measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Absolute Phase Noise (using a phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 4 E + 6 Hz
	• Minimum Number of Averages	• 4
	FFT Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 500 E + 6 Hz
	• Power	• 10 dBm
	• Carrier Source Output is connected to:	• Test Set
	Detector Input	
	• Frequency	• 500 E +6 Hz
	Reference Source	
	• Frequency	• 500 E +6 Hz (same as Carrier Source Frequency)
	• Reference Source Power	• 16 dBm
	VCO Tuning Parameters	
	• Nominal Tune Constant	• 2.5 Hz/V
	• Tune Range ±	• ± 10 Volts
	• Center Voltage	• 0 Volts
	• Input Resistance	• 1 E +6 ohms
3	**Cal Tab**	
	• Phase Detector Constant	• Measure Phase Detector Constant
	• VCO Tune Constant	• Measure from expected VCO Tune Constant
	• Phase Lock Loop Suppression	• Verify calculated phase locked loop suppression
	• If Limit is exceeded	• Show Suppression Graph
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Downconverter	• None
	• Reference Source	• Agilent 8663A
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination	• Reference Source
	• VCO Tune Mode	• EFC

Table 25 Parameter data for the RF synthesizer (EFC) measurement (continued)

Step	Parameters	Data
5	**Test Set Tab**	
	Input Attenuation	• 0 dB
	LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm
6	**Downconverter Tab**	• The downconverter parameters do not apply to this measurement example.
7	**Graph Tab**	
	• Title	• RF Synthesizer vs Agilent 8663A using EFC
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 4 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –170 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	
	• Trace Smoothing Amount	• 0 dB
	• Power present at input of DUT	• 0
		• 0 dB

Microwave Source

This measurement example will help you measure the absolute phase noise of a microwave source (2.5 to 18 GHz) with frequency drift of ≤10E – 9 X Carrier Frequency over a period of thirty minutes.

CAUTION To prevent damage to the test set's components, do not apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 27 on page 195. Apply the input signal when the connection diagram appears

Required equipment

This measurement requires an Agilent 8644A with a DCFM Input port, in addition to the phase noise test system and your DUT. (For more information, see the section "Selecting a reference source" on page 132.) You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the measurement

1 From the **File** menu, choose **Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, choose "**MicroSRC.pnm**". See Figure 132.

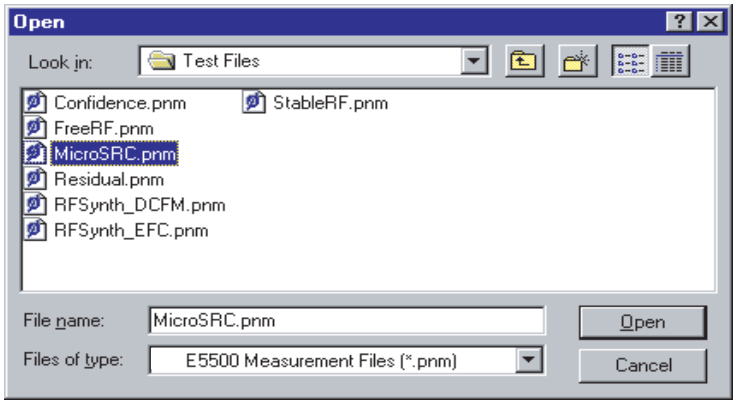


Figure 132 Select the parameters definition file

4 Click the **Open** button.

- The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 28 on page 200 lists the parameter data that has been entered for the Microwave Source measurement example.)

NOTE

Note that the source parameters in Table 28 on page 200 may not be appropriate for the reference source you are using. To change these values, refer to Table 26 on page 190, then continue with step 5 below. Otherwise, go to the section "Beginning the measurement" on page 193.

5 Using Figure 133 on page 190 as a guide, navigate to the **Sources** tab.

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.

b Enter the VCO Tuning Constant (see Table 26 on page 190). Use the following equation to calculate the appropriate VCO Tuning Constant to enter for the measurement.

- VCO Tuning Constant = T x Carrier Frequency, where T= 5E-9

For example, to calculate the Tuning Constant value to enter for EFC tuning when the center frequency is 18 GHz:

- (5 E – 9) X (18 E + 9) = 90

c Enter the Tune Range of VCO (see Table 26 on page 190).

d Enter the Center Voltage of VCO (see Table 26).

e Enter the Input Resistance of VCO (see Table 26).

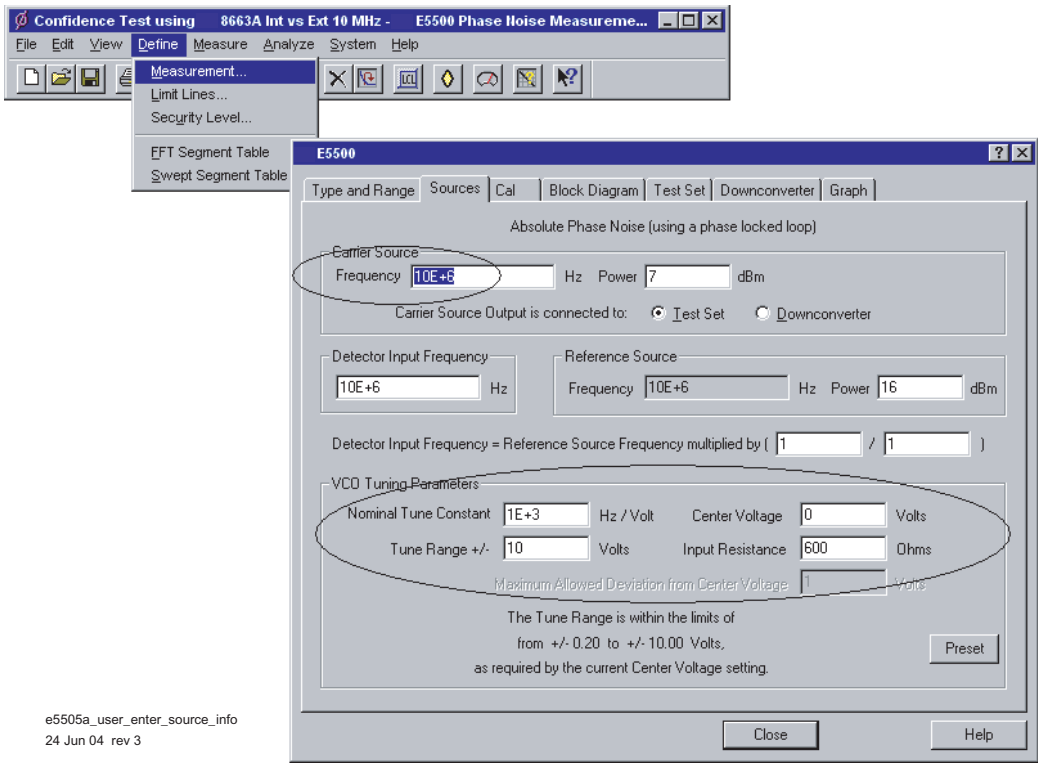


Figure 133 Enter source information

Table 26 Tuning characteristics for various sources

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (±V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A EFC DCFM	υ_0	5 E – 9 x υ_0 FM Deviation	0 0	10 10	1E + 6 1 K (8662) 600 (8663)	Measure Compute Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Compute
Other User VCO Source		Estimated within a factor of 2	–10 to +10		1 E + 6	Measure

Selecting a reference source

1 Using Figure 134 on page 191, navigate to the **Block Diagram** tab.

2 From the **Reference Source** pull-down list, select your source.

3 When you have completed these operations, click the **Close** button

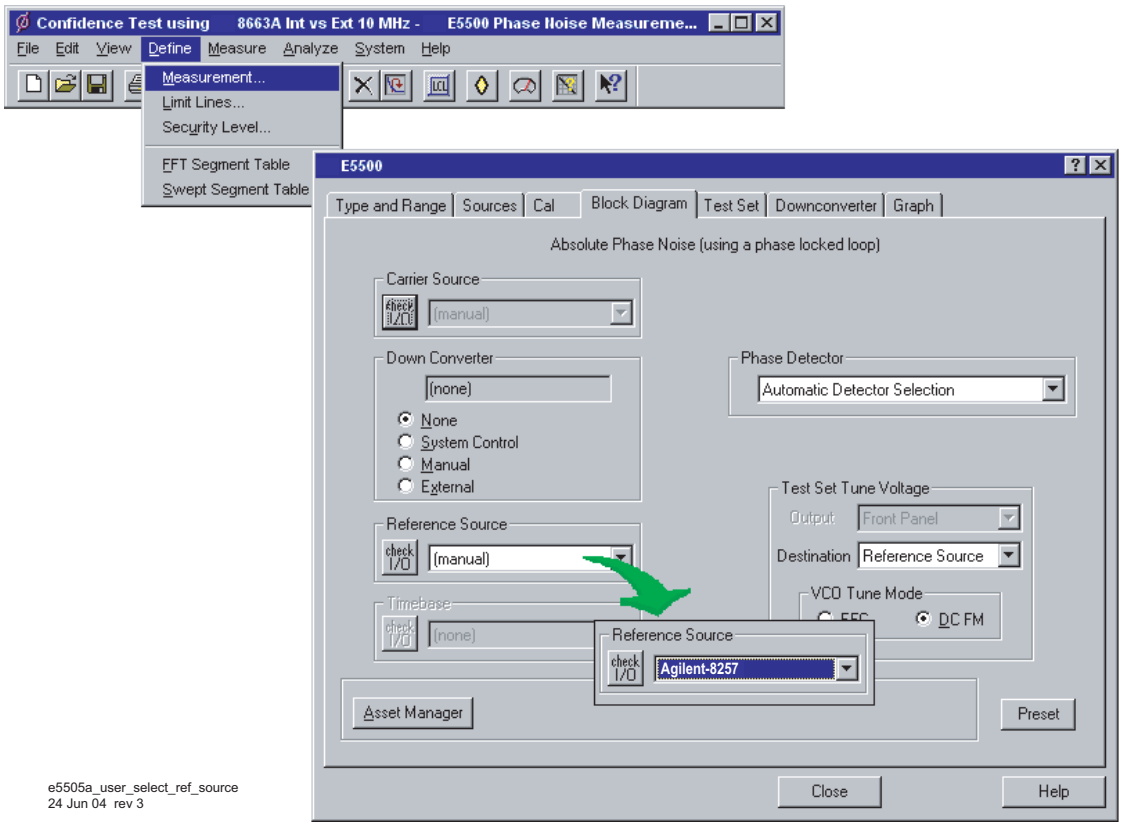


Figure 134 Selecting a reference source

Selecting Loop Suppression Verification

1 Using Figure 135 on page 192 as a guide, navigate to the **Cal** tab.

2 In the **Cal** dialog box, check **Verify calculated phase locked loop suppression** and **Always Show Suppression Graph**. Select **If limit is exceeded: Show Loop Suppression Graph**.

3 When you have completed these operations, click the **Close** button.

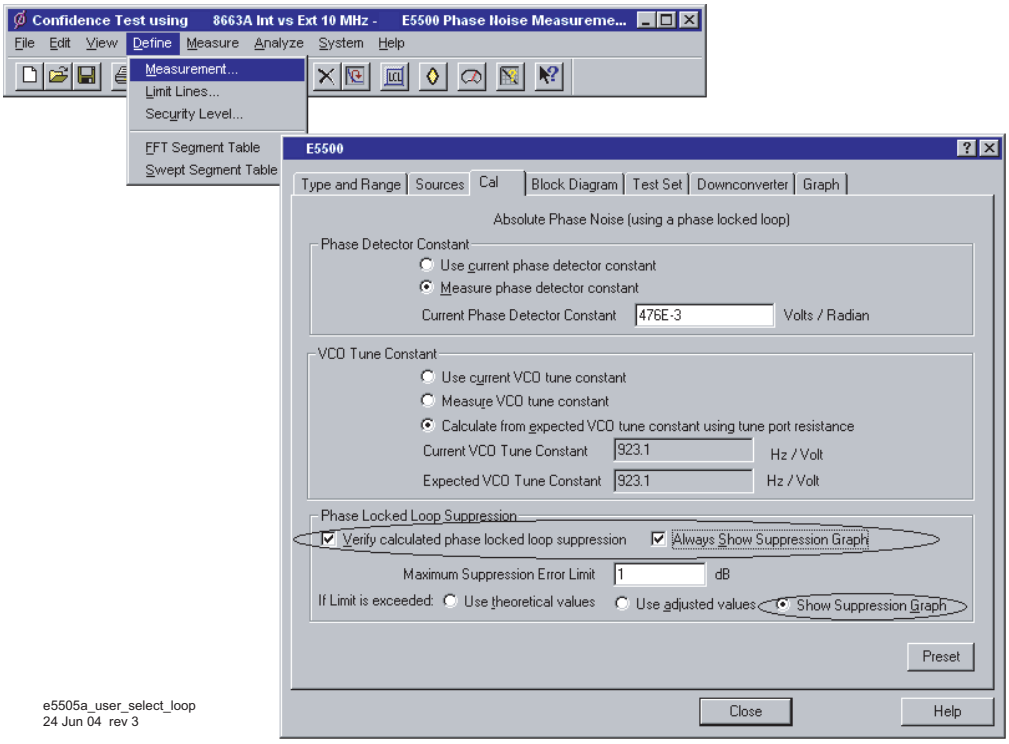


Figure 135 Selecting loop suppression verification

Setup considerations for the microwave source measurement

Measurement noise floor

Figure 136 shows a typical noise level for the N5502A/**70422A downconverter when used with the 8644B**. Use it to help you estimate if the measurement noise floor is below the expected noise level of your DUT.

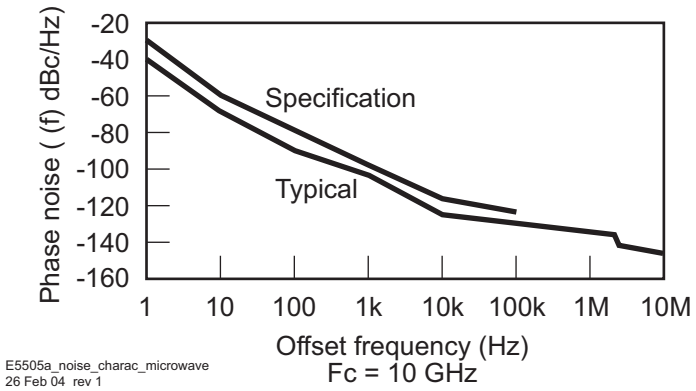


Figure 136 Noise characteristics for the microwave measurement

If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT and the downconverter **input**. (Refer to "Inserting a Device" on page 122 for details on determining the effect that the amplifier's noise will have on the measured noise floor.)

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement. See Figure 137.**

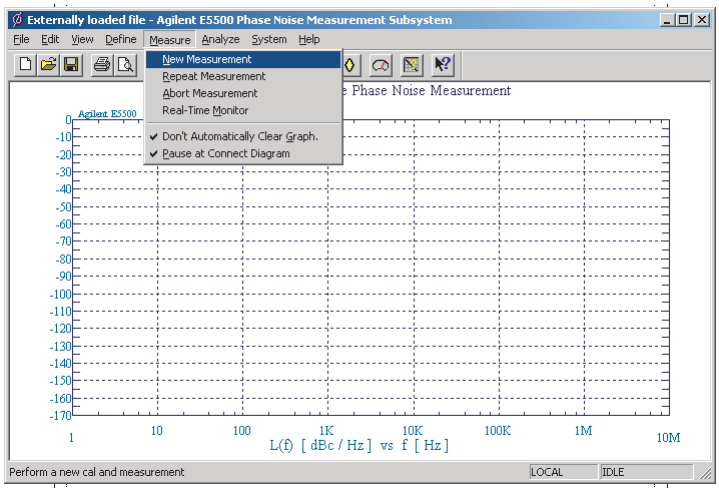


Figure 137 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

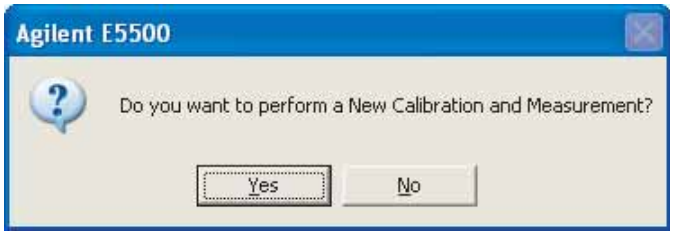


Figure 138 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select your hardware configuration from the list. See Figure 139 on page 194.

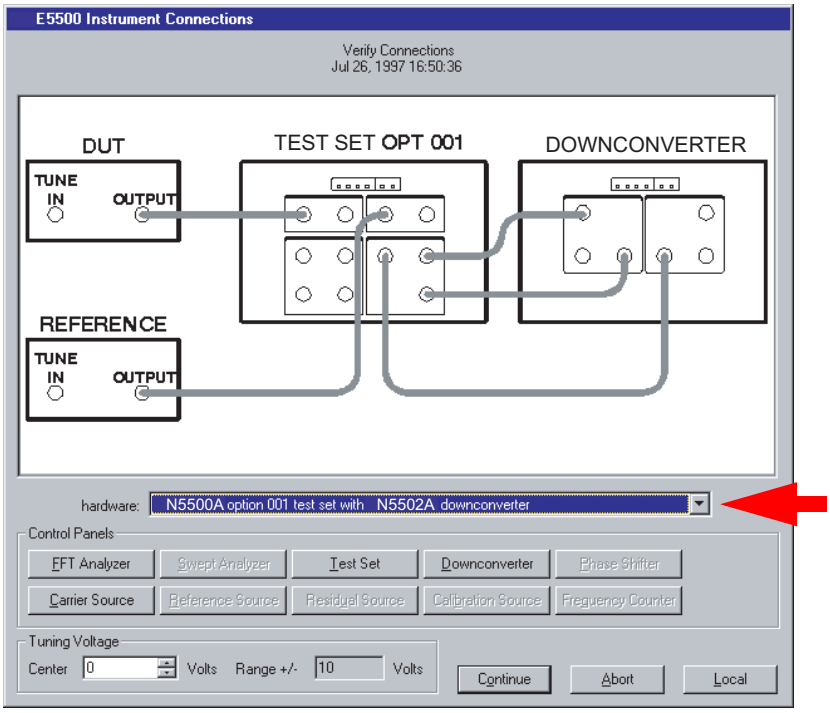


Figure 139 Connect diagram for the microwave source measurement

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics in Table 27.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which will occur when the connection diagram appears.

Table 27 Test set signal input limits and characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm (+30 dBm with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω Nominal
AM Noise	DC coupled to 50 Ω load

NOTE

Refer to the following system connect diagram examples in Chapter 18, “System Interconnections,” for more information about system interconnections.

- Figure 307, “E5505A system connections with standard test set,” on page 403
- Figure 308, “E5505A system connections with test set option 001,” on page 404
- Figure 309, “E5505A system connections with test set option 201,” on page 405

Checking the beatnote

While the connect diagram is still displayed, Agilent recommends that you use an oscilloscope (connected to the Monitor port on the test set) or a counter to check the beatnote being created between the reference source and your DUT. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the capture range of the system.

The phase lock loop (PLL) capture range is 5% of the peak tuning range of the VCO source you are using. (The peak tuning range for your VCO can be estimated by multiplying the VCO tuning constant by the tune range of VCO.

Refer to Chapter 14, “Evaluating Your Measurement Results” if you are not familiar with the relationship between the PLL capture range and the peak tuning range of the VCO.)

NOTE If the center frequencies of the sources are not close enough to create a beatnote within the capture range, the system will not be able to complete its measurement.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz.

Searching for the beatnote will require that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the oscilloscope’s display.

If incrementing the frequency of one of the sources does not produce a beatnote, you will need to verify the presence of an output signal from each source before proceeding. See Figure 140.

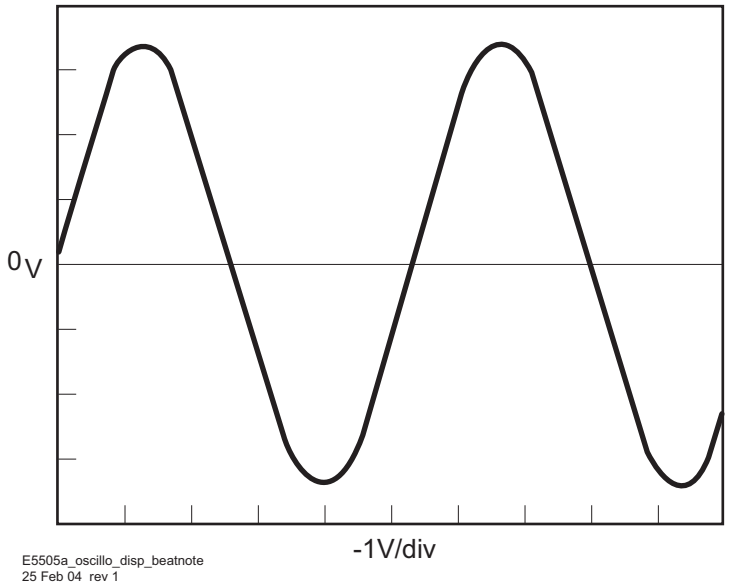


Figure 140 Oscilloscope display of a beatnote from the test set Monitor port

Estimate the system's capture range (using the VCO source parameters entered for this measurement) using the equation below. The estimated VCO tuning constant must be accurate within a factor of 2.

$$\textit{Capture Range}\ (Hz) = \frac{\text{VCO Tuning Constant (Hz/V) X Tuning Range (V)}}{5}$$

$$\textit{Capture Range}\ (Hz) = \frac{\text{(Hz/V) X} \qquad \text{(V)}}{5} = _____(Hz)$$

NOTE If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to Minimizing Injection Locking in the Problem Solving section of this chapter for recommended actions.

NOTE If you are not able to tune the beatnote to within the capture range due to frequency drift, refer to Tracking Frequency Drift in the Problem Solving section of this chapter for information about measuring drifting signals.

Making the measurement

1. Click the **Continue** button when you have completed the beatnote check and are ready to make the measurement.
2. When the PLL Suppression Curve dialog box appears, select **View Measured Loop Suppression**, **View Smoothed Loop Suppression**, and **View Adjusted Loop Suppression**. See Figure 141 on page 198.

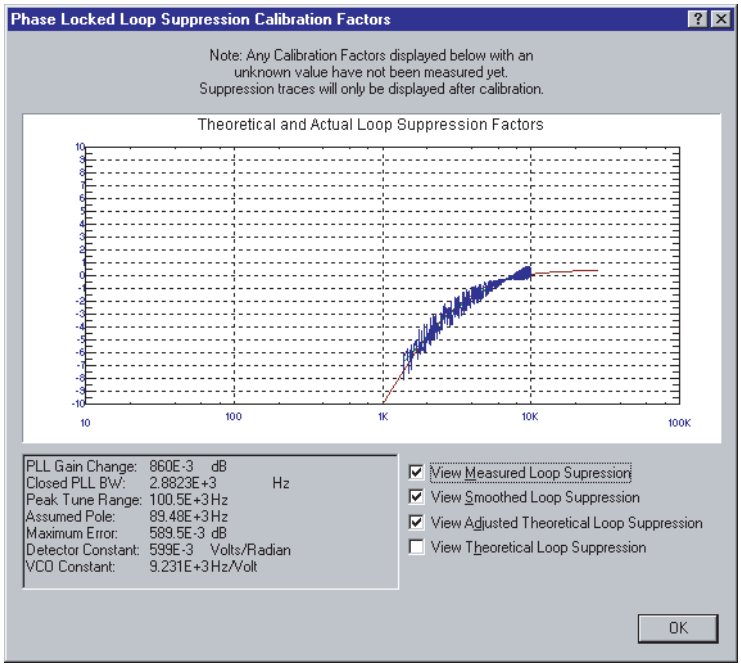


Figure 141 Selecting suppressions

- There are four different curves for this graph. (For more information about loop suppression verification, refer to Chapter 15, “Advanced Software Features.”)
  - **a** “Measured” loop suppression curve—this is the result of the loop suppression measurement performed by the E5505A system.
  - **b** “Smoothed” measured suppression curve—this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression.
  - **c** “Theoretical” suppression curve—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, etc).
  - **d** “Adjusted” theoretical suppression curve—this is the new “adjusted” theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the “smoothed” measured curve as closely as possible.

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results” for help with using the results.

Figure 142 shows a typical phase noise curve for a microwave source.

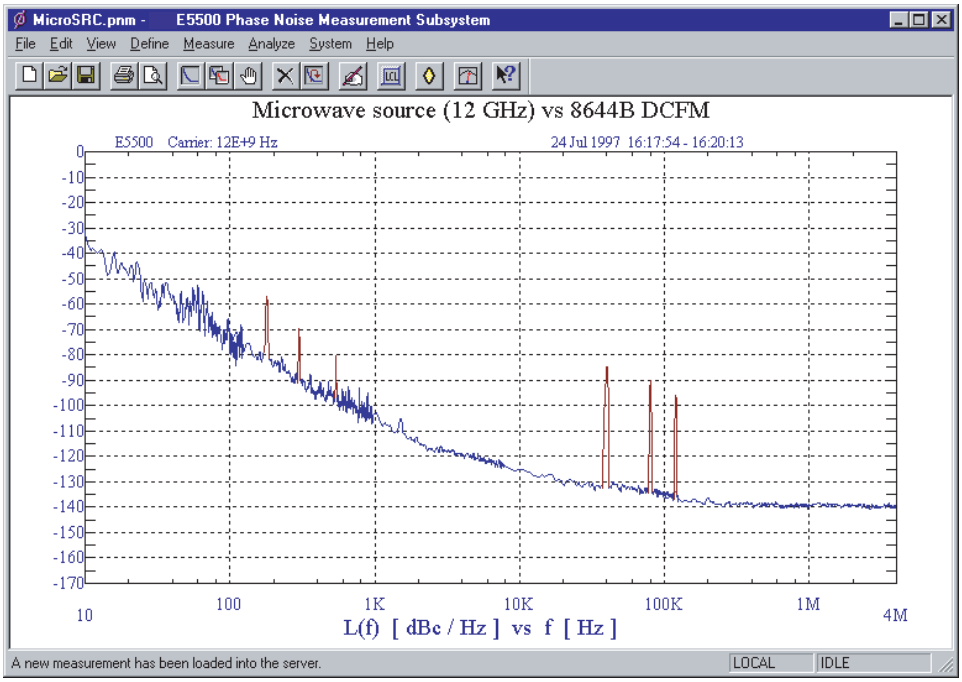


Figure 142 Typical phase noise curve for a microwave source

Table 28 Parameter data for the microwave source measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Absolute Phase Noise (using a phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 4 E + 6 Hz
	• Minimum Number of Averages	• 4
	FFT Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 12 E + 9 Hz
	• Power	• 10 dBm
	• Carrier Source Output is connected to:	• Test Set
	Detector Input	
	• Frequency	• 600 E +6 Hz
	Reference Source	
	• Frequency	• 600 E +6 Hz (same as Carrier Source Frequency)
	• Reference Source Power	• 16 dBm
	VCO Tuning Parameters	•
	• Nominal Tune Constant	• 40 E +3 Hz/V
	• Tune Range ± Center Voltage	• ± 10 Volts
	• Input Resistance	• 0 Volts
		• 600 Ω
3	**Cal Tab**	
	• Phase Detector Constant	• Measure Phase Detector Constant
	• VCO Tune Constant	• Calculate from expected VCO Tune Constant
	• Phase Lock Loop Suppression	• Verify calculated phase locked loop suppression
	• If Limit is exceeded	• Show Suppression Graph
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Downconverter	• Agilent N5502A/70422A
	• Reference Source	• Agilent 8644B (System Control)
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination	• Reference Source
	• VCO Tune Mode	• DCFM

Table 28 Parameter data for the microwave source measurement (continued)

Step	Parameters	Data
5	**Test Set Tab**	
	Input Attenuation	• 0 dB
	LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm
6	**Downconverter Tab**	
	Input Frequency	• 12 E + 9
	L.O. Frequency	• Auto
	I.F. Frequency	• (Calculated by software)
	Millimeter Frequency	• 0
	L.O. Power	• 20 dBM
	Maximum AM Detector Level	• 0 dBm
	Input Attenuation	• 0 dB
	I.F. Gain	• 0 dB
	• Auto	• Checked
	Microwave/Millimeter Band	• Microwave (0 to 26.5 GHz)
	Millimeter Band Mixer Bias	
	• Enable	• Unchecked
	• Current	• 0 mA
	Reference Chain	
	• Reference	• 10 MHz
	• External Tune Enable	• Unchecked
	Tuning Sensitivity	• 0 ppm/v
	• Nominal	• 0 ppm/V
	• 100 MHz PLL Bandwidth	• 126 Hz
	• 600 MHz PLL Bandwidth	• 10000 Hz
7	**Graph Tab**	
	• Title	• Microwave Source (12 GHz) vs. Agilent 8644B using EFC
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 4 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –170 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

6 Absolute Measurement Examples

7
Residual Measurement Fundamentals

What is Residual Noise? 204
Assumptions about Residual Phase Noise Measurements 206
Calibrating the Measurement 208
Measurement Difficulties 228

What is Residual Noise?

Residual or two-port noise is the noise added to a signal when the signal is processed by a two-port device. Such devices include amplifiers, dividers, filters, mixers, multipliers, phase-locked loop synthesizers or any other two-port electronic networks. Residual noise is composed of both AM and FM components.

The noise mechanisms

Residual noise is the sum of two basic noise mechanisms:

- additive noise
- multiplicative noise

Additive noise

Additive noise is the noise generated by the two-port device at or near the signal frequency which adds in a linear fashion to the signal. See Figure 143.

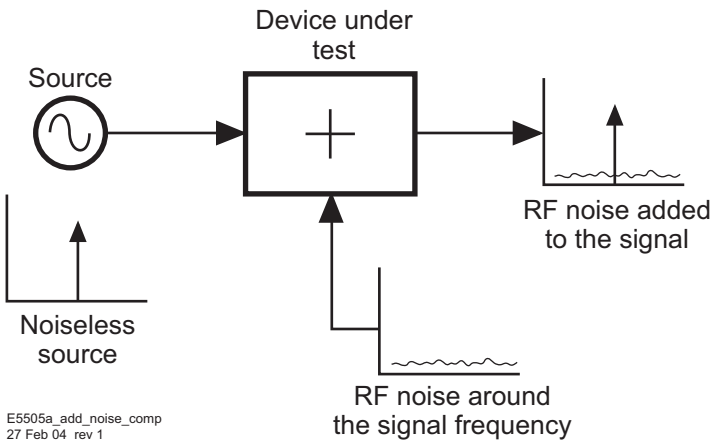


Figure 143 Additive noise components

Multiplicative noise

This noise has two known causes. The first, is an intrinsic, direct, phase modulation with a 1/f spectral density and the exact origin of this noise component is unknown. The second, in the case of amplifiers or multipliers, is noise which may modulate an RF signal by the multiplication of baseband noise with the signal. This mixing is due to any non-linearities in the two-port network. The baseband noise may be produced by the active device(s) of the internal network, or may come from low-frequency noise on the signal or power supply. See Figure 144.

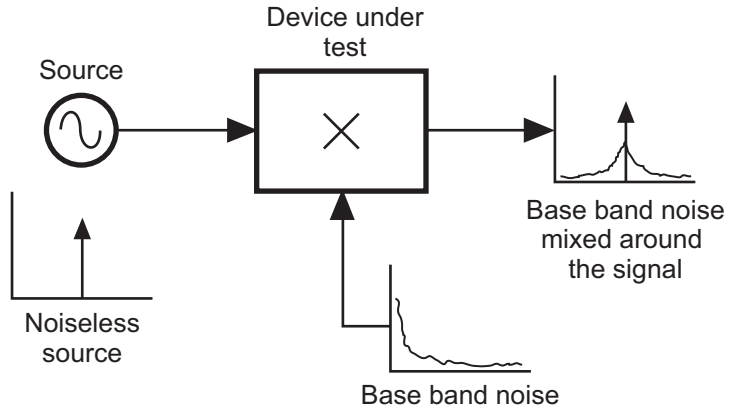


Figure 144 Multiplicative noise components

Assumptions about Residual Phase Noise Measurements

The following are some basic assumptions regarding Residual Phase Noise measurements. If these assumptions are not valid they will affect the measured results.

- The source noise in each of the two phase detector paths is correlated at the phase detector for the frequency offset range of interest. When the source noise is correlated at the phase detector, the source phase noise cancels, leaving only the residual phase noise of the DUT.
- Source AM noise is comparatively small. A typical mixer-type phase detector only has about 20 to 30 dB of AM noise rejection. If the AM component of the signal is greater than 20 to 30 dB above the residual phase noise, it will contribute to the residual phase noise measurement and show the residual phase noise as being greater than it really is.
- The DUT does not exhibit a bandpass filter function. A bandpass filter type response will cause the source noise to be decorrelated at the edge of the filter. This decorrelation of the noise causes the system to measure the source noise level directly at offsets beyond the filter bandwidth.

Given these assumptions, when the DUT is connected to either of the two inputs of the phase detector, all of the source noise cancels and only the residual noise of the DUT is measured. See Figure 145.

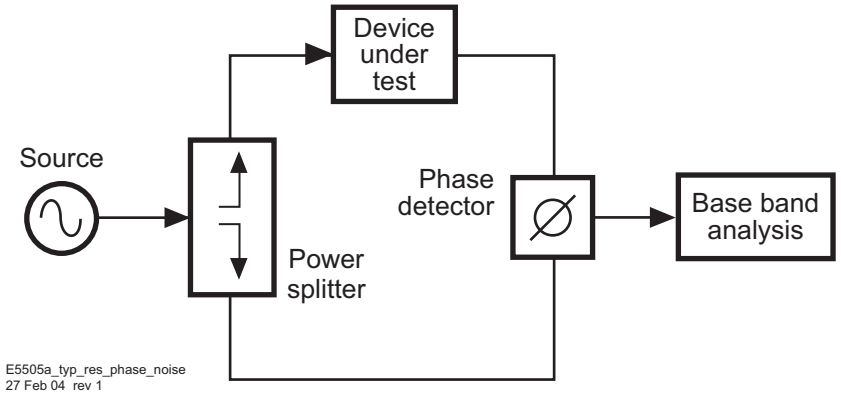


Figure 145 Setup for typical residual phase noise measurement

Frequency translation devices

If the DUT is a frequency translating device (such as a divider, multiplier, or mixer), then one DUT must be put in each path. The result is the sum of the noise from each DUT. In other words, each DUT is at least as quiet as the measured result.

If the DUTs are identical, a possible (but not recommended) assumption is that the noise of each DUT is half the measured result, or 3 dB less. All that really can be concluded is that the noise level of one of the DUTs is at least 3 dB lower than the measured result at any particular offset frequency.

If a more precise determination is required at any particular offset frequency, a third DUT must also be measured against the other two DUTs. The data from each of the three measurements can then be processed by the phase noise software to give the noise of each of the individual DUTs. See Figure 146.

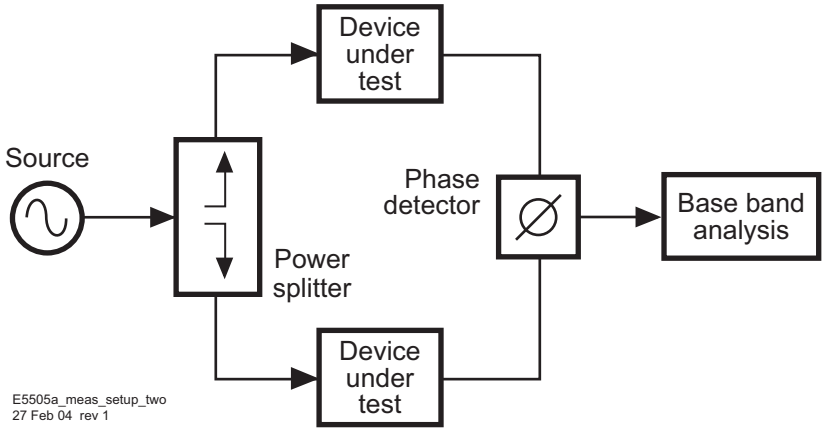


Figure 146 Measurement setup for two similar DUTs

Calibrating the Measurement

In the E5505A Phase Noise Measurement System, residual phase noise measurements are made by selecting Residual Phase Noise (without using a phase locked loop).

There are six calibration methods available for use when making residual phase noise measurements. They are:

- User Entry of Phase Detector Constant
- Measured ±DC Peak
- Measured beatnote
- Measured beatnote/automatic cal
- Double-Sided ΦM Spur
- Single-Sided Spur

The method used will mainly be determined by the sources and equipment available to you.

When calibrating the system for measurements, remember that the calibration is only as accurate as the data input to the system software. See Figure 147.

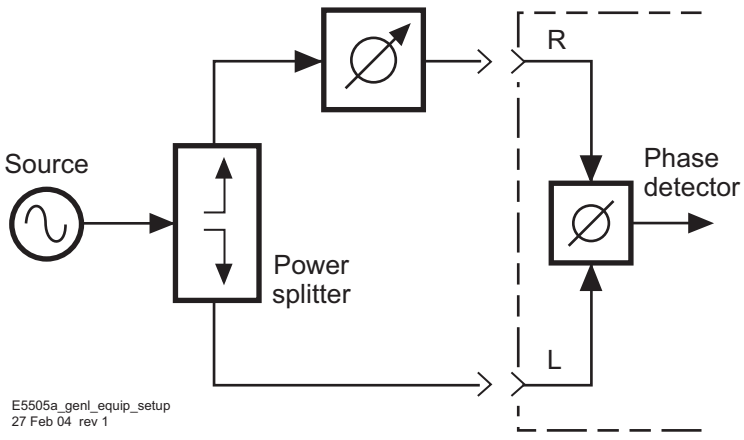


Figure 147 General equipment setup for making residual phase noise measurements

Calibration and measurement guidelines

The following general guidelines should be considered when setting up and making a residual two-port phase noise measurement.

1 For residual phase noise measurements, the source noise must be correlated.

a The phase delay difference in the paths between the power splitter and the phase detector must be kept to a minimum when making residual noise measurements. In other words, by keeping the cables between the phase detector and power splitter short, τ will be small. The attenuation of the source noise is a function of the carrier offset frequency, and the delay time (τ) and is equal to:

$$Attenuation\ (dB) = 20\log|2\sin(\pi \times f \times \tau)$$

Where :

f = *carrier offset frequency*

$\pi = 3.14159$

τ = *time delay* (sec.)

b The source should also have a good broadband phase noise floor because at sufficiently large carrier offsets it will tend to decorrelate when measuring components with large delays. At $f = \frac{1}{\tau}$, source noise is rejected completely. the first null in noise can be used to determine the delay difference. At $f = \frac{1}{2\pi\tau}$, source noise shows up unattenuated. At lower offsets, source noise is attenuated at 20 dB per decade rate at 0.1 of $\frac{1}{2\pi\tau}$, source noise is attenuated 20 dB. Examples of sources which best meet these requirements are the 8644B and 8642A/B.

The source used for making residual phase noise measurements must be low in AM noise because source AM noise can cause AM to ΦM conversion in the DUT.

Mixer-type phase detectors only provide about 20 to 30 dB of rejection to AM noise in a ΦM noise measurement so the AM noise can appear in the phase noise plot.

2 It is very important that all components in the test setup be well shielded from RFI. Unwanted RF coupling between components will make a measurement setup very vulnerable to external electric fields around it. The result may well be a setup going out of quadrature simply by people moving around in the test setup area and altering surrounding electric fields. A loss of quadrature stops the measurement.

3 When making low-level measurements, the best results will be obtained from uncluttered setups. Soft foam rubber is very useful for isolating the DUT and other phase-sensitive components from mechanically-induced phase noise. The mechanical shock of bumping the test set or kicking the

table will often knock a sensitive residual phase noise measurement out of quadrature.

4 When making an extremely sensitive measurement it is essential to use semi-rigid cable between the components. The bending of a flexible cable from vibrations and temperature variations in the room can cause enough phase noise in flexible connecting cables to destroy the accuracy of a sensitive measurement. The connectors also must be tight; a torque wrench is the best tool.

5 When measuring a low-noise device, it is important that the source and any amplification, required to achieve the proper power at the phase detector, be placed before the splitter so it will be correlated out of the measurement. In cases where this is not possible; remember that any noise source, such as an amplifier, placed after the splitter in either phase detector path, will contribute to the measured noise.

6 An amplifier must be used in cases where the signal level out of the DUT is too small to drive the phase detector, or the drive level is inadequate to provide a low enough system noise floor. In this case the amplifier should have the following characteristics:

- It should have the lowest possible noise figure, and the greatest possible dynamic range.
- The signal level must be kept as high as possible at all points in the setup to minimize degradation from the thermal noise floor.
- It should have only enough gain to provide the required signal levels. Excess gain leads to amplifiers operating in gain compression, making them very vulnerable to multiplicative noise problems. The non-linearity of the active device produces mixing which multiplies the baseband noise of the active device and power supply noise around the carrier.
- The amplifier's sensitivity to power supply noise and the power supply noise itself must both be minimized.

Calibration options

There are six calibration methods that to choose from for calibrating a two-port measurement. The procedure for each method is provided on the following pages. The advantages and disadvantages of each method are also provided to help you select the best method for your application. The primary considerations for selecting a calibration method are:

- Measurement accuracy
- Equipment availability

User entry of phase detector constant

This calibration option requires that you know the phase detector constant for the specific measurement to be made. The phase detector constant can be estimated from the source power levels (or a monitor oscilloscope) or it can be determined using one of the other calibration methods.

Once determined, the phase detector constant can be entered directly into the system software without going through a calibration sequence. Remember, however, that the phase detector constant is unique to a particular set of sources, the RF level into the phase detector and the test configuration.

Advantages

- Easy method for calibrating the measurement system.
- Requires little additional equipment: only an RF power meter to manually measure the drive levels into the phase detector or monitor oscilloscope.
- Fastest method of calibration. If the same power levels are always at the phase detector, (as in the case of leveled outputs), the phase detector sensitivity will always be essentially the same (within a dB or two). If this accuracy is adequate, it is not necessary to recalibrate.
- Only one RF source is required.
- Super-quick method of estimating the phase detector constant and noise floor to verify other calibration methods and check available dynamic range.

Disadvantages

- The user entry of the phase detector constant is the least accurate of all the calibration methods.
- It does not take into account the amount of power at harmonics of the signal.

Procedure

1 Connect circuit as per Figure 148, and tighten all connections.

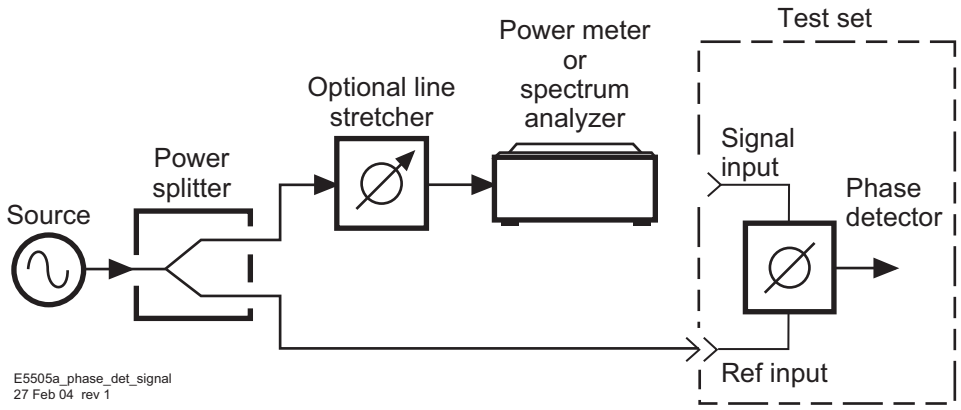


Figure 148 Measuring power at phase detector signal input port

2 Measure the power level that will be applied to the signal input of the test set's phase detector. Table 29 shows the acceptable amplitude ranges for the E5505A phase detectors.

Table 29 Acceptable amplitude ranges for the phase detectors.

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz[1]	
Ref Input (L Port)	Signal Input (R Port)	Ref Input (L Port)	Signal Input (R Port)
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm

1 Phase noise test set Options 001 and 201.

3 Locate the power level you measured on the left side of the Phase Detector Sensitivity Graph (Figure 154 on page 219). Now move across the graph at the measured level and find the corresponding Phase Detector constant along the right edge of the graph. This is the value you will enter as the Current Detector Constant when you define your measurement. (Note that the approximate measurement noise floor provided by the Signal Input port level is shown across the bottom of the graph.).

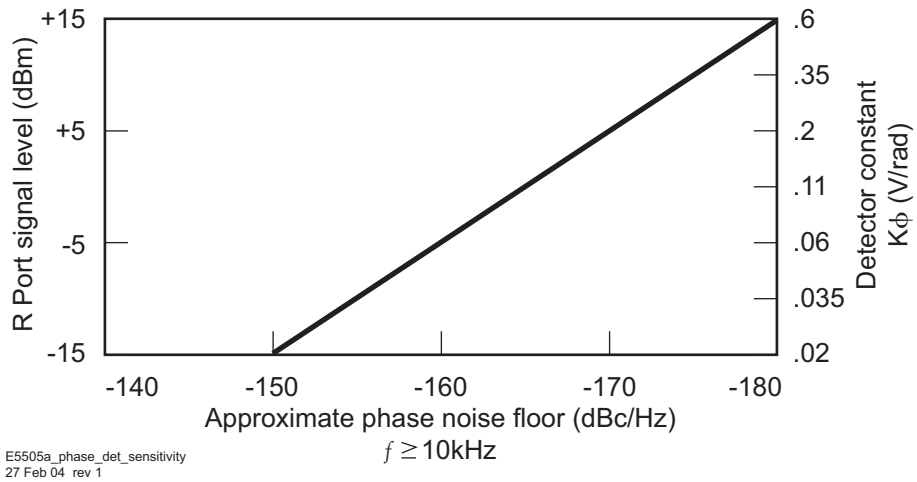


Figure 149 Phase detector sensitivity

4 Remove the power meter and reconnect the cable from the splitter to the Signal Input port.

5 If you are not certain that the power level at the Reference Input port is within the range shown in the preceding graph, measure the level using the setup shown in Figure 151, “Measuring power at phase detector reference input port,” on page 214.

6 Remove the power meter and reconnect the cable from the splitter to the Signal Input port.

7 After you complete the measurement set up procedures and begin running the measurement, the computer will prompt you to adjust for quadrature (Figure 150 on page 214). Adjust the phase difference at the phase detector to 90 degrees (quadrature) by either adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is attained when the meter is set to center scale, zero.

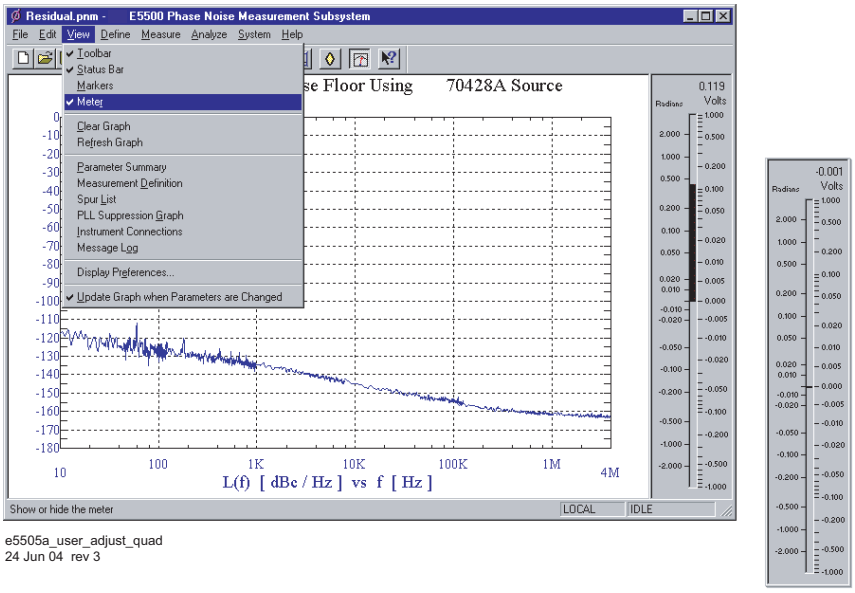


Figure 150 Adjust for quadrature

NOTE For the system to accept the adjustment to quadrature, the meter must be within ±2 mV to ±4 mV.

8 Once you have attained quadrature, you are ready to proceed with the measurement.

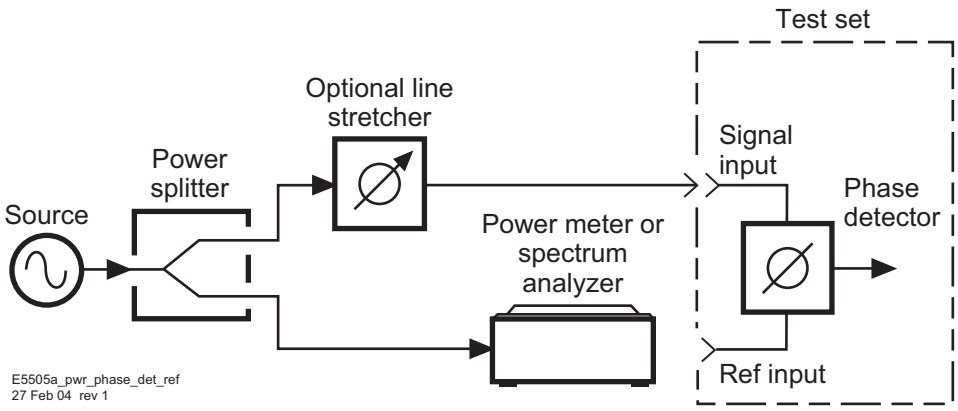


Figure 151 Measuring power at phase detector reference input port

Measured ± DC peak voltage

Advantages

- Easy method for calibrating the measurement system.
- This calibration technique can be performed using the baseband analyzer.
- Fastest method of calibration. If, for example, the same power levels are always at the phase detector, as in the case of leveled, or limited outputs, the phase detector sensitivity will always be essentially equivalent (within one or two dB). Recalibration becomes unnecessary if this accuracy is adequate.
- Only one RF source is required.
- Measures the phase detector gain in the actual measurement configuration. This technique requires you to adjust off of quadrature to both the positive and the negative peak output of the Phase Detector. This is done by either adjusting the phase shifter or the frequency of the source. An oscilloscope or voltmeter can optionally be used for setting the positive and negative peaks.

Disadvantages

- Has only moderate accuracy compared to the other calibration methods.
- Does not take into account the amount of phase detector harmonic distortion relative to the measured phase detector gain, hence the phase detector must operate in its linear region.
- Requires manual adjustments to the source and/or phase shifter to find the phase detector's positive and negative output peaks. The system will read the value of the positive and negative peak and automatically calculate the mean of the peak voltages which is the phase detector constant used by the system.

Procedure

1 Connect circuit as per Figure 152 on page 216, and tighten all connections.

2 Measure the power level that will be applied to the Signal Input port of the test set's phase detector. Table 30 on page 216 shows the acceptable amplitude ranges for the E5505A system phase detectors.

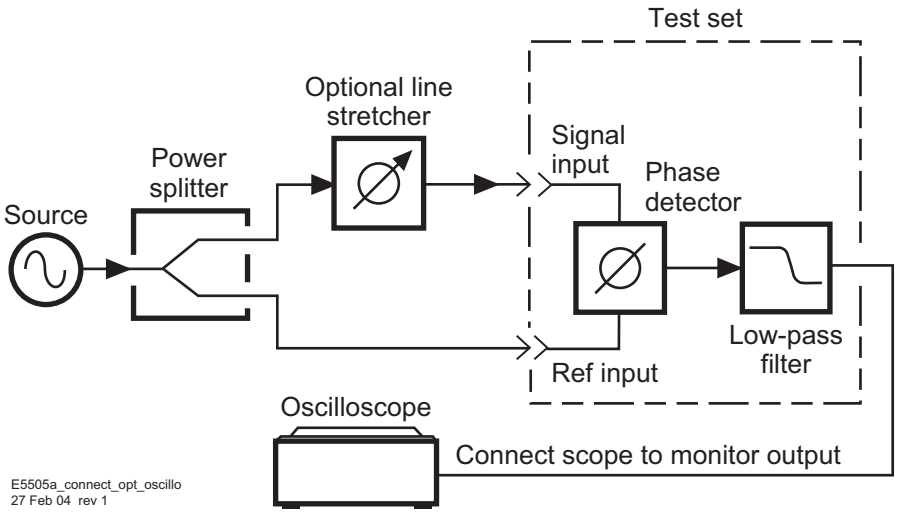


Figure 152 Connection to optional oscilloscope for determining voltage peaks

Table 30 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
50 kHz to 1.6 GHz		**1.2 to 26.5 GHz[1]**	
Ref Input (L Port)	**Signal Input (R Port)**	**Ref Input (L Port)**	**Signal Input (R Port)**
+ 15 dBm to + 23 dBm	0 dBm to + 23 dBm	+ 7 dBm to + 10 dBm	0 dBm to + 5 dBm

1 Phase noise test Options 001 and 201.

3 Adjust the phase difference at the phase detector as prompted by the phase noise software.

4 The system will measure the positive and negative peak voltage of the phase detector using an internal voltmeter. The quadrature meter digital display can be used to find the peak. The phase may be adjusted either by varying the frequency of the source or by adjusting a variable phase shifter or line stretcher.

NOTE Connecting an oscilloscope to the MONITOR port is recommended because the signal can then be viewed to give visual confidence in the signal being measured. As an example, noise could affect a voltmeter reading, whereas, on the oscilloscope any noise can be viewed and the signal corrected to minimize the noise before making the reading.

5 The system software will then calculate the phase detector constant automatically using the following algorithm:

$$\text{Phase Detector Constant} = \frac{((+V_{peak}) - (-V_{peak}))}{2}$$

6 The system software will then prompt you to set the phase noise software's meter to quadrature.

7 The system will now measure the noise data.

Measured beatnote

This calibration option requires that one of the input frequency sources be tunable such that a beatnote can be acquired from the two sources. For the system to calibrate, the beatnote frequency must be within the following ranges shown in Table 31.

Table 31 Frequency ranges

Carrier Frequency	Beatnote Frequency Range
<500 kHz	10 Hz to 10 kHz
<5 MHz	10 Hz to 100 kHz
<50 MHz	10 Hz to 1 MHz
<250 MHz	10 Hz to 10 MHz
>250 MHz	10 Hz to 50 MHz
or 1/2 the frequency range of the configured analyzer, or whichever is lower.	

Advantages

- Simple method of calibration.

Disadvantages

- It requires two RF sources, separated by 0.1 Hz to 50 MHz at the phase detector. The calibration source output power must be manually adjusted to the same level as the power splitter output it replaces (requires a power meter).

Procedure

1 Connect circuit as per Figure 153, and tighten all connections.

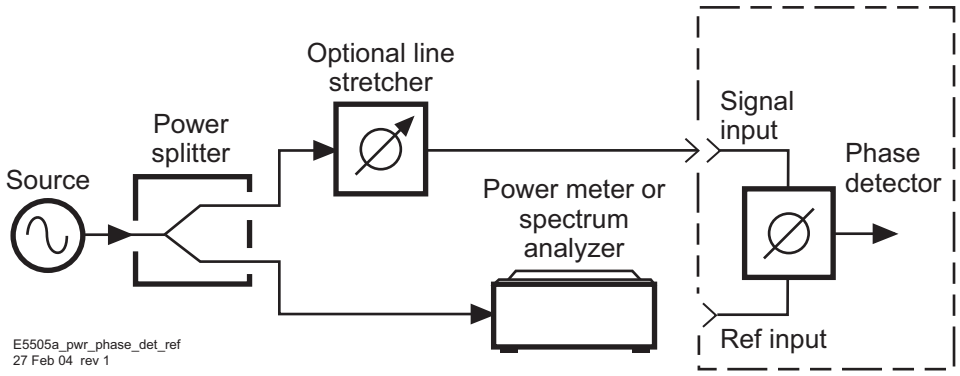


Figure 153 Measuring power from splitter

2 Measure the power level that will be applied to the Signal Input port of the test set's phase detector. Table 32 on page 218 shows the acceptable amplitude ranges for the test set phase detectors.

Table 32 Acceptable amplitude ranges for the phase detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz[1]	
Ref Input (L Port)	Signal Input (R Port)	Ref Input (L Port)	Signal Input (R Port)
+ 15 dBm to + 23 dBm	0 dBm to + 23 dBm	+ 7 dBm to + 10 dBm	0 dBm to + 5 dBm

1 Phase noise test set options 001 and 201

3 Measure the output power at the side of the power splitter where the calibration source will be substituted, then terminate in 50 ohms. See Figure 154 on page 219.

4 Adjust the calibration source to the same output power as the measured output power of the power splitter.

5 Adjust the output frequency such that the beatnote frequency is within the range of the analyzers being used.

6 The system can now measure the calibration constant.

7 Disconnect the calibration source and reconnect the power splitter.

8 Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the test frequency or by adjusting an

optional variable phase shifter or line stretcher. Quadrature is achieved when the meter on the front panel of the phase noise interface is set to zero.

NOTE For the system to accept the adjustment to quadrature, the meter must be within ±2 mV to ±4 mV.

9 Reset quadrature and measure phase noise data.

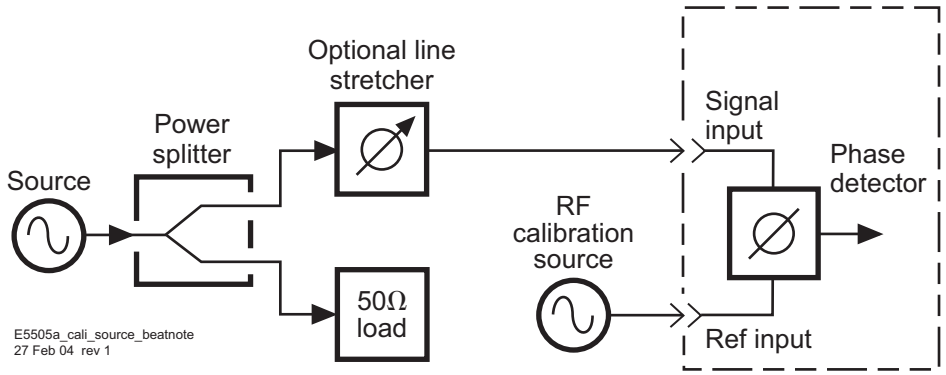


Figure 154 Calibration source beatnote injection

Synthesized residual measurement using beatnote cal

10 This calibration option requires two synthesizers of which one must be tunable such that a beatnote can be acquired. For the system to calibrate, the beatnote frequency must be within the following ranges shown in Table 33.

Table 33 Frequency Ranges

Carrier Frequency	Beatnote Frequency Range
<500 kHz	10 Hz to 10 kHz
<5 MHz	10 Hz to 100 kHz
<50 MHz	10 Hz to 1 MHz
<250 MHz	10 Hz to 10 MHz
>250 MHz	10 Hz to 50 MHz
or 1/2 the frequency range of the configured analyzer, or whichever is lower.	

Procedure

1 Connect circuit as per Figure 155 and tighten all connections.

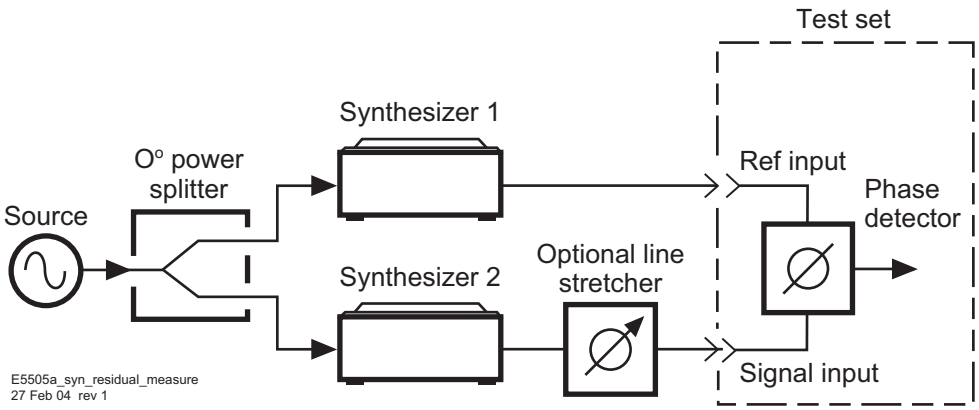


Figure 155 Synthesized residual measurement using beatnote cal

2 Offset the carrier frequency of one synthesizer to produce a beatnote for cal.

3 After the phase noise system reads the beatnote, set the software to the same carrier frequency.

4 Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the synthesizer or by adjusting an optional variable phase shifter or line stretcher. Quadrature is achieved when the meter on the front panel of the phase noise interface is set to zero.

Measured beatnote/automatic calibration

This calibration option requires the reference source to be a PSG (E8257D, E8267D, or E8663D) which has the functionality to adjust the phase remotely.

Advantages

- Simple method of calibration.
- Eliminates the need for a line stretcher or phase shifter.

Disadvantages

- Requires the reference source to be a PSG-D.

Procedure

1 Connect the equipment as shown in Figure 156.

2 The reference source must be either an E8257D, E8267D, or E8663D.

3 The Device Under Test (DUT) and the reference source should be locked by the same 10MHz reference. The 10MHz reference is split and provided to the DUT and reference source.

4 The frequencies of the DUT and reference source equal each other.

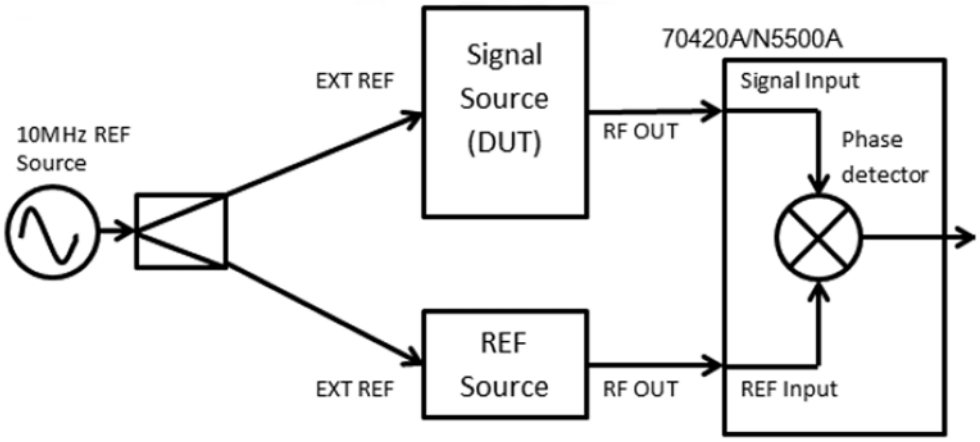


Figure 156 Automatic Calibration Connection Diagram

Auto Cal Process

When a user selects measured beatnote / auto cal, the system does the following process.

1 Offsets frequency of a reference source to produce a beatnote for cal.

2 Reads a beatnote and calculates the phase detector constant, then turns the frequency of the reference source back to be equal to that of the DUT.

3 Adjust phase of reference source's output so that the 70420A/N5500A Signal Input and the REF Input are in quadrature. Quadrature is achieved when the output of the phase detector equals 0 V (precisely, less than 0.002V).

Double-Sided spur

This calibration option has the following requirements:

- One of the input frequency sources must be capable of being phase modulated.
- The resultant sideband spurs from the phase modulation must have amplitudes that are –100 dB and –20 dB relative to the carrier amplitude.
- The offset frequency or modulation frequency must be between 10 Hz and maximum (See the"Measured beatnote" on page 217).

Advantages

- Requires only one RF source.
- Calibration is done under actual measurement conditions so all non-linearities and harmonics of the phase detector are calibrated out.

NOTE Because the calibration is performed under actual measurement conditions, the Double-sided Spur Method and the Single-sided Spur Method are the two most accurate calibration methods.

Disadvantages

- Requires a phase modulator which operates at the desired carrier frequency.
- Requires audio calibration source.
- Requires RF spectrum analyzer for manual measurement of ΦM sidebands or preferably a modulation analyzer.

NOTE Most phase modulators are typically narrow-band devices; therefore, a wide range of test frequencies may require multiple phase modulator.

Procedure

1 Connect circuit as per Figure 157 and tighten all connections.

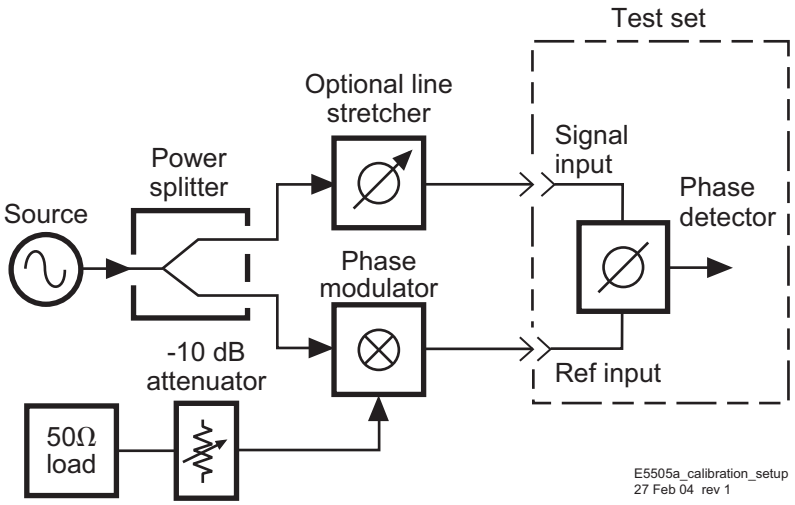


Figure 157 Calibration setup

2 Measure the power level that will be applied to the signal input port of the test set's phase detector. Table 34 shows the acceptable amplitude ranges for the E5505A system phase detectors.

Table 34 Acceptable amplitude ranges for the phase detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz[1]	
Ref Input (L Port)	Signal Input (R Port)	Ref Input (L Port)	Signal Input (R Port)
+ 15 dBm to + 23 dBm	0 dBm to + 23 dBm	+ 7 dBm to + 10 dBm	0 dBm to + 5 dBm

1 Phase noise test set options 001 and 201

3 Using the RF spectrum analyzer or modulation analyzer, measure the carrier-to-sideband ratio of the phase modulation at the phase detector's modulated port and the modulation frequency. The audio calibration source should be adjusted such that the sidebands are between –30 and –60 dB below the carrier and the audio frequency is between 50 Hz and 50 MHz. See Figure 158.

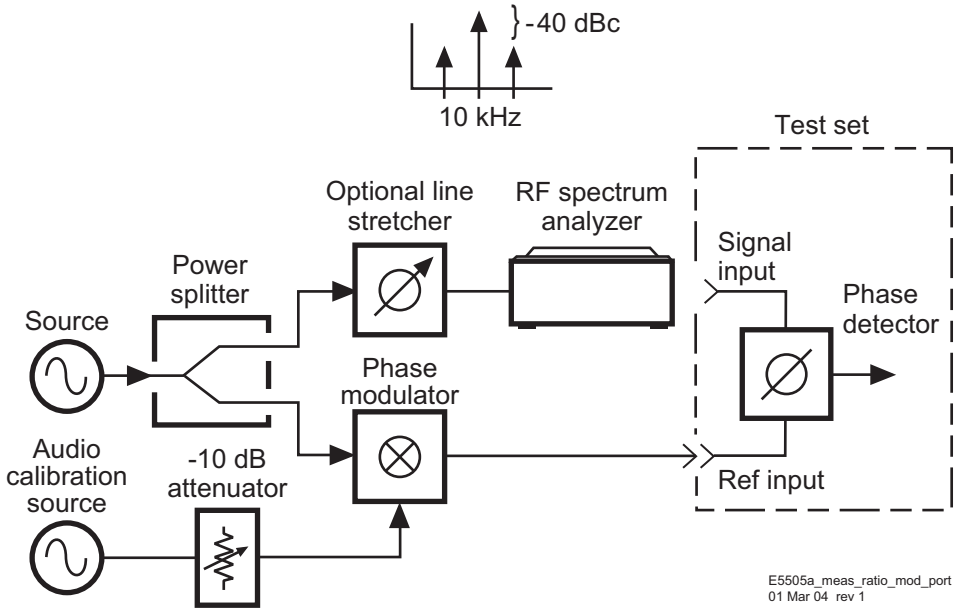


Figure 158 Measuring carrier-to-sideband ratio of the modulated port

4 Measure the carrier-to-sideband ratio of the non-modulated side of the phase detector. It must be at least 20 dB less than the modulation level of the modulated port. This level is necessary to prevent cancellation of the modulation in the phase detector. Cancellation would result in a smaller phase detector constant, or a measured noise level that is worse than the actual performance. The modulation level is set by the port-to-port isolation of the power splitter and the isolation of the phase modulator. This isolation can be improved at the expense of signal level by adding an attenuator between the phase modulator and the power splitter.

5 Connect the phase detector.

6 Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is achieved when the meter in the phase noise software is set to center scale (±2 mV).

NOTE For the system to accept the adjustment to quadrature, the meter must be within ±2 mV to ±4 mV.

7 Set the Type of Measurement to Phase Noise Without Using a PLL.

8 Set the Calibration Technique to Derive From Double-sided Spur and enter the sideband amplitude and offset frequency.

9 Select New Measurement.

10 Check quadrature and measure the phase detector constant by pressing Y to proceed.

11 Remove audio source.

12 Reset quadrature and measure phase noise data.

Single-Sided spur

This calibration option has the following requirements:

- A third source to generate a single sided spur
- An external power combiner (or directional coupler) to add the calibration spur to the frequency carrier under test. The calibration spur must have an amplitude –100 dB and –20 dB relative to the carrier amplitude. The offset frequency of the spur must be 20 Hz and 20 MHz.
- A spectrum analyzer or other means to measure the single sided spur relative to the carrier signal

You will find that the equipment setup for this calibration option is similar to the others except that an additional source and a power splitter have been added so that the spur can be summed with the input carrier frequency.

Advantages

Calibration is done under actual measurement conditions so all non-linearities and harmonics of the phase detector are calibrated out.

NOTE The Single-sided Spur Method and the Double-sided Spur Method (Option 4) are the two most accurate methods.

Broadband couplers with good directivity are available, at reasonable cost, to couple in the calibration spur.

Disadvantages

Requires a second RF sources that can be set between 10 Hz and up to 50 MHz (depending on the baseband analyzer used) from the carrier source frequency.

Requires an RF spectrum analyzer for manual measurement of the signal-to-spur ratio and the spur offset frequency.

Procedure

1 Connect circuit as per Figure 159, and tighten all connections. Note that the input signal into the directional coupler is being supplied to the coupler's output port.

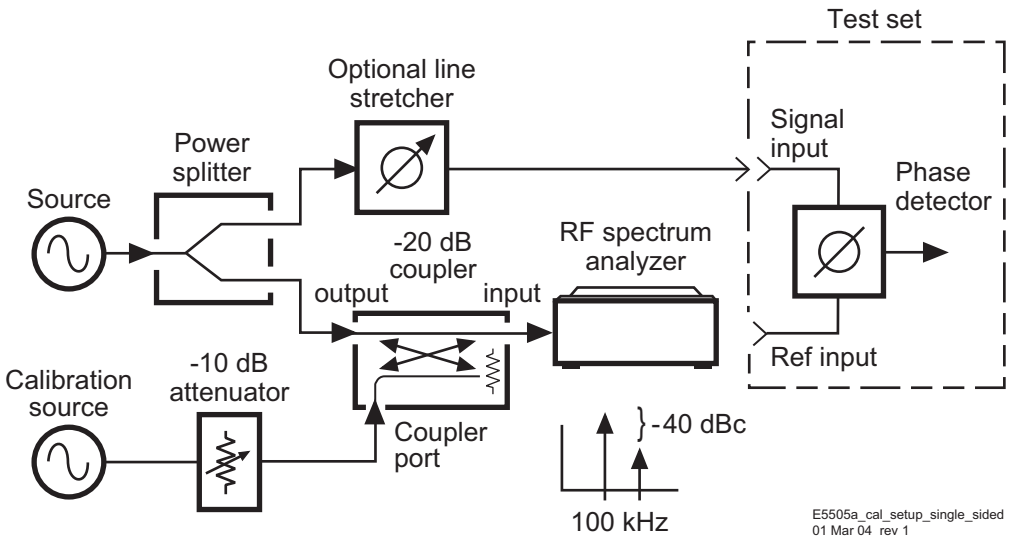


Figure 159 Calibration setup for single-sided spur

2 Measure the power level that will be applied to the Signal Input port of the test set's phase detector. Table 35 on page 226 shows the acceptable amplitude ranges for the E5505A system phase detectors.

Table 35 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz[1]	
Ref Input (L Port)	Signal Input (R Port)	Ref Input (L Port)	Signal Input (R Port)
+ 15 dBm to + 23 dBm	0 dBm to + 23 dBm	+ 7 dBm to + 10 dBm	0 dBm to + 5 dBm

1 Phase noise test set options 001 and 201

3 Measure the carrier-to-single-sided-spur ratio out of the coupler at the phase detector's modulated port and the offset frequency with the RF spectrum analyzer (Figure 160). The RF calibration source should be adjusted such that the sidebands are between –30 and –60 dB below the carrier and the frequency offset of the spur between 10 Hz and 50 MHz.

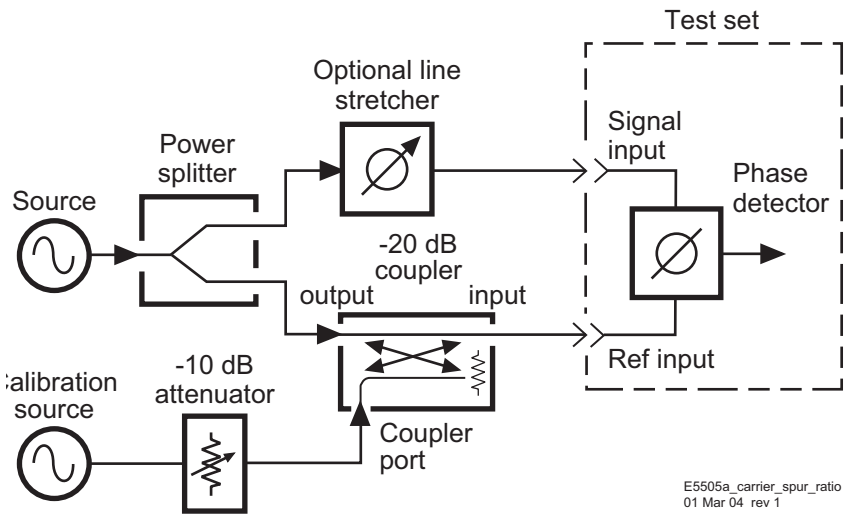


Figure 160 Carrier-to-spur ratio of modulated signal

4 Measure the carrier-to-spur ratio of the non-modulated side of the phase detector (Figure 161 on page 227). It must be at least 20 dB less than the spur ratio of the modulated port. This level is necessary to prevent cancellation of the modulation in the phase detector. Cancellation would result in a smaller phase detector constant, or a measured noise level that is worse than the actual performance. The isolation level is set by the port-to-port isolation of the power splitter and the isolation of the –20 dB

coupler. This isolation can be improved at the expense of signal level by adding an attenuator between the coupler and the power splitter.

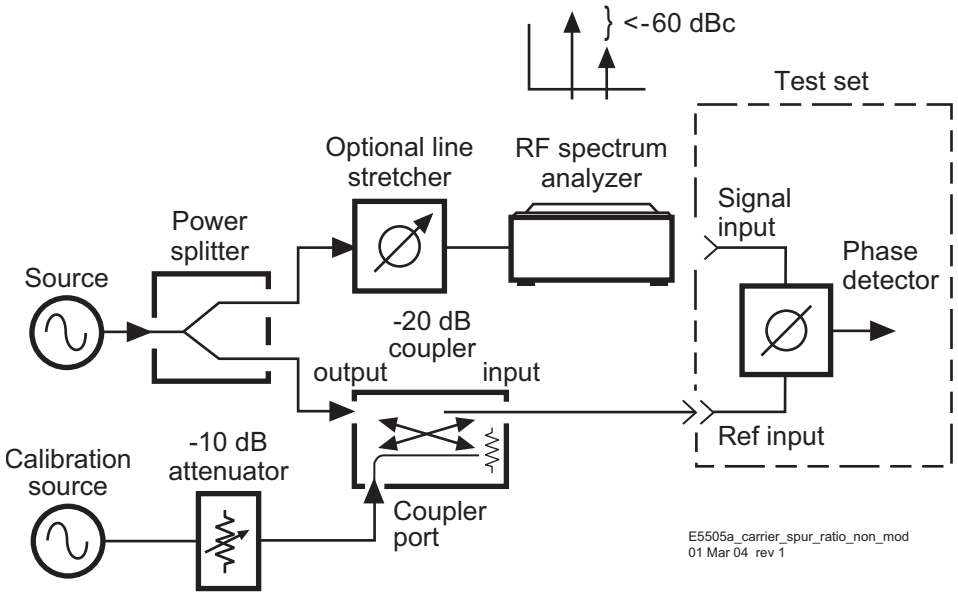


Figure 161 Carrier-to-spur ratio of non-modulated signal

5 Connect the phase detector.

6 Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is achieved when the meter on the front panel of the test set is set to center scale.

NOTE For the system to accept the adjustment to quadrature, the meter must be within ±2 mV to ±4 mV.

7 Enter sideband level and offset.

8 Check quadrature and measure the phase detector constant.

9 Remove audio source.

10 Reset quadrature and measure phase noise data.

Measurement Difficulties

Chapter 14, “Evaluating Your Measurement Results” contains troubleshooting information to be used after the measurement has been made, and a plot has been obtained.

When making phase noise measurements it is important to keep your equipment connected until the measurements have been made, all problems corrected, and the results have been evaluated to make sure that the measurement is valid. If the equipment is disconnected before the results have been fully evaluated, it may be difficult to troubleshoot the measurement.

System connections

The first thing to check if problems occur is the instrument connections and settings as this is the most common error. It is also important to make sure the levels are correct into the test set phase detector inputs.

8
Residual Measurement Examples

Amplifier Measurement Example 230

Amplifier Measurement Example

This example contains information about measuring the residual noise of two-port devices. It demonstrates a residual phase noise measurement for an RF Amplifier. Refer to Chapter 7, “Residual Measurement Fundamentals for more information about residual phase noise measurements.

CAUTION To prevent damage to the test set’s components, do not apply the input signal to the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 36 on page 238. Apply the input signal when the connection diagram appears.

Required equipment

This measurement requires the following equipment:

- RF amplifier
- Stimulus source (frequency of amplitude under test)
- Power splitter (NARDA 30183)
- Coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

The setup for a residual phase noise measurement uses a phase shifter to set quadrature at the phase detector. See Figure 162 on page 231.

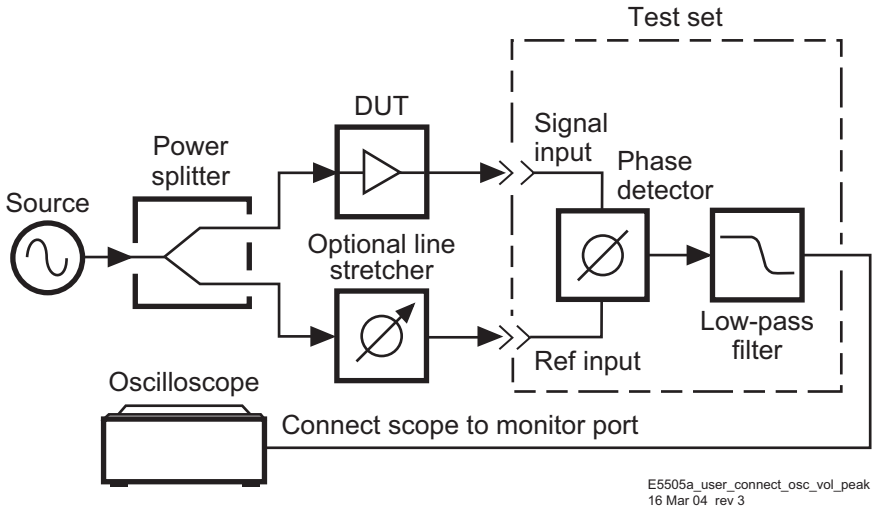


Figure 162 Setup for residual phase noise measurement

Defining the measurement

1 From the **File** menu, choose **Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, choose "**res_noise_1ghz_demoamp.pnm**" See Figure 163.

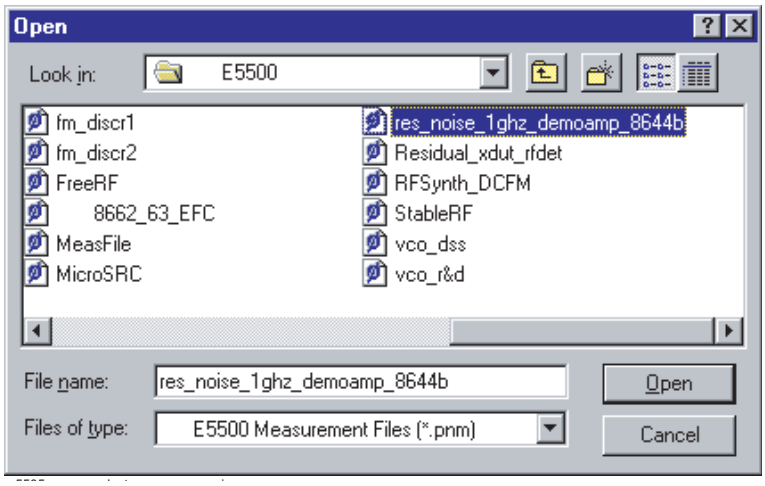


Figure 163 Select the parameters definition file

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 38 on page 243 lists the parameter data that has been entered for this residual phase noise measurement example.

5 From the **Define** menu, choose **Measurement**; then choose the **Type and Range** tab from the **Define Measurement** window.

6 From the Measurement Type pull-down, select **Residual Phase Noise (without using phase lock loop).** See Figure 164.

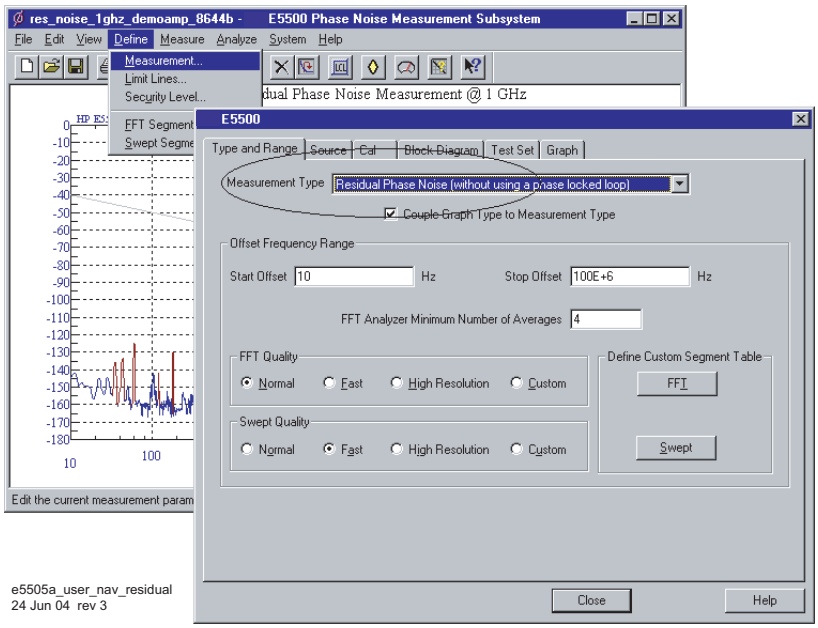


Figure 164 Navigate to residual phase noise

7 Choose the **Sources** tab from the **Define Measurement** window.

8 Enter the carrier (center) frequency of your DUT. Enter the same frequency for the detector input frequency. See Figure 165 on page 232.

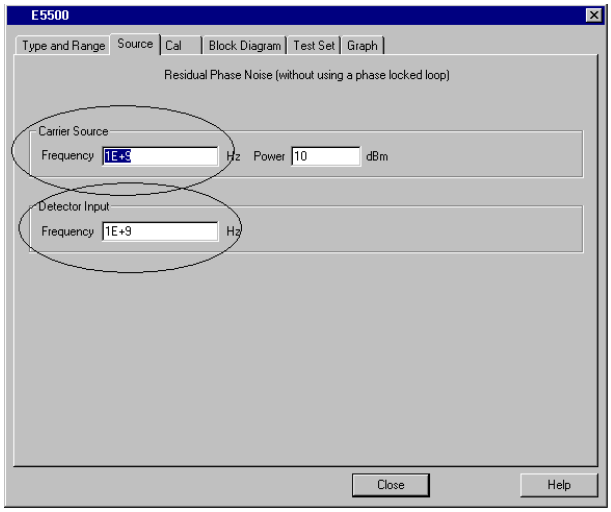


Figure 165 Enter frequencies into source tab

9 Choose the **Cal** tab from the **Define Measurement** window.

10 Select **Derive detector constant from measured ± DC peak voltage** as the calibration method. See Figure 166.

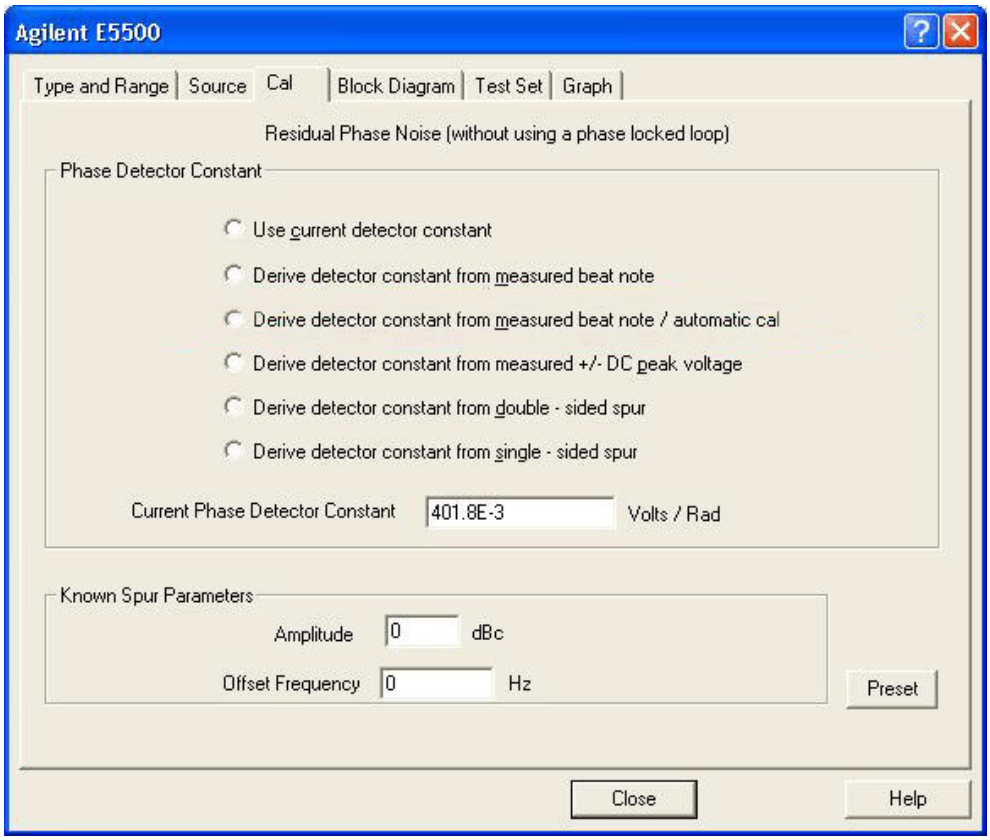


Figure 166 Select constant in the cal tab

11 Choose the Block Diagram tab from the Define Measurement window. Refer to Figure 167.

a From the **Phase Shifter** pull-down, select **Manual**.

b From the **Phase Detector** pull-down, select **Automatic Detector Selection.**

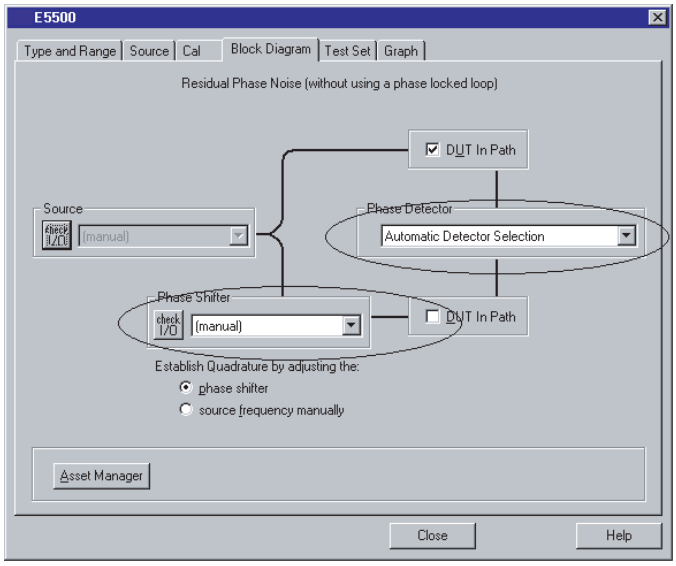


Figure 167 Select parameters in the block diagram tab

12 Choose the **Graph** tab from the **Define Measurement** window.

13 Enter a graph description of your choice (E5500 Residual Phase Noise Measurement @ 1 GHz, for example). See Figure 168 on page 234.

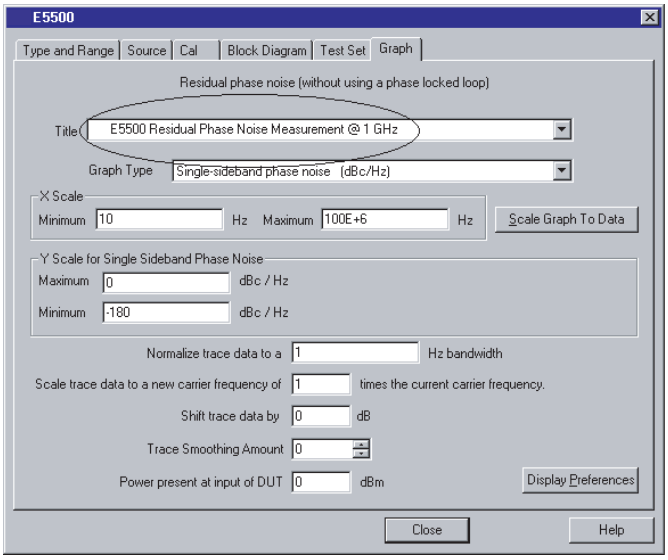


Figure 168 Select graph description on graph tab

14 When you have completed these operations, click the **Close** button.

Setup considerations for amplifier measurement

Connecting cables

The best results will be obtained if semi-rigid coaxial cables are used to connect the components used in the measurement; however, BNC cables have been specified because they are more widely available. Using BNC cables may degrade the close-in phase noise results and, while adequate for this example, should not be used for an actual measurement on an unknown device unless absolutely necessary.

Measurement environment

The low noise floors typical of these devices may require that special attention be given to the measurement environment. The following precautions will help ensure reliable test results:

- Filtering on power supply lines
- Protection from microphonics
- Shielding from air currents may be necessary.

Beginning the measurement

1 From the **View** menu, choose **Meter** to select the quadrature meter. See Figure 169.

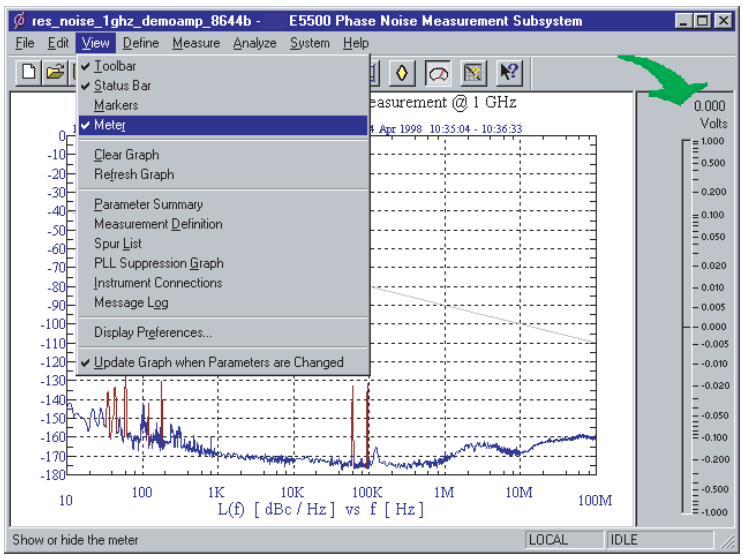


Figure 169 Select meter from view menu

1 From the **Measurement** menu, choose **New Measurement. See** Figure 170**.**

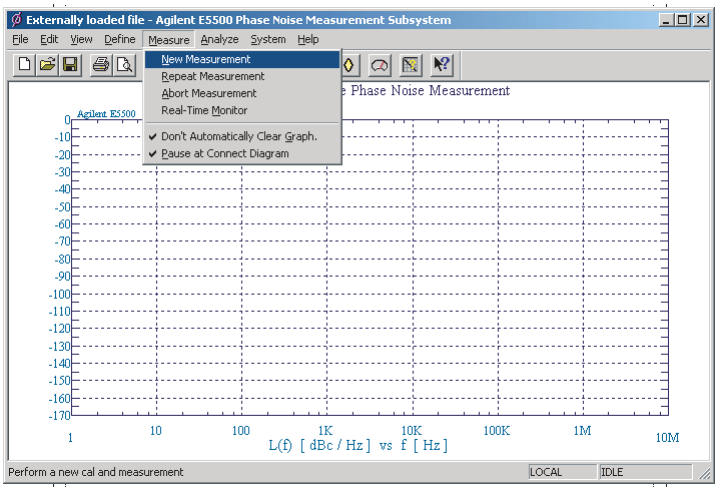


Figure 170 Selecting New Measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes.**

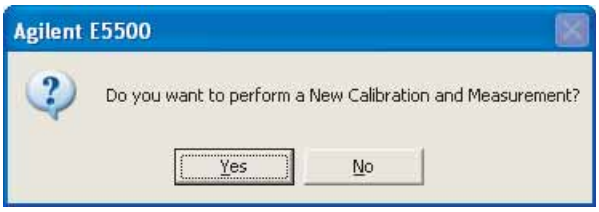


Figure 171 Confirm new measurement

3 When the **Connect Diagram** dialog box appears, click on the hardware down arrow and select your hardware configuration from the pull-down list. Refer to Figure 172.

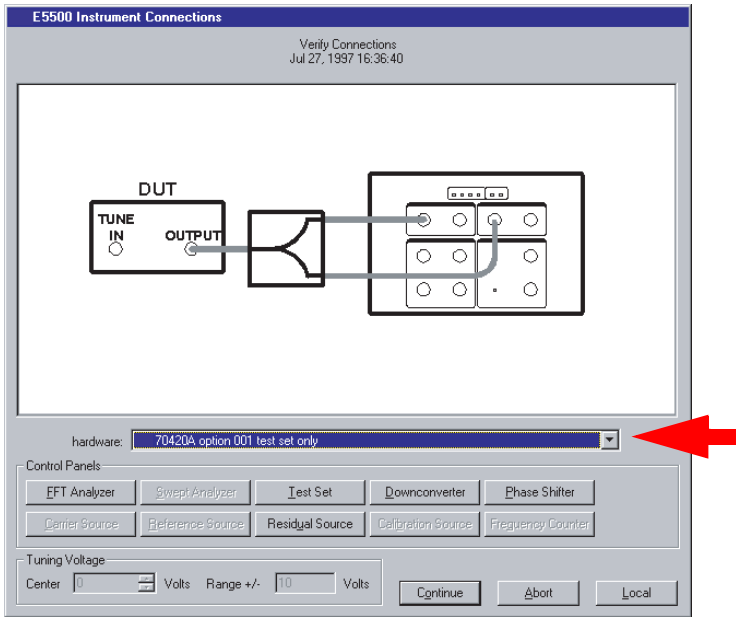


Figure 172 Setup diagram for the 8349A amplifier measurement example

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the appropriate connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics contained in Table 36.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which occurs at the connection diagram.

Table 36 Test set signal input limits and characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm (+30 dBm for Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
Characteristics	
Input Impedance	50 Ω nominal

NOTE

Refer to the following system connect diagram examples in Chapter 18, "System Interconnections" for more information about system interconnections.

- Figure 307, "E5505A system connections with standard test set," on page 403
- Figure 308, "E5505A system connections with test set option 001," on page 404
- Figure 309, "E5505A system connections with test set option 201," on page 405

Making the measurement

Calibrate the measurement using measured ± DC peak voltage

Refer to Chapter 7, “Residual Measurement Fundamentals for more information about residual phase noise measurements calibration types.

Procedure

1 Using Figure 173 and Figure 174 on page 240 as guides, connect the circuit and tighten all connections.

2 Measure the power level that will be applied to the Signal Input port of the test set phase detector. Table 37 shows the acceptable amplitude ranges for the test set phase detectors.

Table 37 Acceptable amplitude ranges for the phase detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz[1]	
Ref Input (L Port)	Signal Input (R Port)	Ref Input (L Port)	Signal Input (R Port)
+ 15 dBm to + 23 dBm	0 dBm to + 23 dBm	+ 7 dBm to + 10 dBm	0 dBm to + 5 dBm

1 Phase Noise Test Set Options 001 and 201

NOTE Connecting an oscilloscope to the monitor port is recommended because the signal can then be viewed to give visual confidence in the signal being measured. See Figure 173 and Figure 174 on page 240.

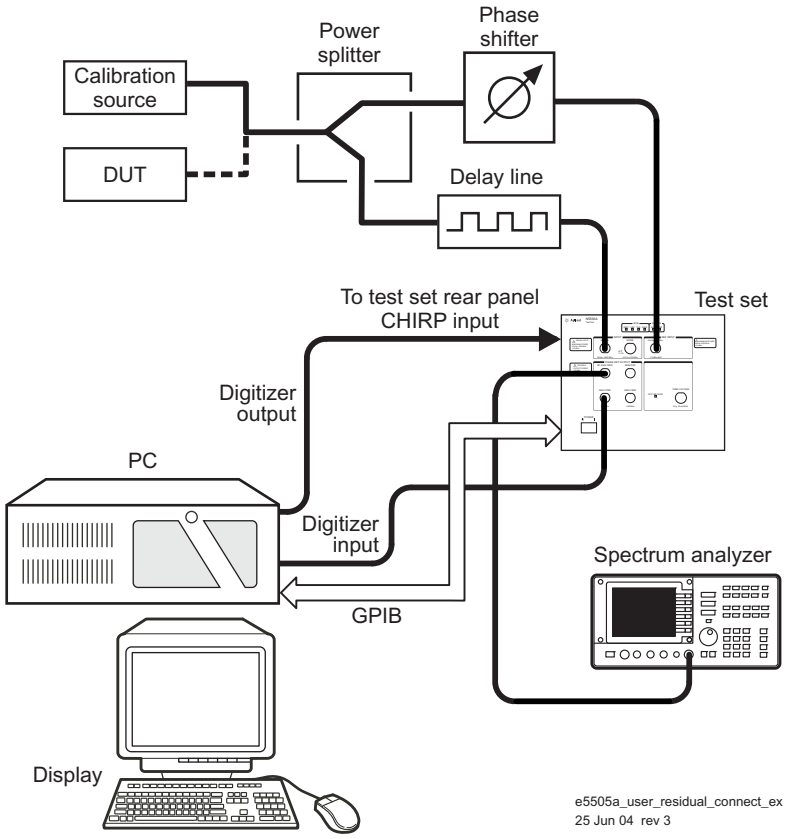


Figure 173 Residual connect diagram example

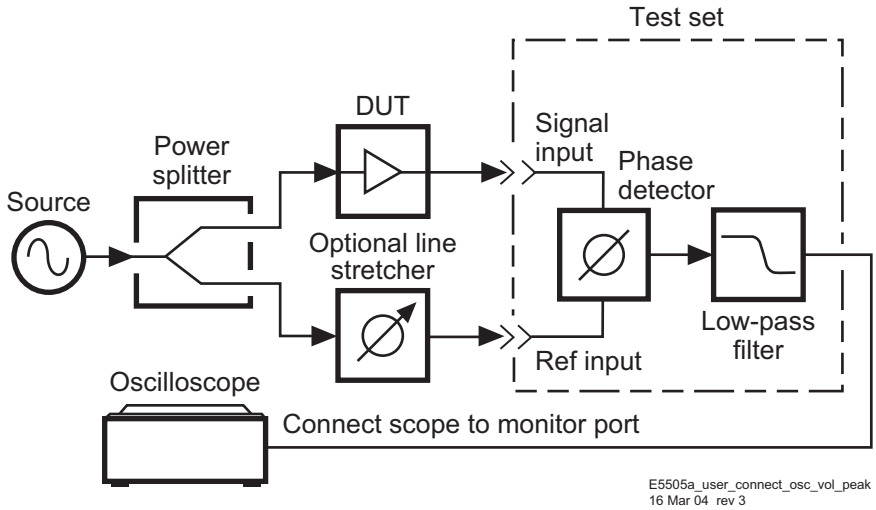


Figure 174 Connection to optional oscilloscope for determining voltage peaks

3 Press the **Continue** button when ready to calibrate the measurement.

4 Adjust the phase difference at the phase detector as prompted by the phase noise software. See Figure 175.

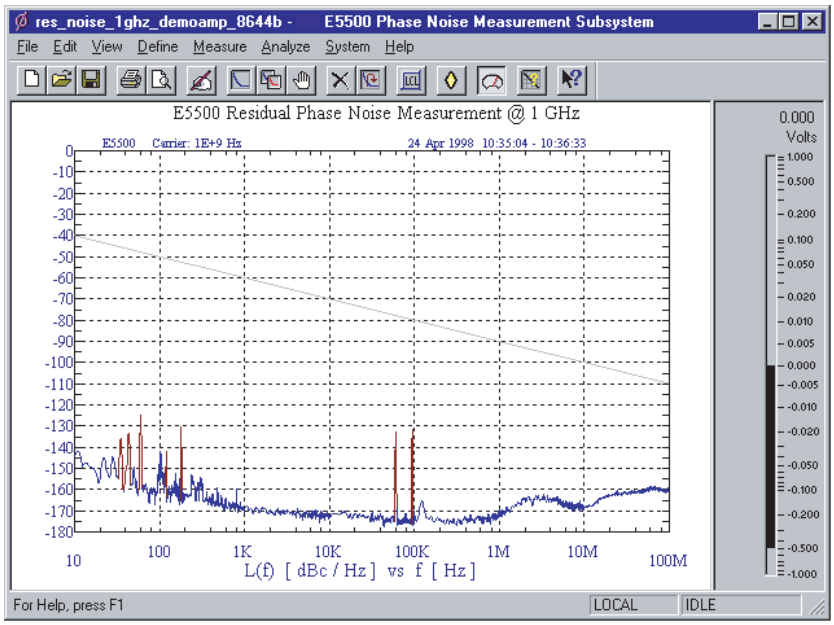


Figure 175 Adjust phase difference at phase detector

5 The system will measure the positive and negative peak voltage of the phase detector using an internal voltmeter. The quadrature meter's digital display can be used to find the peak. The phase may be adjusted either by varying the frequency of the source or by adjusting a variable phase shifter or line stretcher.

6 The system software will then prompt you to set the phase noise software's meter to quadrature by adjusting the phase shifter until the meter indicates 0 volts, then press Continue. See Figure 176 on page 242.

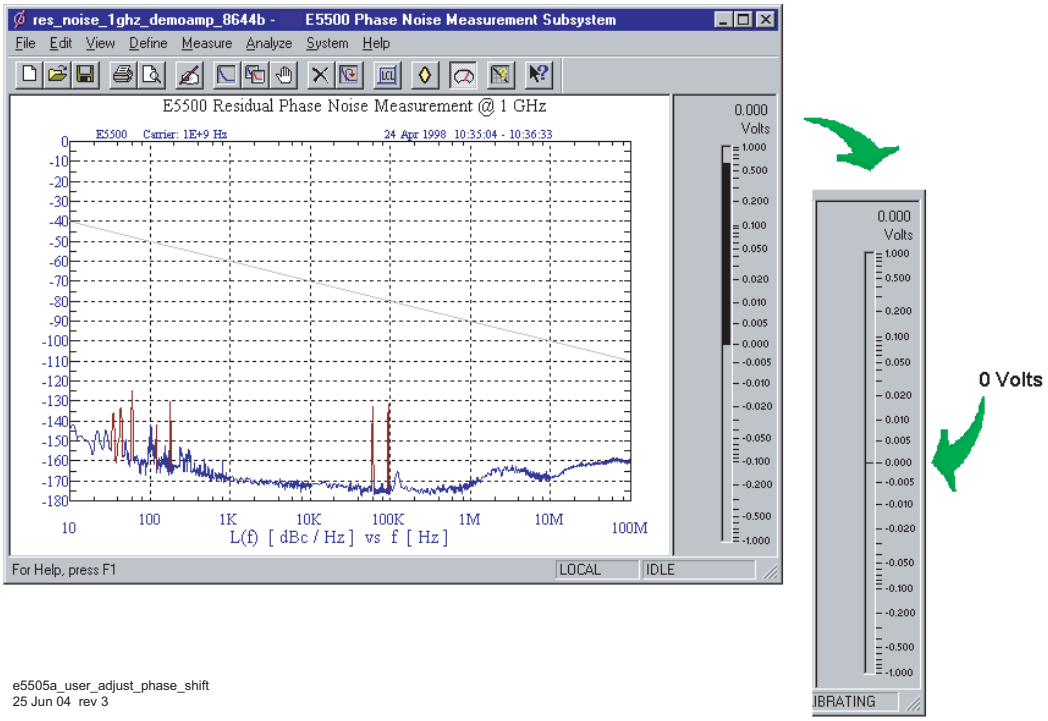


Figure 176 Adjust phase shifter until meter indicates 0 volts

7 The system will now measure the noise data.

The system can now run the measurement. The segment data will be displayed on the computer screen as the data is taken until all segments have been taken over the entire range you specified in the Measurement definition's Type and Range.

When the measurement is complete

When the measurement is complete, refer to Chapter 14, "Evaluating Your Measurement Results for help in evaluating your measurement results.

Figure 177 on page 243 shows a typical phase noise curve for an RF Amplifier.

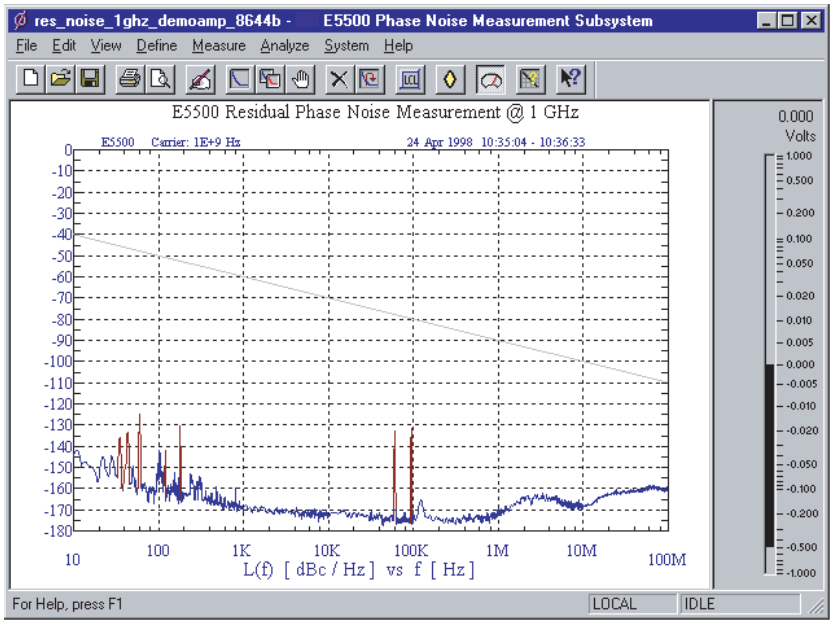


Figure 177 Typical phase noise curve for a residual measurement

Table 38 Parameter data for the amplifier measurement example

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Residual Phase Noise (without using a phase locked loop)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 100 E + 6 Hz
	• Minimum Number of Averages	• 4
	FFT Quality	• Normal
	Swept Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 1 E + 9 Hz
	• Power	• 10 dBm
	Detector Input	
	• Frequency	• 1 E + 9 Hz

Table 38 Parameter data for the amplifier measurement example (continued)

Step	Parameters	Data
3	**Cal Tab**	
	• Phase Detector Constant	• Derive detector constant from measured ± DC peak
	• Current Phase Detector Constant	• 410.8 E-3
	• Know Spur Parameters	
	• Amplitude	• 0 dBc
	• Offset Frequency	• 0 Hz
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Phase Shifter	• Manual
	• DUT in Path	• checked
	• Phase Detector	• Automatic Detector Selection
	• Adjust the Quadrature by adjusting the	• phase shifter
5	**Test Set Tab**	
	Input Attenuation	• 0 dB
	LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm
6	• Dowconverter Tab	• The downconverter parameters do not apply to this measurement example.
7	**Graph Tab**	
	• Title	• E5505A Residual Phase Noise Measurement @ 1 GHz.
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 100 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• - 180 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

9
FM Discriminator Fundamentals

The Frequency Discriminator Method 246

The Frequency Discriminator Method

Unlike the phase detector method, the frequency discriminator method does not require a second reference source phase locked to the source under test. See Figure 178.

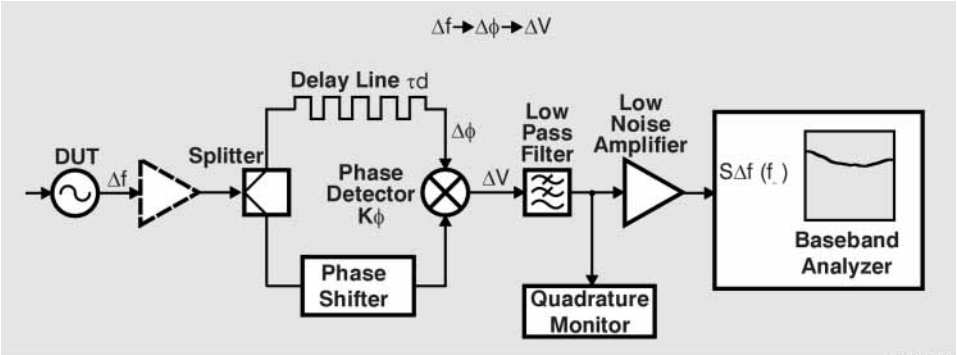


Figure 178 Basic delay line/mixer frequency discriminator method

This makes the frequency discriminator method extremely useful for measuring sources that are difficult to phase lock, including sources that are microphonic or drift quickly. It can also be used to measure sources with high-level, low-rate phase noise, or high close-in spurious sidebands, conditions with can pose serious problems for the phase detector method. A wide-band delay line frequency discriminator is easy to implement using the E5505A Phase Noise Measurement System and common coaxial cable.

Basic theory

The delay line implementation of the frequency discriminator (Figure 178) converts short-term frequency fluctuations of a source into voltage fluctuations that can be measured by a baseband analyzer. The conversion is a two part process, first converting the frequency fluctuations into phase fluctuations, and then converting the phase fluctuations to voltage fluctuations.

The frequency fluctuation to phase fluctuation transformation ($\Delta f \rightarrow \Delta\phi$) takes place in the delay line. The nominal frequency arrives at the double-balanced mixer at a particular phase. As the frequency changes slightly, the phase shift incurred in the fixed delay time will change proportionally. The delay line converts the frequency change at the line input to a phase change a the line output when compared to the undelayed signal arriving at the mixer in the second path.

The double-balanced mixer, acting as a phase detector, transforms the instantaneous phase fluctuations into voltage fluctuations (ιϕ → Δι). With the two input signals 90° out of phase (phase quadrature), the voltage out is proportional to the input phase fluctuations. The voltage fluctuations can then be measured by the baseband analyzer and converted to phase noise units.

The discriminator transfer response

The important equation is the final magnitude of the transfer response.

$$\Delta V(f_m) = K_\phi 2\pi\tau_d \Delta f(f_m) \frac{\sin(\pi f_m \tau_d)}{(\pi f_m \tau_d)}$$

Where ιV(fm) represents the voltage fluctuations out of the discriminator and Δf(fm) represents the frequency fluctuations of the DUT. Kϕ is the phase detector constant (phase to voltage translation). τd is the amount of delay provided by the delay line and f_m is the frequency offset from the carrier that the phase noise measurement is made.

System sensitivity

A frequency discriminator's system sensitivity is determined by the transfer response. As shown below, it is desirable to make both the phase detector constant Kϕ and the amount of delay τd large so that the voltage fluctuations ΔV out of a frequency discriminator will be measurable for even small fluctuations Δf .

$$\Delta V(f_m) = \left[K_\phi 2\pi\tau_d \frac{\sin(\pi f_m \tau_d)}{(\pi f_m \tau_d)} \right] (\Delta f(fm))$$

NOTE The system sensitivity is independent of carrier frequency f_o.

The magnitude of the sinusoidal output term or the frequency discriminator is proportional to ι(πfmτd)/(πfmτ. This implies that the output response will have peaks and nulls, with the first null occurring at $n = 1/\tau$. Increasing the rate of a modulation signal applied to the system will cause nulls to appear at frequency multiples of ι/τd (Figure 179).

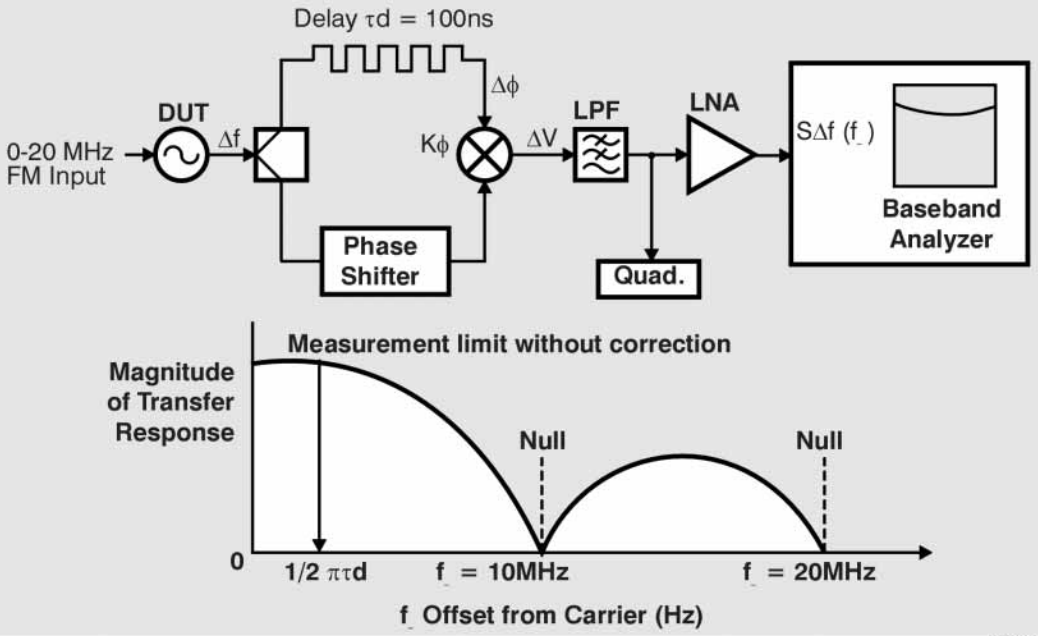


Figure 179 Nulls in sensitivity of delay line discriminator

To avoid having to compensate for sin (x)/x response, measurements are typically made at offset frequencies (f_m) much less $1/2\tau d$. It is possible to measure at offset frequencies out to and beyond the null by scaling the measured results using the transfer equation. However, the sensitivity of the system get very poor results near the nulls.

The transfer function shows that increasing the delay τd increases the sensitivity of the system. However, increasing τd also decreases the offset frequencies (f_m) that can be measured without compensating for the sin(x)/x response. For example, a 200 ns delay line will have better sensitivity close to carrier than a 50 ns delay line., but will not be usable beyond 2.5 MHz offsets without compensating for the sin(x)/x response; the 50 ns line is usable to offsets of 10 MHz.

Increasing the delay τd, also increases the attenuation of the line. While this has no direct effect on the sensitivity provided by the delay line, it does reduce the signal into the phase detector and can result in decreased K_ϕ and decreased system sensitivity.

The phase detector constant K_ϕ equals the slope of the mixer sine wave output at the zero crossings. When the mixer is not in compression, K_ϕ equals $K_L V_R$ where K_L is the mixer efficiency and V_R is the voltage into the Signal Input port (R port) of the mixer. V_R is also the voltage available at the output of the delay line.

Optimum sensitivity

If measurements are made such that the offset frequency of interest (f_m) is <$1/2\pi\tau_d$ the sin(x)/x term can be ignored and the transfer response can be reduced to $V(f_m) = K_d\Delta f(f_m) = K_\phi\pi\tau_d\Delta f(f_m$

where K_d is the discriminator constant.

The reduced transfer equation implies that a frequency discriminator's system sensitivity can be increased simply by increasing the delay τ_d or by increasing the phase detector constant K_ϕ. This assumption is not completely correct. K_ϕ is dependent on the signal level provided by the delay line and cannot exceed a device dependent maximum. This maximum is achieved when the phase detector is operating in **compression**[1]. Increasing the delay τ_d will reduce the signal level out of the delay line often reducing the sensitivity of the phase detector. Optimum system sensitivity is obtained in a trade-off between delay and attenuation.

$$\text{Sensitivity} = K_L V_{in} LX(10)^{-LZ/20}$$

Where K_L is the phase detector efficiency, V_{in} is the signal voltage into the delay line, LX (dB) is the sensitivity provided by the delay line and LZ is the attenuation of the delay line. Taking the derivative with respect to the length L to find the maximum of this equation results in

LZ = 8.7 dB of attenuation

The optimum sensitivity of a system with the phase detector operating out of results from using a length of coaxial line that has 8.7 dB of attenuation.

One way to increase the sensitivity of the discriminator when the phase detector is out of compression is to increase the signal into the delay line. This can be accomplished with an RF amplifier before the signal splitter. The noise of the RF amplifier will not degrade the measurement if the two-port noise of the amplifier is much less than the noise of the DUT. However, some attenuation may be needed in the signal path to the reference input to the double-balanced mixer (phase detector) to protect it from excessive power levels.

If the amplifier signal puts the phase detector into compression, K_ϕ is at its maximum and system sensitivity is now dependent on the length of the delay τ_d. For maximum sensitivity more delay can be added until the signal level out of the delay line is 8.7 dB below the phase detector compression point.

The following example illustrates how to choose a delay line that provided the optimum sensitivity given certain system parameters. (See Table 39 on page 250).

1 **Compression**: The level of the output signal at which the gain of a device is reduced by a specific amount, usually expressed in decibels (dB), as in the 1 dB compression point.

Table 39 Choosing a delay line

Parameters	
Source signal level	+7dBm
Mixer compression point	+3 dBm
Delay line attenuation at source carrier frequency	30 dB per 100 ns of Delay
Highest offset frequency of interest	5 MHz

1 To avoid having to correct for the sin(x)/x response choose the delay such that:

   A delay τ_d of 32 ns or less can be used for offset frequencies out to 5 MHz.

2 The attenuation for 32 ns of delay is 30 dB x 32 ns/100 ns or 9.6 dB. The total signal attenuation through the splitter and the delay line is 15.6 dB. The signal level out of the delay line is –8.6 dBm which is 11.6 dB below the phase detector compression point. Improved sensitivity can be achieved by reducing the length of the delay or by using a more efficient line so that the signal level out is –5.7 dBm or 8.7 dB below the mixer compression point.

Careful delay line selection is crucial for good system sensitivity. In cases where the phase detector is operating out of compression, sensitivity can be increased by using a low loss delay line, or by amplifying the signal from the DUT. Because attenuation in coaxial lines is frequency dependent, optimum system sensitivity will be achieved with different lengths of line for different carrier frequencies.

10
FM Discriminator Measurement Examples

Introduction 252

FM Discriminator Measurement using Double-Sided Spur Calibration 253

Discriminator Measurement using FM Rate and Deviation Calibration 268

Introduction

These two measurement examples demonstrates the FM Discriminator measurement technique for measuring the phase noise of a signal source using two different calibration methods.

These measurement techniques work well for measuring free-running oscillators that drift over a range that exceeds the tuning range limits of the phase-locked-loop measurement technique. The Discriminator measurement is also useful for measuring sources when a VCO reference source is not available to provide adequate drift tracking.

The setup for a discriminator measurement uses a delay line to convert frequency fluctuations to phase fluctuations and a phase shifter to set quadrature at the phase detector.

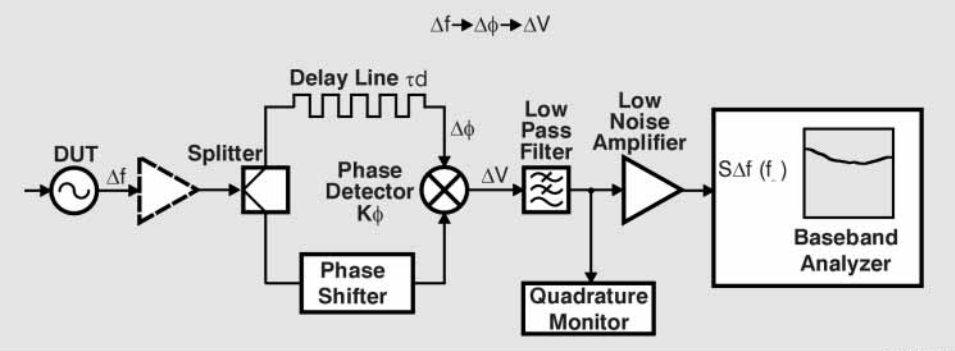


Figure 180FM Discriminator measurement setup

In the Discriminator measurement, the source is placed ahead of the power splitter. One output of the splitter feeds a delay line with enough delay to decorrelate the source noise. The delay line generates a phase shift proportional to the frequency. The phase shift is measured in the phase detector by comparing the delay output with the other output from the splitter. The output of the phase detector is a voltage proportional to the frequency fluctuations of the source.

For more information about FM Discrimination basics, refer to Chapter 9, “FM Discriminator Fundamentals.

FM Discriminator Measurement using Double-Sided Spur Calibration

CAUTION To prevent damage to the test set's components, *do not* apply the input signal to the signal input connector until the input attenuator (N5500A Option 001) has been correctly set for the desired configuration, as shown in Table 41. Apply the input signal when the connection diagram appears.

Required Equipment

Table 40 shows equipment required for this example in addition to the phase noise test system and your DUT.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Table 40 Required Equipment for the FM Discriminator Measurement Example

Equipment	Quantity	Comments
Signal Generator	1	+19 dBm output level at tested carrier frequency. Calibrated FM at a 20 kHz rate with 10 kHz Peak Deviation.
Power Splitter	1	NARDA 30183
Delay Line		Delay (or length) adequate to decorrelate source noise.
Phase Shifter	1	±180° phase shifter at lowest carrier frequency tested.

Determining the discriminator (delay line) length

Perform the following steps to determine the minimum delay line length (τ) Possible to provide an adequate noise to measure the source.

1. Determine the delay necessary to provide a discriminator noise floor that is below the expected noise level of the DUT. Figure 181 on page 254 shows the noise floor of the discriminator for given delay times (τ).
2. Determine the length of coax required to provide the necessary delay (τ). (Eight feet of BNC cable will provide 12 ns of delay for this example.)
3. Determine the loss in the delay line. Verify that the signal source will be able to provide a power level at the output of the delay line of between +5 and +17 ICBM. Be sure to take into account an additional 4 to 6 dB of loss in the power splitter. (The loss across 8 feet of BNC cable specified in this

example is negligible.) The test set Signal and Reference inputs requires +15 ICBM.

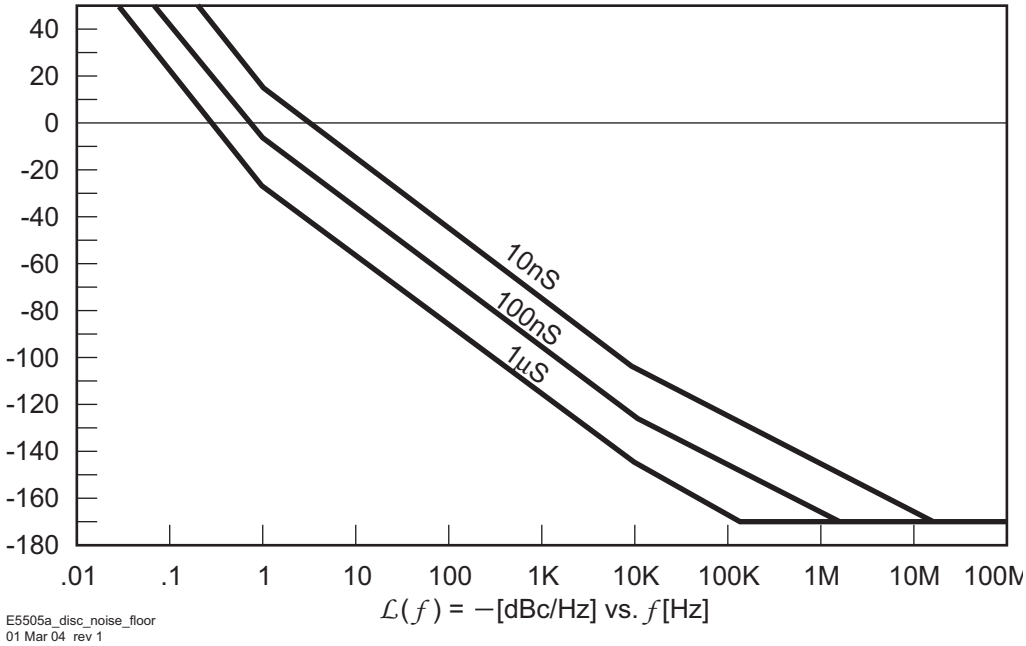


Figure 181 Discriminator noise floor as a function of delay time

Defining the measurement

1. From the File menu, choose Open.
2. If necessary, choose the drive or directory where the file you want is stored.
3. In the File Name box, choose “vco_dss.pnm.” See Figure 182.

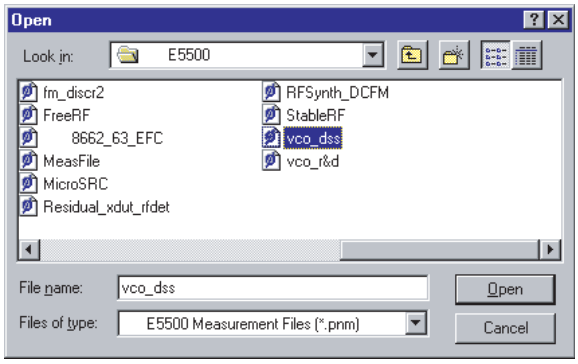


Figure 182 Select the parameters definition file

4. Click the Open button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 42 on page 266 lists the parameter data that has been entered for the FM discriminator measurement example.

5 From the **Define** menu, navigate to the Measurement window. Using Figure 183 as a guide:

a Choose the **Type and Range** tab from the **Define Measurement** window.

b From the **Measurement Type** pull-down in Type and Range tab, select Absolute Phase Noise (using an FM discriminator).

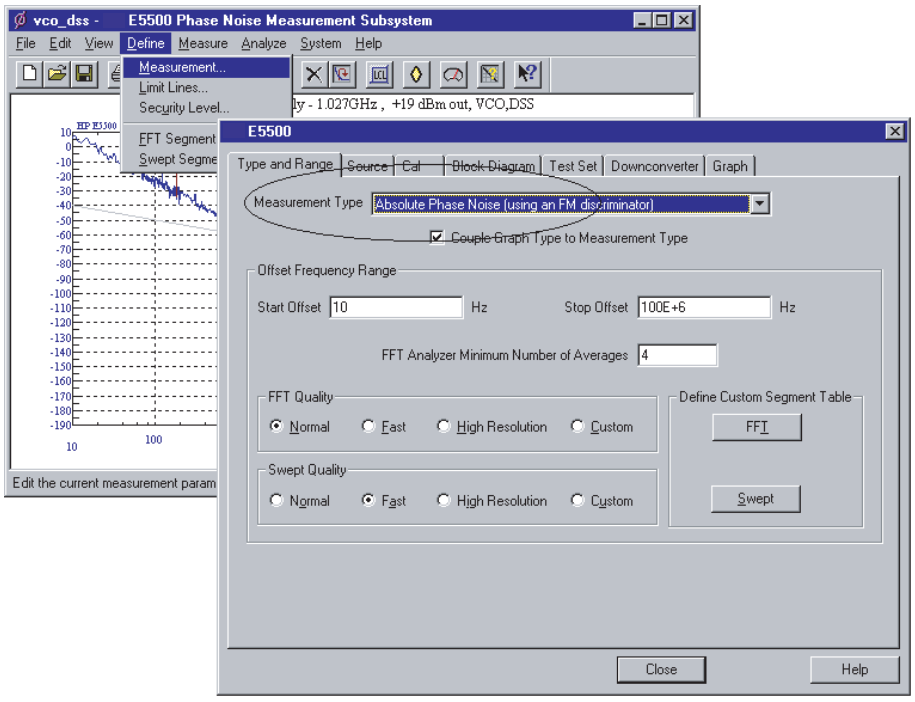


Figure 183 Select measurement type

6 Choose the **Sources** tab from the **Define Measurement** window.

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 Gaze). Enter the same frequency for the detector input frequency. See Figure 184.

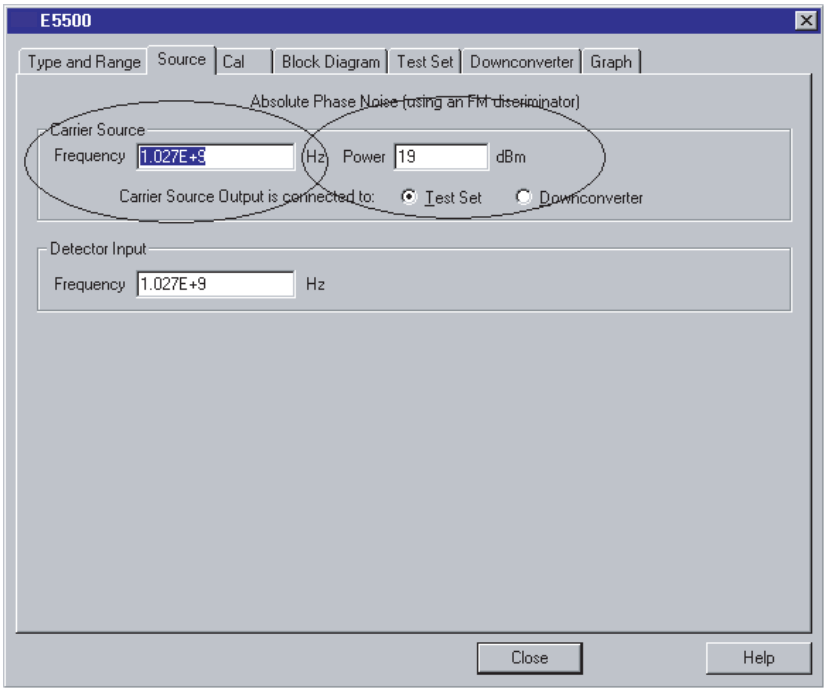


Figure 184 Enter frequencies in source tab

7 Choose the **Cal** tab from the **Define Measurement** window.

a Select **Derive constant from double-sided spur** as the calibration method.

b Feed the output from a modulated calibration source into a spectrum analyzer and measure the 1st modulation sideband frequency and power relative to the carrier's frequency and power. Enter the parameters in the following step.

c Set the **Know Spur Parameters Offset Frequency** and **Amplitude** for the spur you plan to use for calibration purposes.This calibration method requires that you enter the offset and amplitude for a *known* spur. See Figure 185 on page 257.

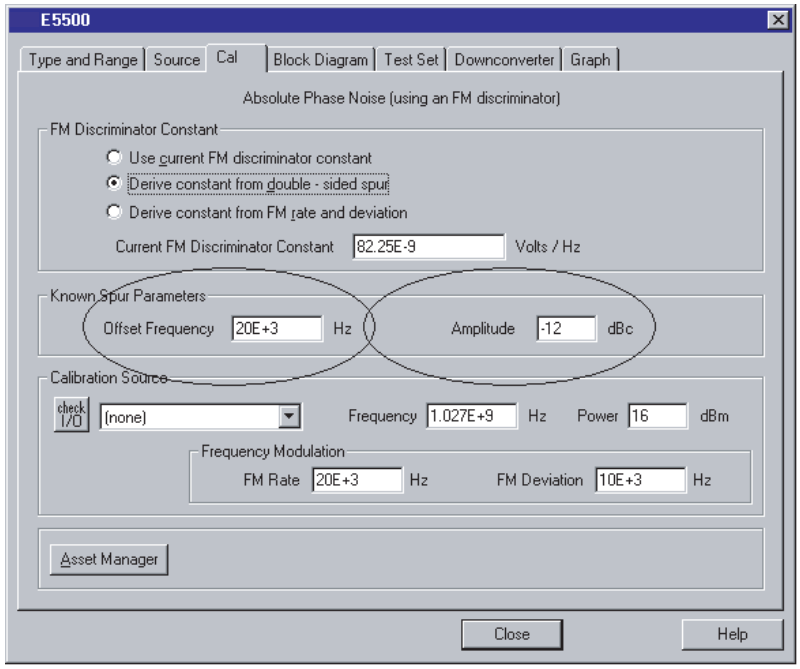


Figure 185 Enter parameters into the call tab

8 Choose the **Block Diagram** tab from the **Define Measurement** window.

a From the **Reference Source** pull-down, select **Manual**.

b From the **Phase Detector** pull-down, select **Automatic Detector Selection**. See Figure 186 on page 257.

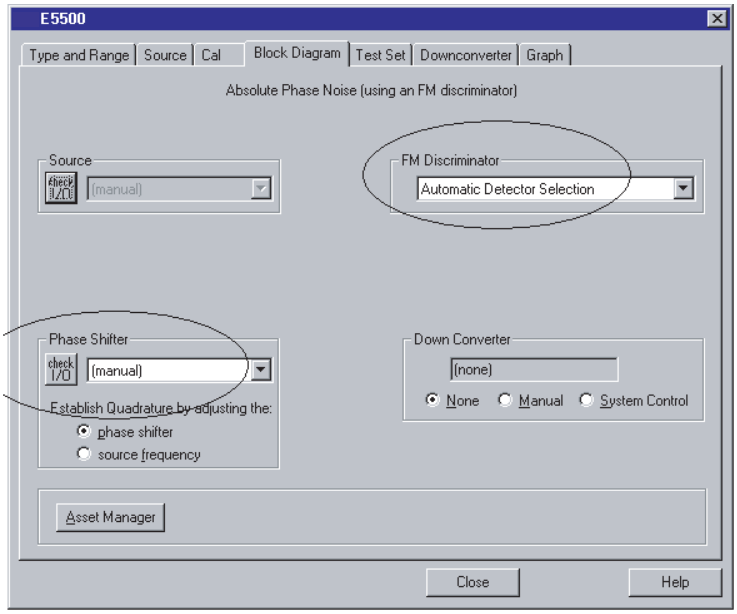


Figure 186 Select parameters in the block diagram tab

9 Choose the **Graph** tab from the **Define Measurement** window.

10 Enter a graph description of your choice. See Figure 187.

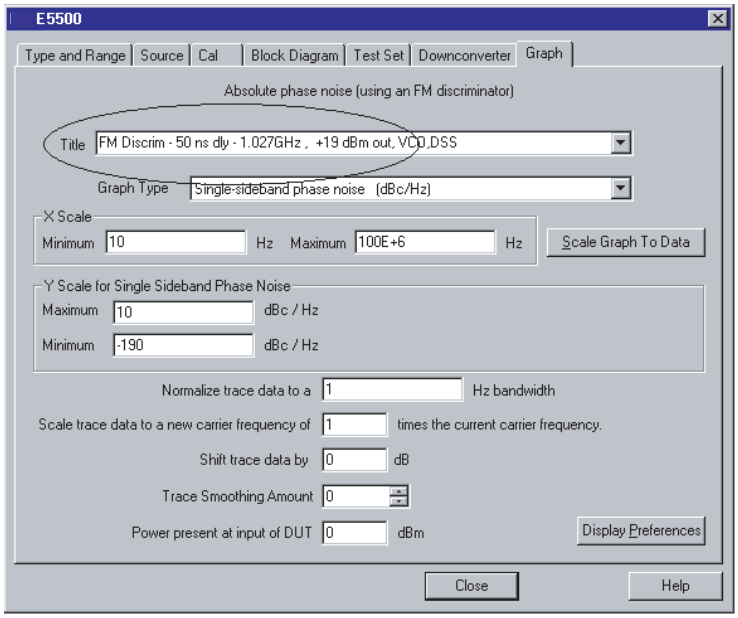


Figure 187 Select Graph Description on Graph Tab

11 When you have completed these operations, click the **Close** button.

Setup considerations

Connecting cables

The best results will be obtained if semi-rigid coaxial cables are used to connect the components used in the measurement; however, BNC cables have been specified because they are more widely available. Using BNC cables may degrade the close-in phase noise results and, while adequate for this example, should not be used for an actual measurement on an unknown device unless absolutely necessary.

Measurement environment

The low noise floors typical of these devices may require that special attention be given to the measurement environment. The following precautions will help ensure reliable test results:

- Filtering on power supply lines
- Protection from microphonics
- Shielding from air currents may be necessary.

Beginning the measurement

From the **View** menu, choose **Meter** to select the quadrature meter. See Figure 188.

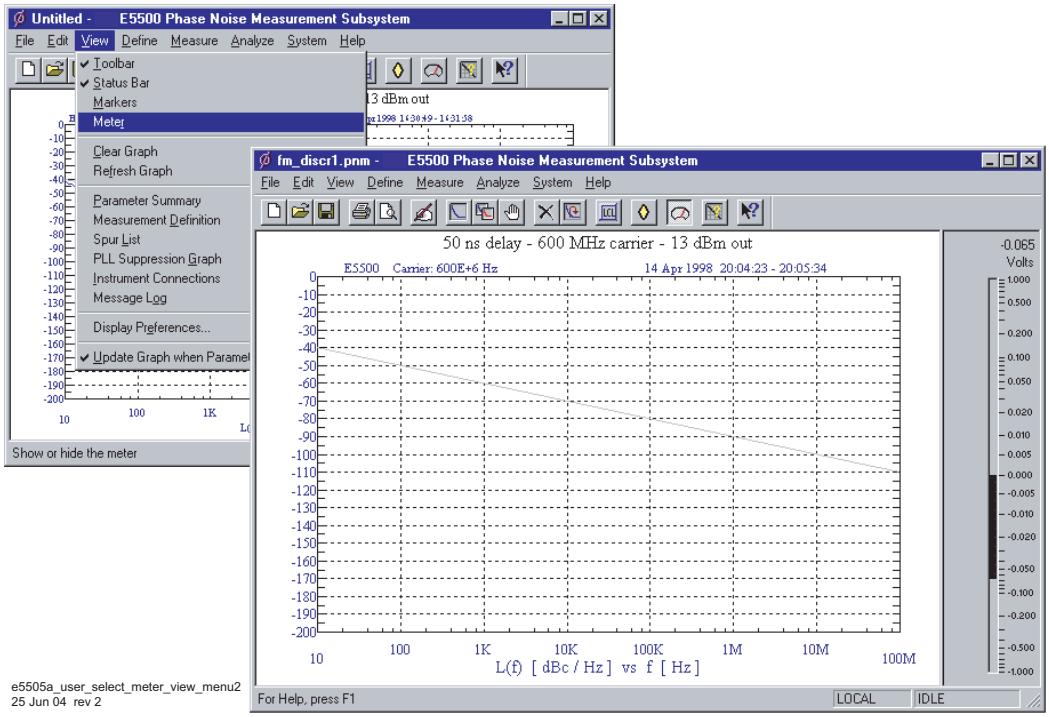


Figure 188 Select meter from view menu

12 From the **Measurement** menu, choose **New Measurement. See** Figure 189**.**

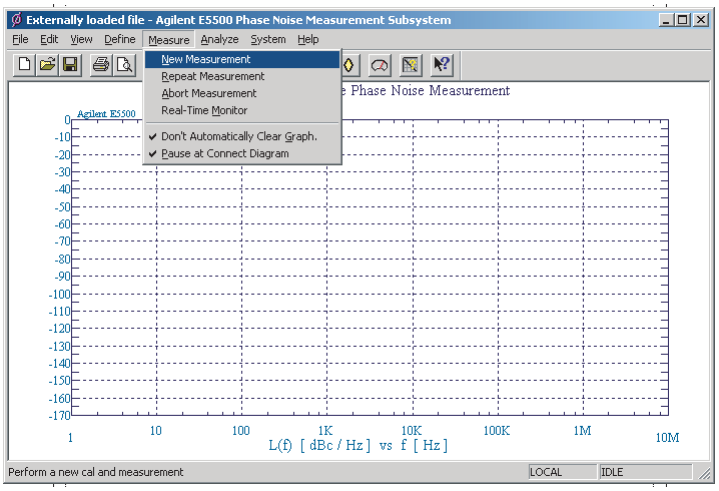


Figure 189 Selecting New Measurement

13 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes.**

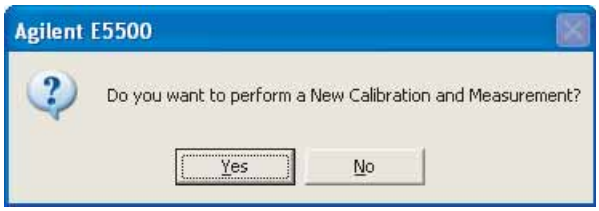


Figure 190 Confirm new measurement

14 When the **Connect Diagram** dialog box appears, click on the hardware pull-down arrow and select your hardware configuration from the list. See Figure 191.

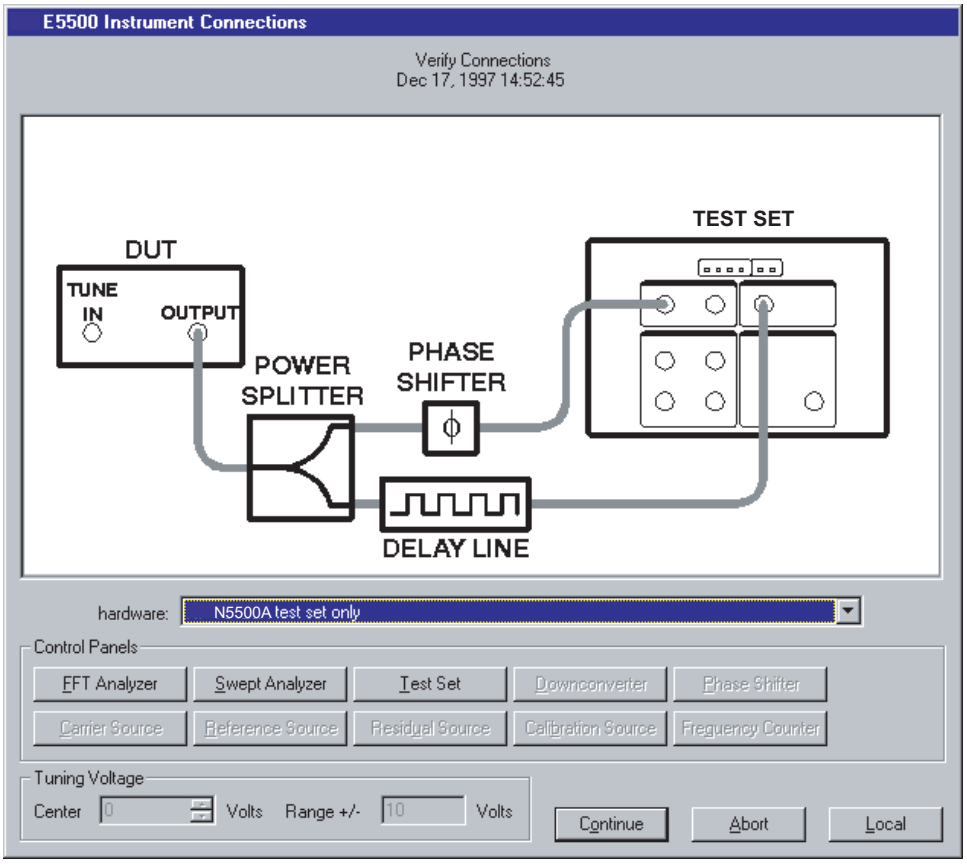


Figure 191 Setup diagram for the FM discrimination measurement example

CAUTION

The test set's signal input is subject to the limits and characteristics contained in Table 41.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which occurs at the connection diagram.

Table 41 Test Set Signal Input Limits and Characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std.) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm (+30 with Option 001)
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

Refer to Figure 192 on page 262 for more information about system interconnections:.

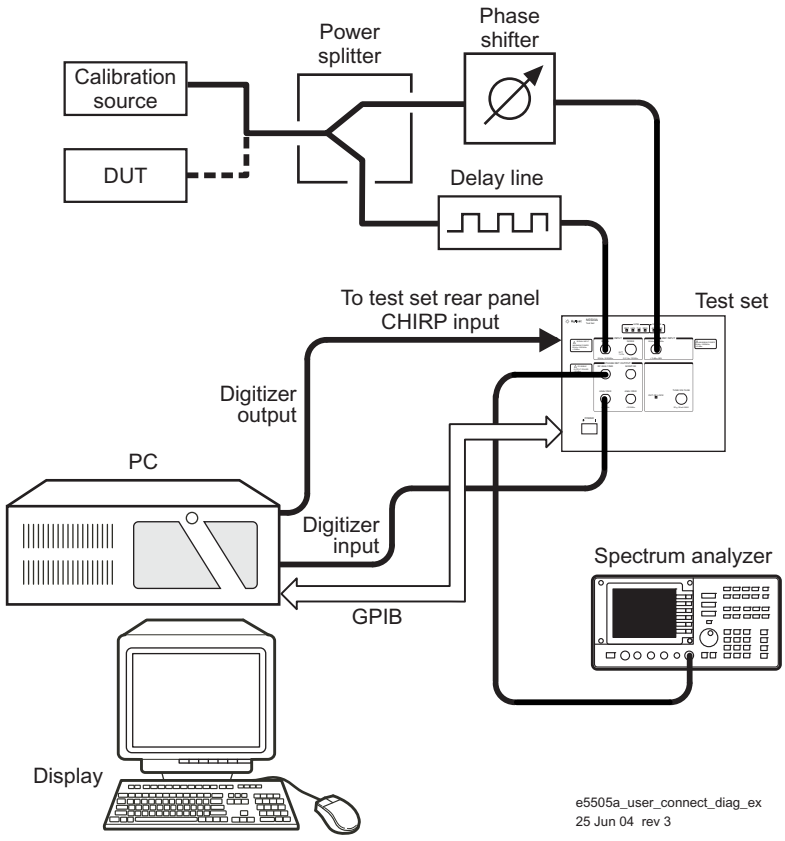


Figure 192 Connect diagram example

Making the measurement

1 Press the **Continue** button when you are ready to make the measurement.

Calibrating the measurement

The calibration procedure determines the discriminator constant to use in the transfer response by measuring the system response to a known FM signal. Refer to Figure 193 on page 263 through Figure 197 on page 264.

NOTE Note that the system must be operating in quadrature during calibration.

2 Establish quadrature by adjusting the phase shifter until the meter indicates 0 volts, then press **Continue**.

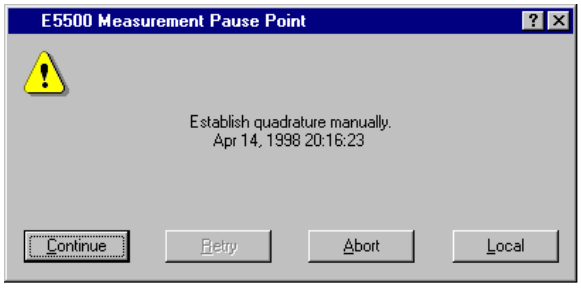


Figure 193 Calibration measurement (1 of 5)

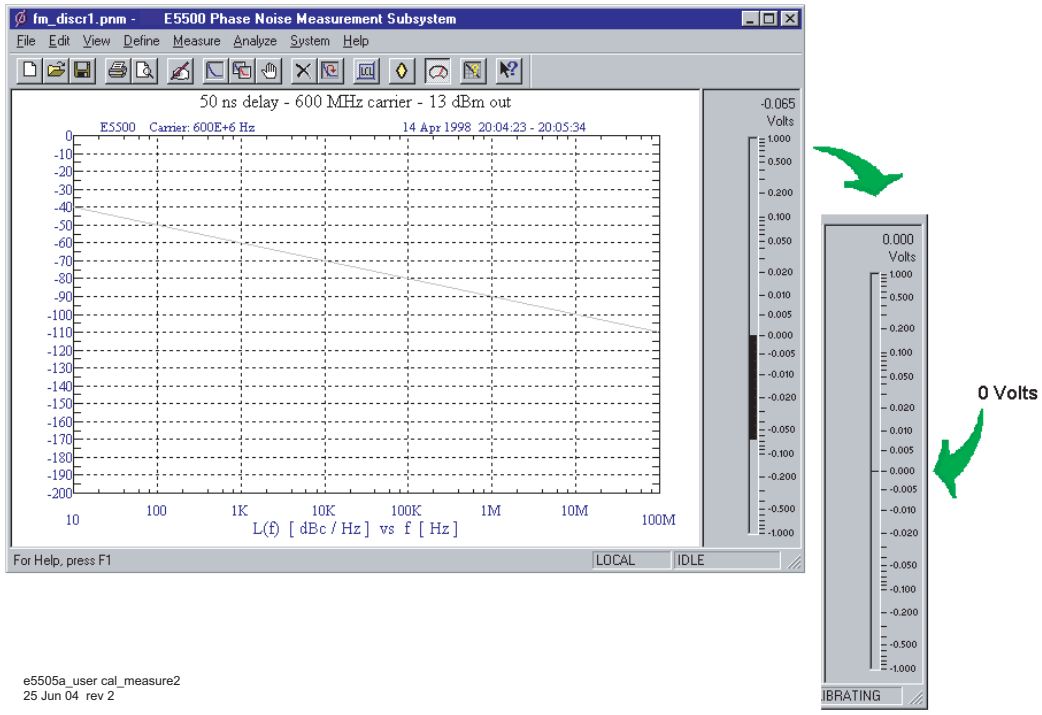


Figure 194 Calibration measurement (2 of 5)

3 Apply modulation to the carrier signal, then press **Continue.**

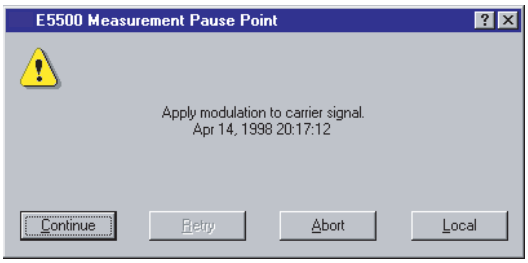


Figure 195 Calibration measurement (3 of 5)

4 Remove the modulation from the carrier and connect your DUT.

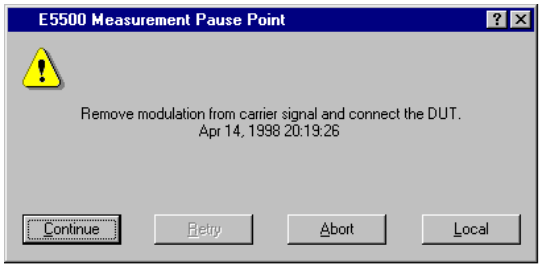


Figure 196 Calibration measurement (4 of 5)

5 The system can now run the measurement. At the appropriate point, re-establish quadrature and continue the measurement.

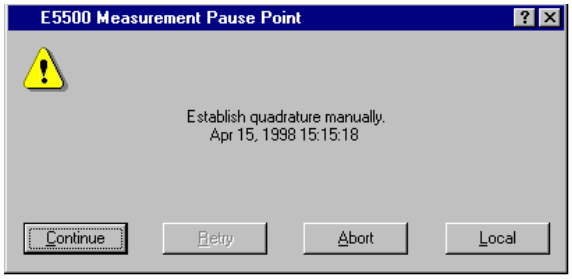


Figure 197 Calibration measurement (5 of 5)

The segment data will be displayed on the computer screen as the data is taken until all segments have been taken over the entire range you specified in the Measurement definition's Type and Range.

When the measurement is complete

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results for help in evaluating your measurement results. (If the test system has problems completing the measurement, it will inform you by placing a message on the computer display.

Figure 198 shows a typical absolute measurement using FM discrimination.

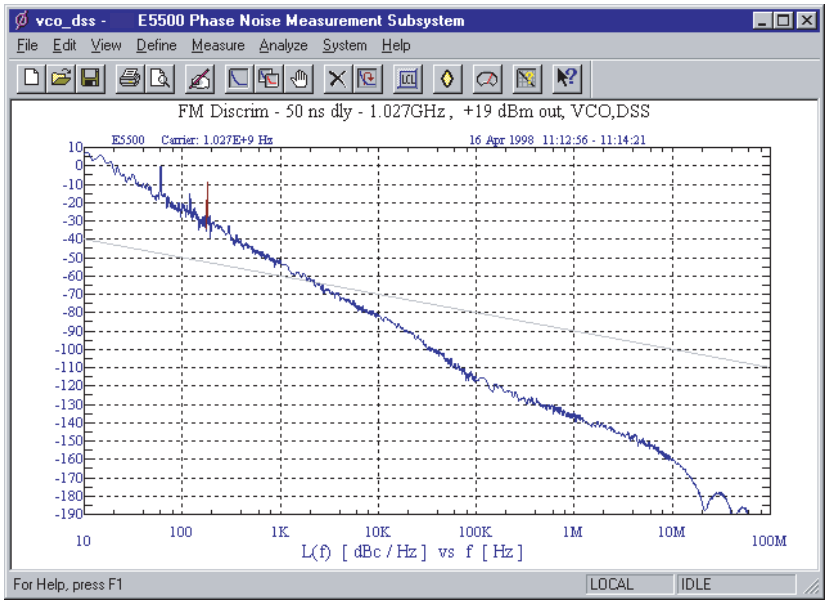


Figure 198 Typical phase noise curve using double-sided spur calibration

Table 42 Parameter data for the double-sided spur calibration example

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Absolute Phase Noise (using an FM Discriminator)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 100 E + 6 Hz
	• Minimum Number of Averages	• 4
		• Normal
	FFT Quality	• Fast
	Swept Quality	
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 1.027 E + 9 Hz
	• Power	• 19 dBm
	• Carrier Source is Connected to:	• Test Set
	Detector Input	• 1.027 E + 9 Hz
	• Frequency	
3	**Cal Tab**	
	FM Discriminator Constant	• Derive Constant from Double-Sided Spur
	• Current Phase Detector Constant	• 82.25 E-9
	Know Spur Parameters	
	• Offset Frequency	• 20 E3
	• Amplitude	• -12 dBc
	Calibration Source	
	• Frequency	• 1.027 E + 9 Hz
	• Power	• 16 dBm
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Phase Shifter	• Manual
	• DUT in Path	• checked
	• Phase Detector	• Automatic Detector Selection
	• Adjust the Quadrature by adjusting the	• phase shifter
5	**Test Set Tab**	The test set parameters do not apply to this measurement example.

Table 42 Parameter data for the double-sided spur calibration example (continued)

Step	Parameters	Data
6	**Downconverter Tab**	The downconverter parameters do not apply to this measurement example.
7	**Graph Tab**	
	• Title	• FM Discrim – 50 ns dly – 1.027GHz, +19 dBm out, VCO,DSS
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 100 E + 6 Hz
	• Y Scale Minimum	• 10 dBc/Hz
	• Y Scale Maximum	• - 190 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

Discriminator Measurement using FM Rate and Deviation Calibration

CAUTION To prevent damage to the test set's components, *do not* apply the input signal to the signal input connector until the input attenuator (N5500A Option 001) has been correctly set for the desired configuration, as show in Table 44 on page 277. Apply the input signal when the connection diagram appears.

NOTE In order to use the FM rate and deviation calibration method you must have a signal source that is calibrated for FM modulation rate and FM deviation parameters. All Agilent Technologies signal generators meet this requirement.

Required equipment

Table 43 shows equipment is required for this example in addition the phase noise test system and your DUT.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Table 43 Required equipment for the FM discriminator measurement example

Equipment	Quantity	Comments
Signal Generator	1	+19 dBm output level at tested carrier frequency. Calibrated FM at a 20 kHz rate with 10 kHz Peak Deviation.
Power Splitter	1	NARDA 30183
Delay Line		Delay (or length) adequate to decorrelate source noise.
Phase Shifter	1	±180° phase shifter at lowest carrier frequency tested.

Determining the discriminator (delay line) length

Perform the following steps to determine the minimum delay line length (τ) Possible to provide an adequate noise to measure the source.

1. Determine the delay necessary to provide a discriminator noise floor that is below the expected noise level of the DUT. Figure 199 shows the noise floor of the discriminator for given delay times (τ).
2. Determine the length of coax required to provide the necessary delay (τ). (Eight feet of BNC cable will provide 12 ns of delay for this example.)
3. Determine the loss in the delay line. Verify that the signal source will be able to provide a power level at the output of the delay line of between +5 and +17 ICBM. Be sure to take into account an additional 4 to 6 dB of loss in the power splitter. (The loss across 8 feet of BNC cable specified in this example is negligible.) The test set Signal and Reference inputs requires +15 ICBM.

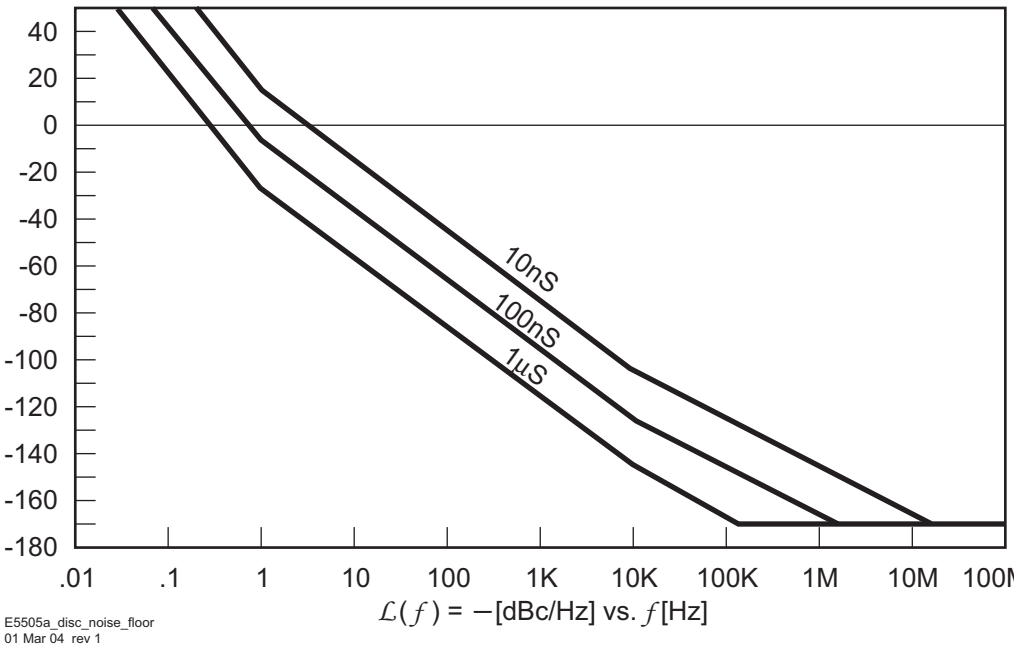


Figure 199 Discriminator noise floor as a function of delay time

Defining the measurement

1. From the **File** menu, choose **Open**.
2. If necessary, choose the drive or directory where the file you want is stored.
3. In the **File Name** box, choose "**vco_r&d.pnm.**" See Figure 200.

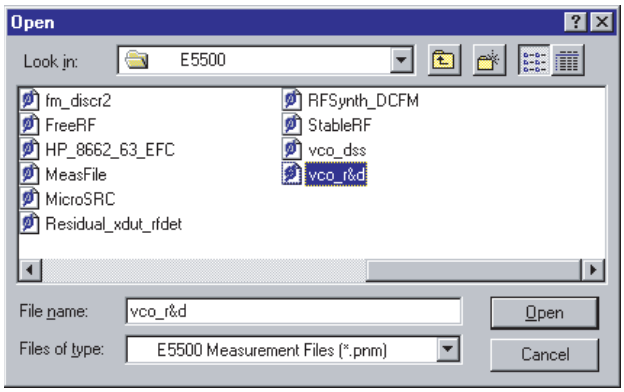


Figure 200 Select the parameters definition file

4 Click the **Open** button.

- The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 45 on page 282 lists the parameter data that has been entered for the FM discriminator measurement example.

5 From the **Define** menu, choose **Measurement**; then choose the **Type and Range** tab from the **Define** Measurement window.

6 From the **Measurement Type** pull-down, select **Absolute Phase Noise (using an FM discriminator)**. See Figure 201.

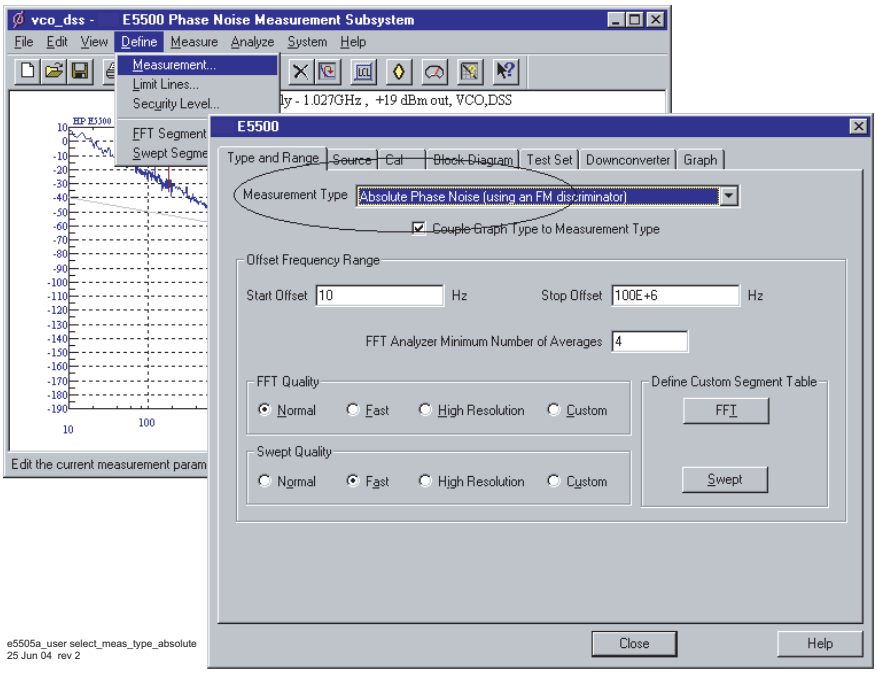


Figure 201 Select measurement type

7 Choose the **Sources** tab from the **Define Measurement** window.

a Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency. See Figure 202.

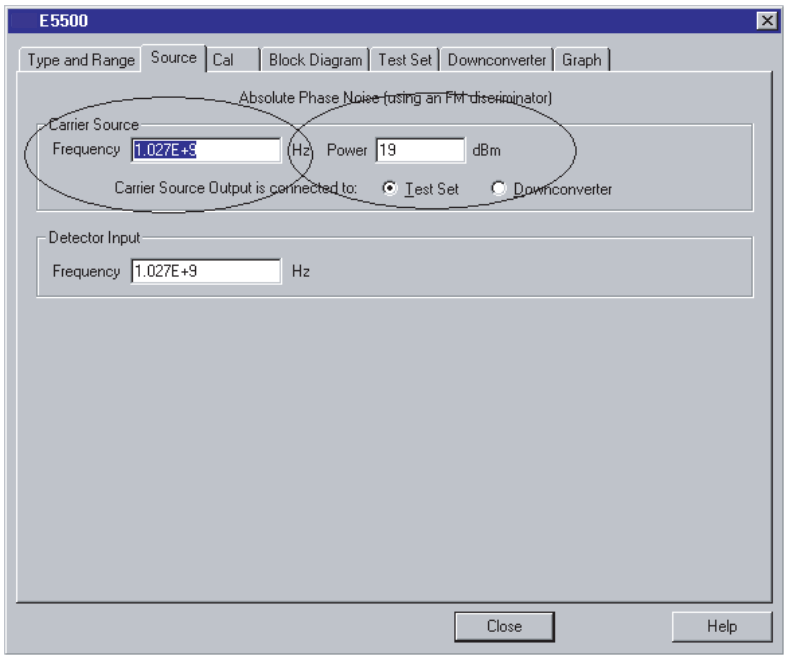


Figure 202 Enter frequencies in Source tab

8 Choose the **Cal** tab from the **Define Measurement** window.

9 Select **Derive constant from FM rate and deviation** as the calibration method.

10 Set the **FM Rate** to 20 kHz and **FM Deviation** to 10 kHz, which are the recommended FM rate and deviation. See Figure 203 on page 272.

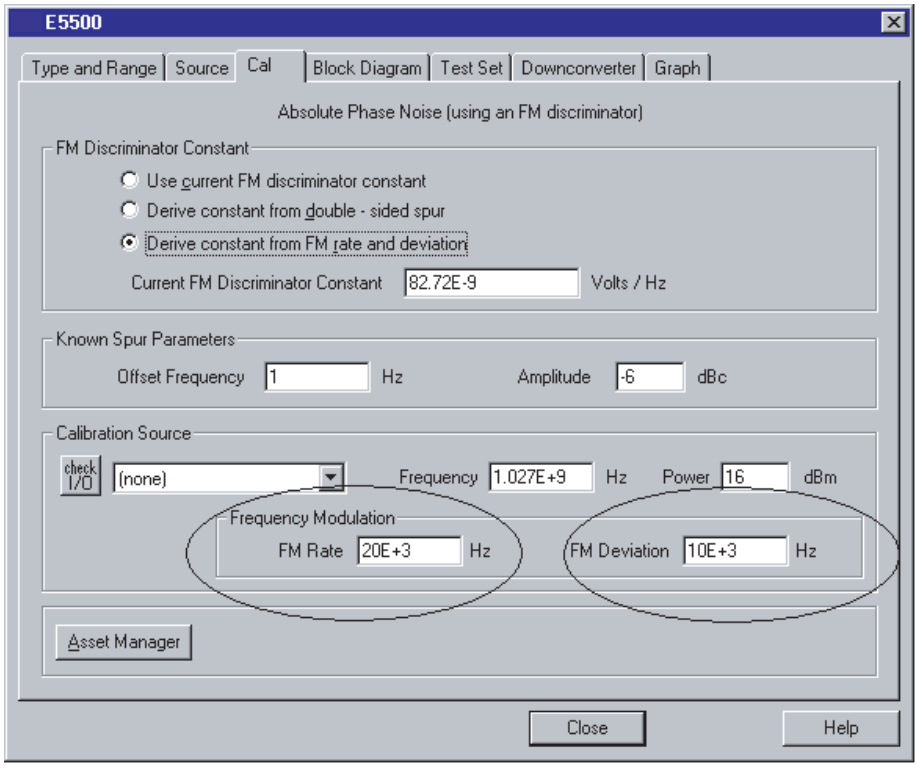


Figure 203 Enter parameters into the Cal tab

11 Choose the **Block Diagram** tab from the **Define Measurement** window. See Figure 204 on page 273.

a From the **Reference Source** pull-down, select Manual.

b From the **Phase Detector** pull-down, select Automatic Detector Selection.

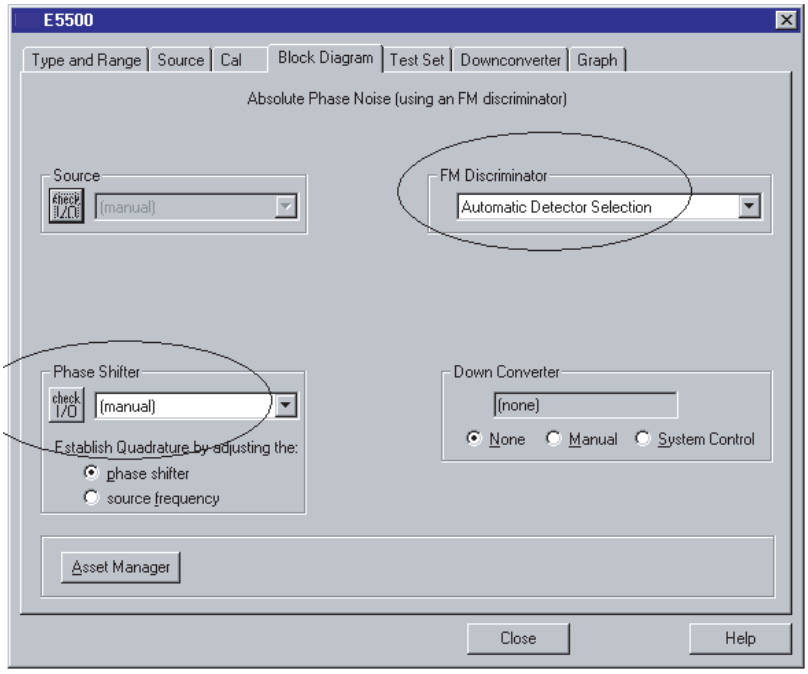


Figure 204 Enter parameters in the Block Diagram tab

12 Choose the **Graph** tab from the **Define Measurement** window.

13 Enter a graph description of your choice. See Figure 205 on page 273.

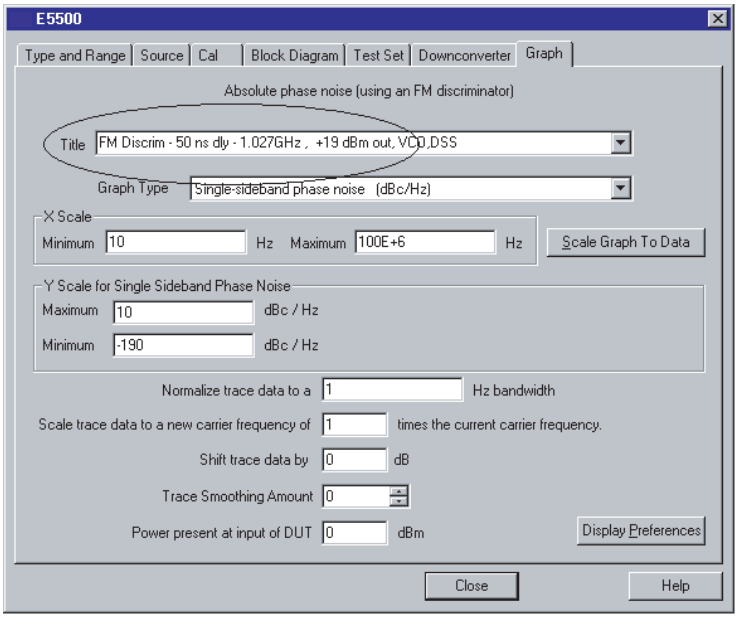


Figure 205 Select graph description on Graph tab

14 When you have completed these operations, click the **Close** button.

Setup considerations

Connecting cables

The best results will be obtained if semi-rigid coaxial cables are used to connect the components used in the measurement; however, BNC cables have been specified because they are more widely available. Using BNC cables may degrade the close-in phase noise results and, while adequate for this example, should not be used for an actual measurement on an unknown device unless absolutely necessary.

Measurement environment

The low noise floors typical of these devices may require that special attention be given to the measurement environment. The following precautions will help ensure reliable test results:

- Filtering on power supply lines
- Protection from microphonics
- Shielding from air currents may be necessary.

Beginning the measurement

1 From the **View** menu, choose **Meter** to select the quadrature meter. See Figure 206.

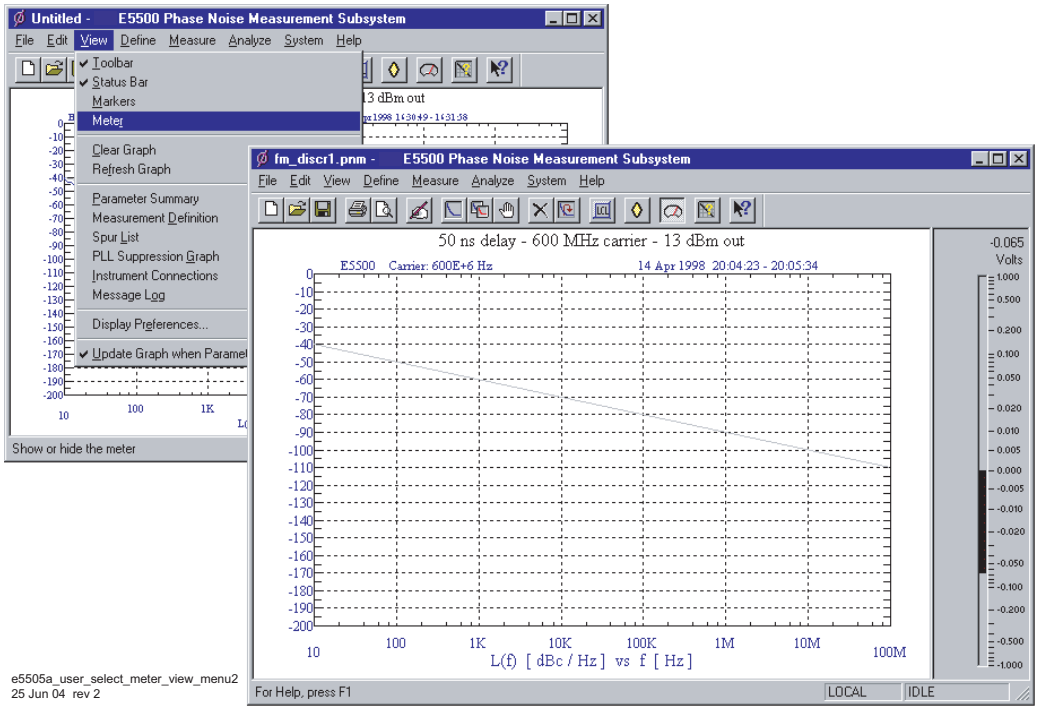


Figure 206 Select meter from the View menu

2 From the **Measurement** menu, choose **New Measurement.** See Figure 207.

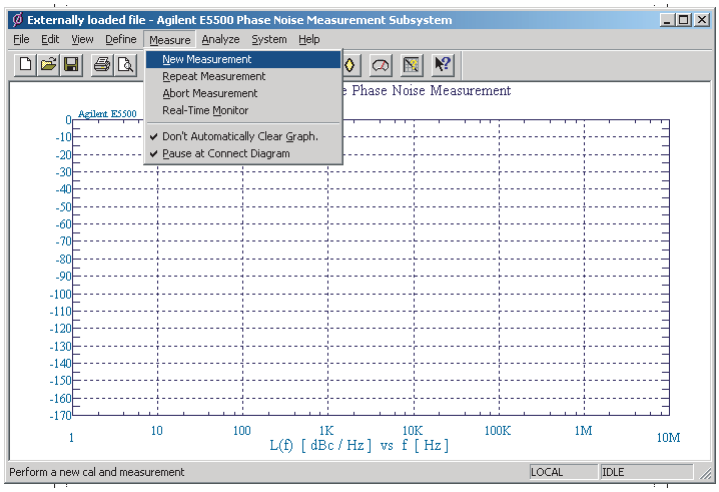


Figure 207 Selecting New Measurement

3 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes.**

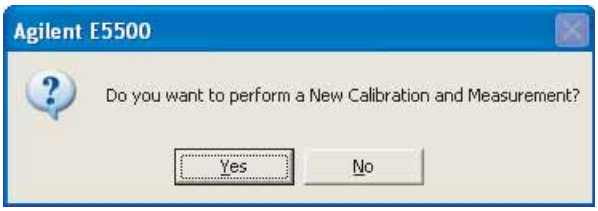


Figure 208 Confirm new measurement

4 When the **Connect Diagram** dialog box appears, click on the hardware pull-down arrow and select your hardware configuration from the list. See Figure 209.

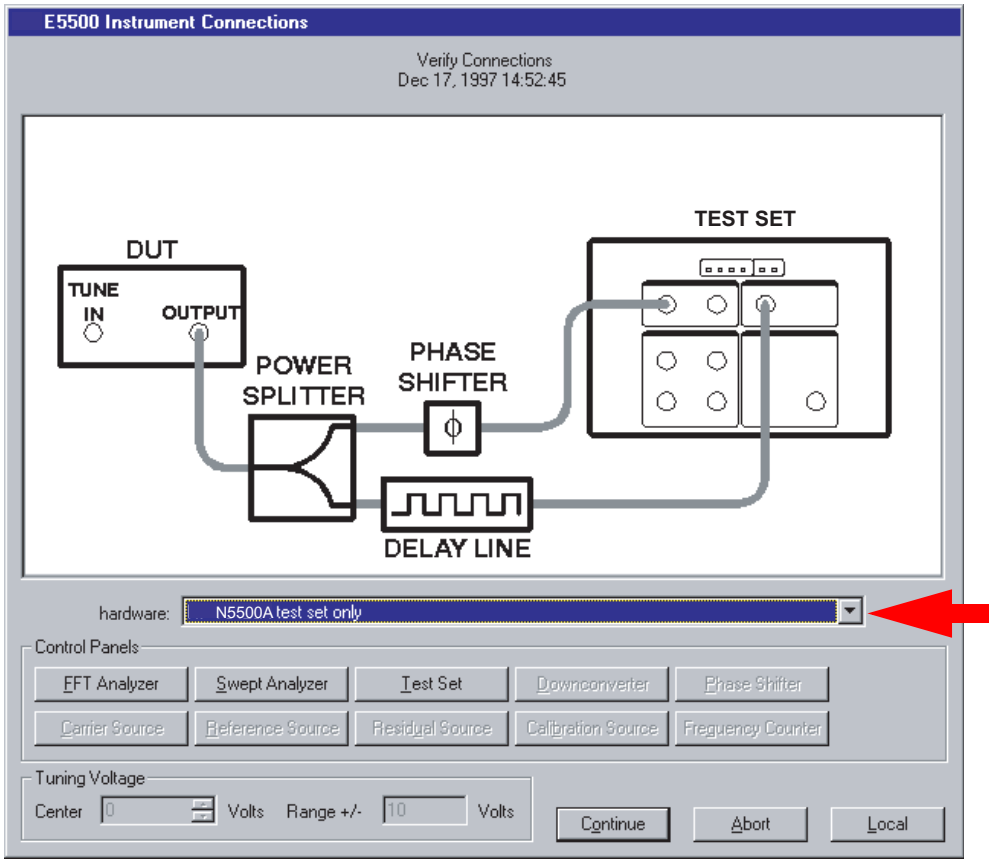


Figure 209 Setup diagram for the FM Discrimination measurement example

CAUTION

The test set's signal input is subject to the limits and characteristics contained in Table 44 on page 277.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which occurs at the connection diagram.

Table 44 Test set signal input limits and characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std.) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm
At Attenuator Output, Operating Level Range:	
• RF Phase Detectors	0 to +23 dBm (Signal Input) +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	0 to +5 dBm (Signal Input) +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	0 to +30 dBm
• Agilent N5507A/70427A	+5 to +15 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

Refer to Figure 210 on page 278 for more information about system interconnections.

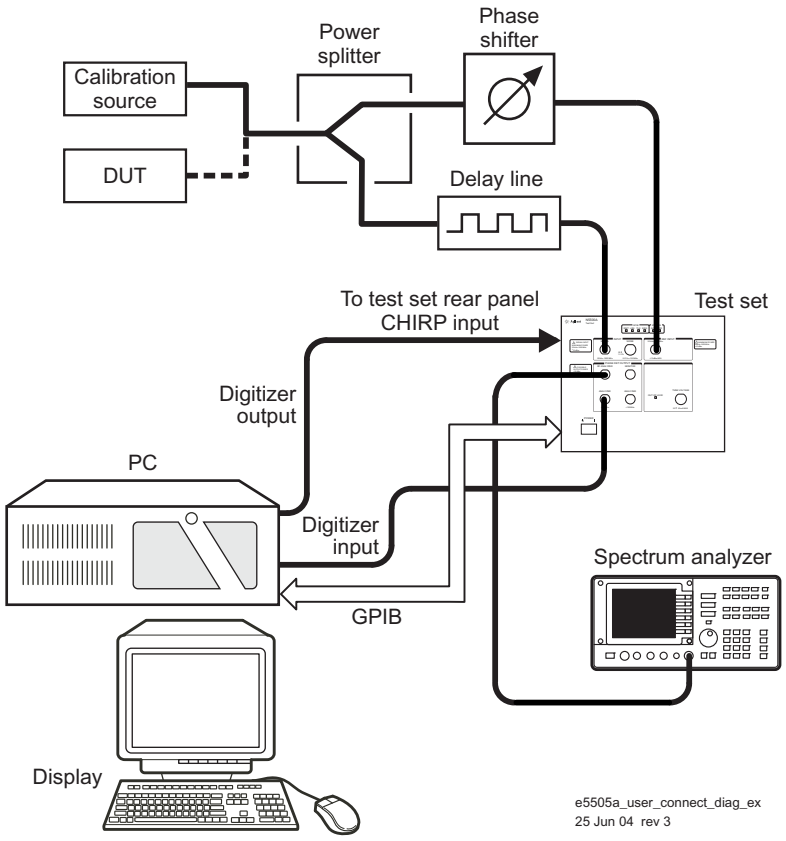


Figure 210 System connect diagram example

Making the measurement

1 Press the **Continue** button when you are ready to make the measurement.

Calibrating the measurement

- The calibration procedure determines the discriminator constant to use in the transfer response by measuring the system response to a known FM signal. Refer to Figure 211 on page 279 through Figure 215 on page 280.

NOTE Note that the system must be operating in quadrature during calibration.

2 Establish quadrature by adjusting the phase shifter until the meter indicates 0 volts, then press **Continue**.

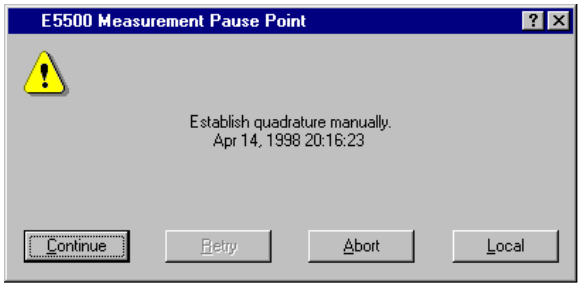


Figure 211 Calibration measurement (1 of 5)

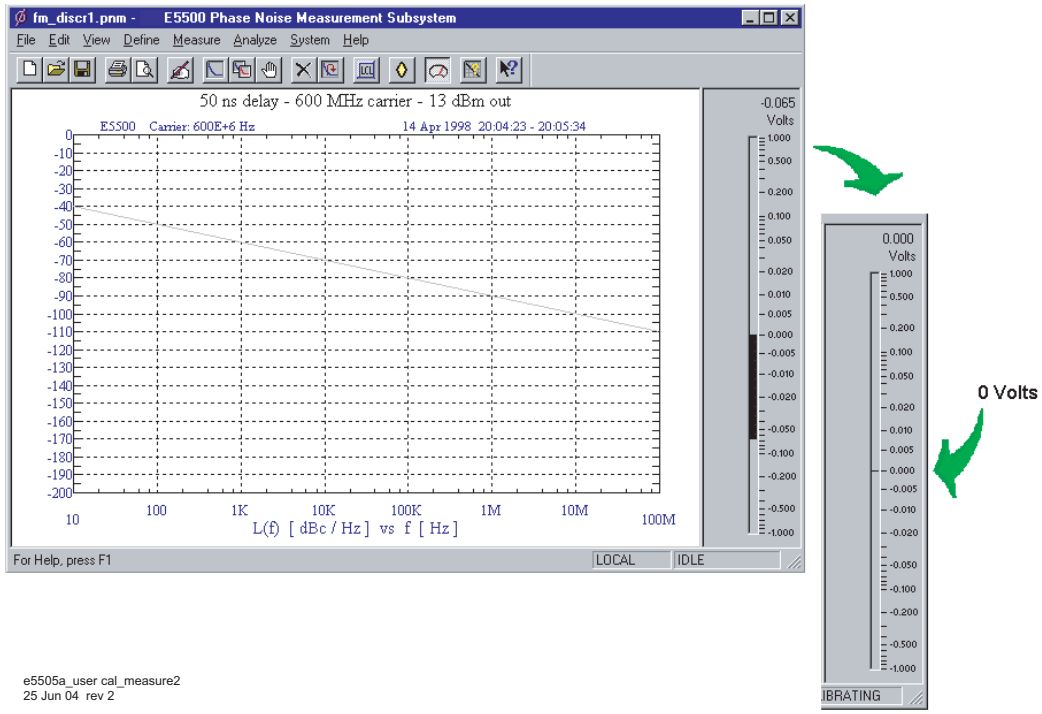


Figure 212 Calibration measurement (2 of 5)

3 Apply modulation to the carrier signal then press **Continue.**

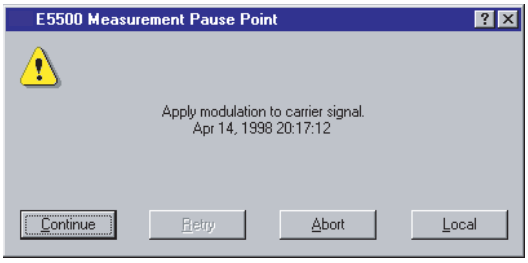


Figure 213 Calibration measurement (3 of 5)

4 Remove the modulation from the carrier and connect your DUT.

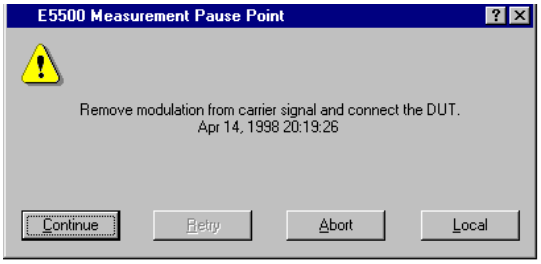


Figure 214 Calibration measurement (4 of 5)

5 The system can now run the measurement. At the appropriate point, re-establish quadrature and continue the measurement.

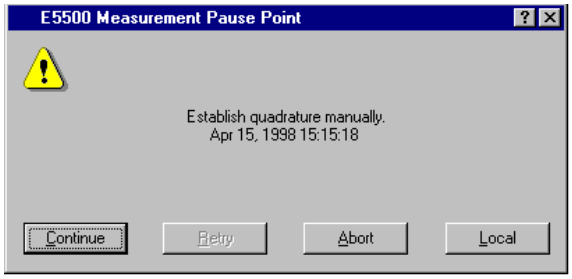


Figure 215 Calibration measurement (5 of 5)

The segment data will be displayed on the computer screen as the data is taken until all segments have been taken over the entire range you specified in the Measurement definition's Type and Range.

When the measurement is complete

When the measurement is complete, refer to Chapter 14, "Evaluating Your Measurement Results for help in evaluating your measurement results. (If the test system has problems completing the measurement, it will inform you by placing a message on the computer display.

Figure 216 on page 281 shows a typical absolute measurement using FM discrimination.

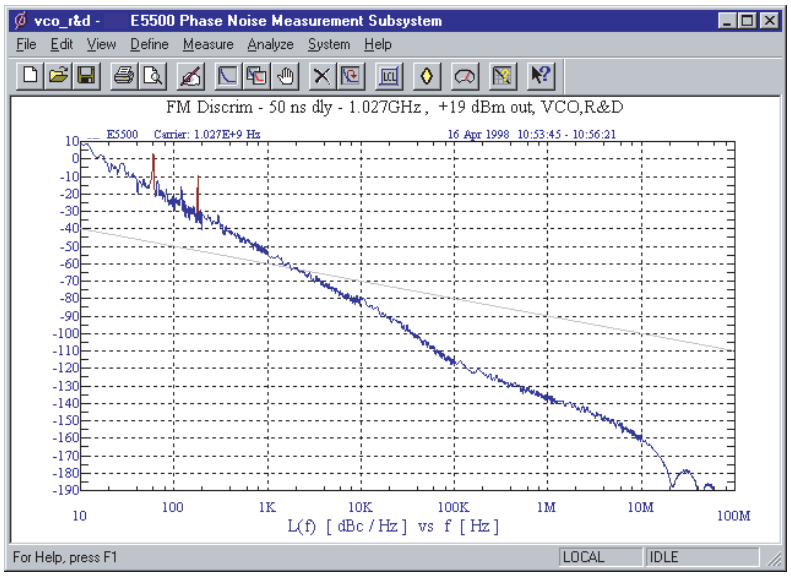


Figure 216 Typical phase noise curve using rate and deviation calibration

Table 45 on page 282 contains the data stored in the parameter definition file.

Table 45 Parameter data for the rate and deviation calibration example

Step	Parameters	Data
1	**Type and Range Tab**	
	Measurement Type	• Absolute Phase Noise (using an FM Discriminator)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 100 E + 6 Hz
	• Minimum Number of Averages	• 4
	FFT Quality	• Normal
	Swept Quality	• Fast
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 1.027 E + 9 Hz
	• Power	• 19 dBm
	• Carrier Source is Connected to:	• Test Set
	Detector Input	• 1.027 E + 9 Hz
	• Frequency	
3	**Cal Tab**	
	FM Discriminator Constant	• Derive Constant from FM rate and deviation
	• Current Phase Detector Constant	• 82.25 E-9
	Know Spur Parameters	
	• Offset Frequency	• 1 E3
	• Amplitude	• -6 dBc
	Calibration Source	
	• Frequency	• 1.027 E + 9 Hz
	• Power	• 16 dBm
	Frequency Modulation	
	• FM Rate	• 20 E +3 Hz
	• FM Deviation	• 10 E +3 Hz
4	**Block Diagram Tab**	
	• Carrier Source	• Manual
	• Phase Shifter	• Manual
	• DUT in Path	• checked
	• Phase Detector	• Automatic Detector Selection
	• Adjust the Quadrature by adjusting the	• phase shifter
5	**Test Set Tab**	The test set parameters do not apply to this measurement example.
6	**Downconverter Tab**	The downconverter parameters do not apply to this measurement example.

Table 45 Parameter data for the rate and deviation calibration example (continued)

Step	Parameters	Data
7	• Graph Tab	
	• Title	• FM Discrim – 50 ns dly – 1.027GHz, +19 ICBM out, VCO,R&D
	• Graph Type	• Single-sideband Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 100 E + 6 Hz
	• Y Scale Minimum	• 10 dBc/Hz
	• Y Scale Maximum	• - 190 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	
	• Shift trace data DOWN by:	• 1 times the current carrier frequency
	• Trace Smoothing Amount	• 0 dB
	• Power present at input of DUT	• 0
		• 0 dB

11 AM Noise Measurement Fundamentals

AM-Noise Measurement Theory of Operation 286
Amplitude Noise Measurement 287
Calibration and Measurement General Guidelines 291
Method 1: User Entry of Phase Detector Constant 292
Method 2: Double-Sided Spur 296
Method 3: Single-Sided Spur 301

AM-Noise Measurement Theory of Operation

Basic noise measurement

The E5500A phase noise measurement software uses the following process to measure carrier noise by:

- Calibrating the noise detector sensitivity.
- Measuring the recovered baseband noise out of the detector.
- Calculating the noise around the signal by correcting the measured data by the detector sensitivity.
- Displaying the measured noise data in the required format.

Given a detector calibration, the system looks at the signal out of the detector as just a noise voltage which must be measured over a band of frequencies regardless of the signal's origin.

The detector calibration is accomplished by applying a known signal to the detector. The known signal is then measured at baseband. Finally, the transfer function between the known signal and the measured baseband signal is calculated.

Phase noise measurement

In the case of small angle phase modulation (<0.1 rad), the modulation sideband amplitude is constant with increasing modulation frequency. The phase detector gain can thus be measured at a single offset frequency, and the same constant will apply at all offset frequencies.

- In the case of calibrating with phase modulation sidebands, the system requires the carrier-to-sideband ratio and the frequency offset of the sidebands. The offset frequency is equal to the baseband modulation frequency. The ratio of the baseband signal voltage to the carrier-to-sideband ratio is the sensitivity of the detector.
- In the case of calibrating with a single-sided spur, it can be shown that a single-sided spur is equal to a PM signal plus an AM signal. The modulation sidebands for both are 6 dB below the original single-sided spur. Since the phase detector attenuates the AM by more than 30 dB, the calibration constant can be measured as in the previous case, but with an additional 6 dB correction factor.

Amplitude Noise Measurement

The level of amplitude modulation sidebands is also constant with increasing modulation frequency. The AM detector gain can thus be measured at a single offset frequency and the same constant will apply at all offset frequencies. Replacing the phase detector with an AM detector, the AM noise measurement can be calibrated in the same way as PM noise measurement, except the phase modulation must be replaced with amplitude modulation.

The AM noise measurement is a characterization of a source. The residual AM noise of a DUT can only be made by using a source with lower AM noise, then subtracting that AM noise from the measured output noise of the DUT. The noise floor of this technique is the noise floor of the source.

AM noise measurement block diagrams

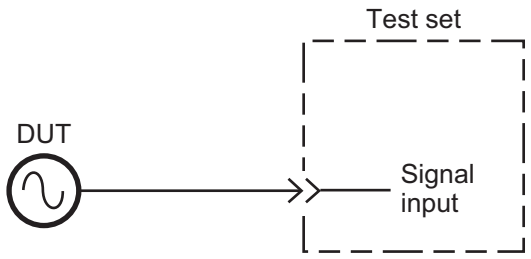


Figure 217AM noise system with N5500A opt 001

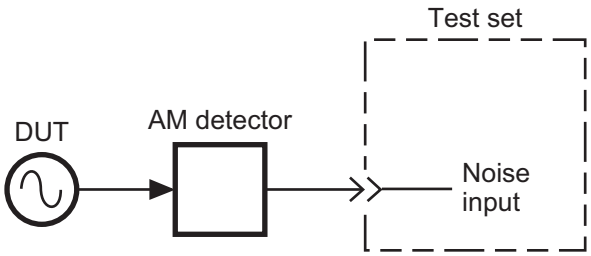


Figure 218AM noise system with external detector

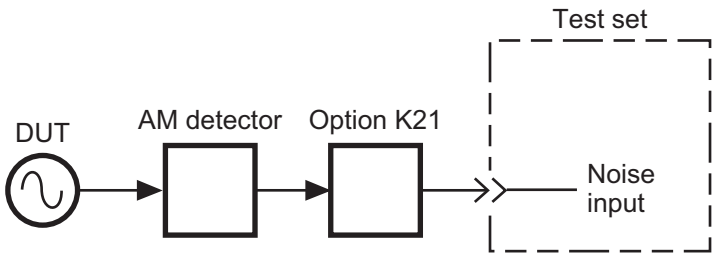


Figure 219AM Noise system with 70429A Opt K21 AM detector

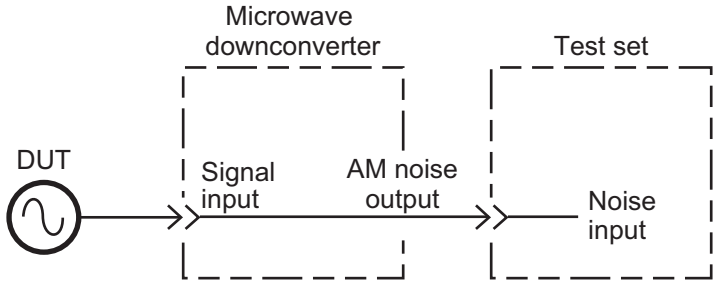


Figure 220AM noise system with N5507A downconverter

AM detector

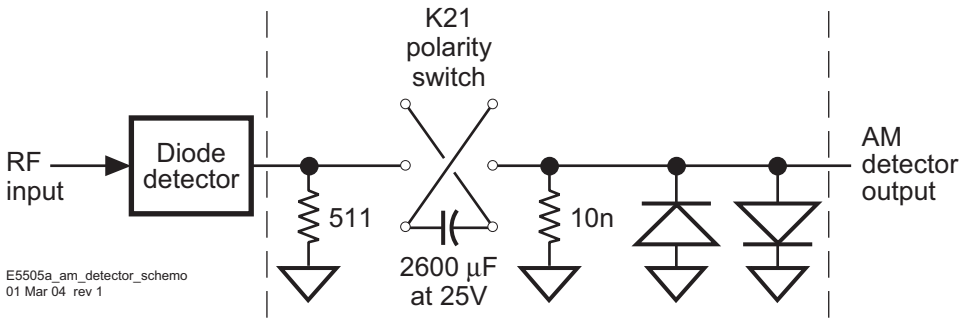


Figure 221AM detector schematic

AM detector specifications

Detector type low barrier Schottky diode

Carrier frequency range 10 MHz to 26.5 GHz

Maximum input power +23 dBm

Minimum input power 0 dBm

Output bandwidth 1 Hz to 40 MHz

AM detector considerations

CAUTION The phase noise test set **must be** DC blocked when using its Noise Input or internal AM detector. The test set **will not tolerate** more than ± 2 mV DC Input without overloading the LNA. A DC block must be connected in series after the AM Detector to remove the DC component. The 70429A Option K21 is designed specifically for this purpose or the internal DC blocking filter in either the N5500A or N5507A may be used.

- The AM detector consists of an Agilent 33330C Low-Barrier Schottky Diode Detector and an AM detector filter (Agilent 70429A K21).
- The detector, for example, is an 33330C Low-Barrier Schottky-Diode Detector. The Schottky detectors will handle more power than the point contact detectors, and are equally as sensitive and quiet.
- The AM detector output blocking capacitor in the 70429A Option K21, N5500A Option 001, or N5507A prevents the DC voltage component of the demodulated signal from saturating the system's low noise amplifier (LNA). The value of this capacitor sets the lower frequency limit of the demodulated output.
- Carrier feedthrough in the detector may be excessive for frequencies below a few hundred megahertz. The LNA is protected from saturation by the internal filters used to absorb phase detector feedthrough and unwanted mixer products. Table 46 shows carrier frequencies with corresponding offset frequencies.

Table 46 Maximum carrier offset frequency

Carrier Frequency	Offset Frequency
≥250 κHz	100 MHz
≥50 MHz	20 MHz
≥5 MHz	2 MHz
≥500 kHz	200 kHz

Table 46 Maximum carrier offset frequency

Carrier Frequency	Offset Frequency
≥50 kHz	20 kHz

- The AC load on the detector is 50 Ω, set by the input impedance of the LNA in the test system. The 50 ohm load increases the detector bandwidth up to than 100 MHz.

Calibration and Measurement General Guidelines

NOTE Read This The following general guidelines should be considered when setting up and making an AM-noise measurement

- The AM detector must be well shielded from external noise especially 60 Hz noise. The components between the diode detector and the test system should be packaged in a metal box to prevent RFI interference.

NOTE The internal detectors in the N5500A Option 001 and N5507A, along with the 70429A Option K21 provide this level of protection.

Also, the AM detector should be connected directly to the test system if possible, to minimize ground loops. If the AM detector and test system must be separated, semi-rigid cable should be used to keep the shield resistance to a minimum.

- Although AM noise measurements are less vulnerable than residual phase-noise measurements to noise induced by vibration and temperature fluctuation, care should be taken to ensure that all connections are tight and that all cables are electrically sound.
- The output voltage monitor on the AM detector must be disconnected from digital voltmeters or other noisy monitoring equipment before noise measurement data is taken.
- The $\frac{1}{f}$ noise floor of the detector may degrade as power increases above +15 dBm. Noise in the $\frac{1}{f}$ region of the detector is best measured with about +10 dBm of drive level. The noise floor is best measured with about +20 dBm of drive level.
- An amplifier must be used in cases where the signal level out of the DUT is too small to drive the AM detector or is inadequate to produce a low enough measurement noise floor. In this case the amplifier should have the following characteristics.
- It should have the lowest possible noise figure, and the greatest possible dynamic range.
- The signal level must be kept as high as possible at all points in the test setup to avoid noise floor degradation.
- It should have only enough gain to get the required signal levels. Excess gain leads to amplifiers operating in gain compression, increasing their likelihood of suppressing the AM noise to be measured.
- The amplifier's sensitivity to power supply noise and the supply noise itself must both be minimized.

Method 1: User Entry of Phase Detector Constant

Method 1, example 1

Advantages

- Easy method of calibrating the measurement system
- Will measure DUT without modulation capability.
- Requires only an RF power meter to measure drive levels into the AM detector.
- Fastest method of calibration. If the same power levels are always at the AM detector, as in the case of leveled outputs, the AM detector sensitivity will always be essentially the same.
- Super-quick method of estimating the equivalent phase detector constant.

Disadvantages

- It is the least accurate of the calibration methods.
- It does not take into account the amount of power at harmonics of the signal.

Procedure

1 Using information shown in Figure 222 and Figure 223 on page 293, Connect the circuit and tighten all connections. If the N5500A Option 001 or N5507A is available, use one of the connection diagrams described in Figure 217 on page 287.

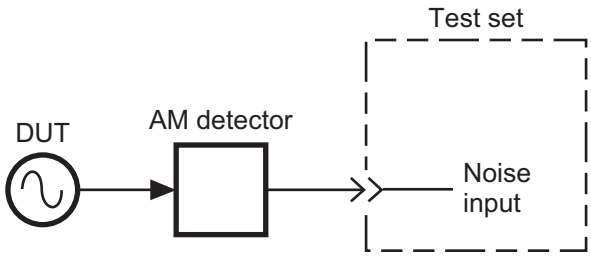


Figure 222 Phase detector constant AM noise setup (method1, example 1)

2 Measure the power which will be applied to the AM detector (see Figure 223 on page 293). It must be between 0 and +23 dBm.

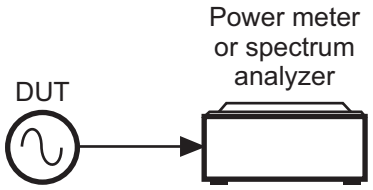


Figure 223AM noise calibration setup

3 Locate the drive level on the AM sensitivity graph (Figure 224), and enter the data.

4 Measure the noise data and interpret the results. The measured data will be plotted as single-sideband AM noise in dBc/Hz.

NOTE The quadrature meter should be at zero volts due to the blocking capacitor at the AM detector's output.

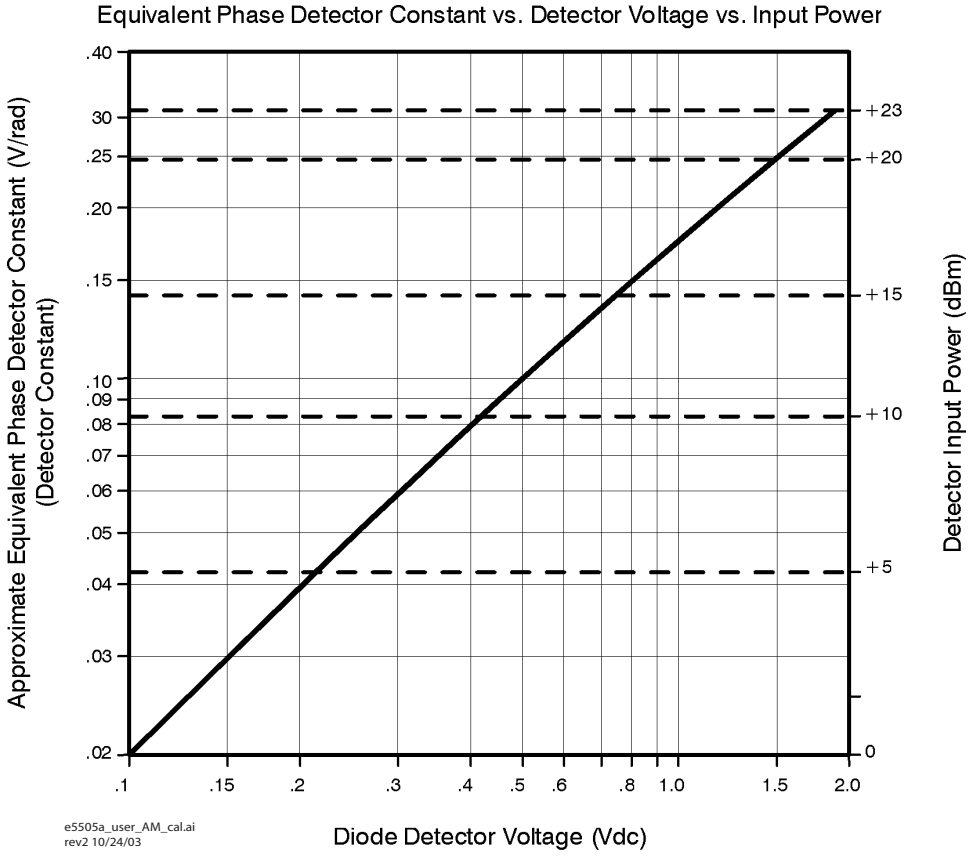


Figure 224AM detector sensitivity graph

Method 1, example 2

Advantages

- Easy method of calibrating the measurement system.
- Will measure DUT without modulation capability.
- Requires little additional equipment: only a voltmeter or an oscilloscope.
- Fastest method of calibration. If the same power levels are always at the AM detector, as in the case of leveled outputs, the AM detector sensitivity will always be essentially the same.
- Measures the AM detector gain in the actual measurement configuration. Super-quick method of estimating the equivalent phase detector constant.

Disadvantages

- Has only moderate accuracy compared to the other calibration methods.

Procedure

1 Using Figure 225 and Figure 226, connect circuit and tighten all connections. If the N5500A Option 001 or N5507A is available, use one of the connection diagrams described in “AM noise measurement block diagrams" on page 287.

2 Measure the power which will be applied to the AM detector. It must be between 0 and +23 dBm.

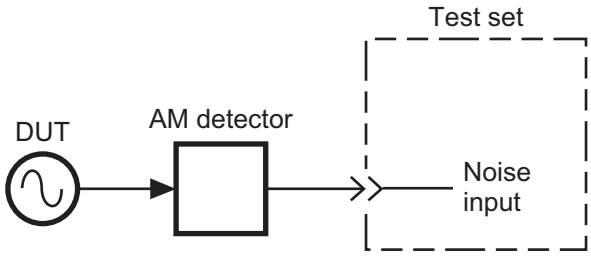


Figure 225 Phase detector constant AM noise setup (method 1, example 2)

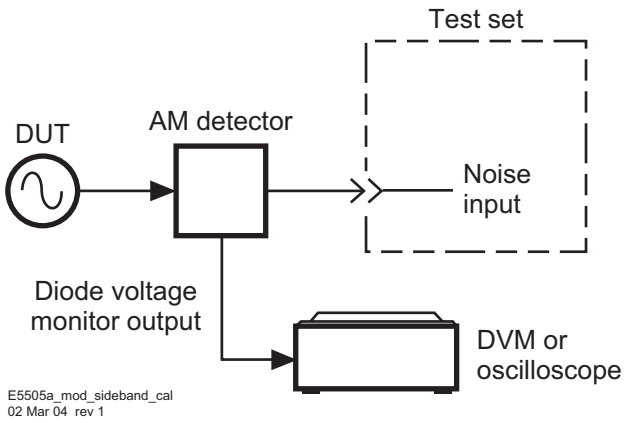


Figure 226 Modulation sideband calibration setup

3 Measure the monitor output voltage on the AM detector with an oscilloscope or voltmeter. Locate the diode detector's DC voltage along the bottom of the AM sensitivity graph (Figure 224). Moving up to the diagonal calibration line and over, the equivalent phase detector constant can then be read from the left side of the graph. The measured data will be plotted as single-sideband AM noise in dBc/Hz.

4 Measure noise data and interpret the results.

NOTE The quadrature meter should be at zero volts due to the blocking capacitor at the AM detector's output.

Method 2: Double-Sided Spur

Method 2, example 1

Advantages

- Requires only one RF source (DUT)
- Calibration is done under actual measurement conditions so all non-linearities and harmonics of the AM detector are calibrated out. The double-sided spur method and the single-sided-spur method are the two most accurate methods for this reason.

Disadvantages

- Required that the DUT have adjustable AM which may also be turned off.
- Requires the AM of the DUT to be extremely accurate; otherwise a modulation analyzer, for manual measurement of AM sidebands is required.

Procedure

1 Connect circuit as shown in Figure 227, and tighten all connections. If the N5500A Option 001 or N5507A is available, use one of the connection diagrams described in “AM noise measurement block diagrams" on page 287.

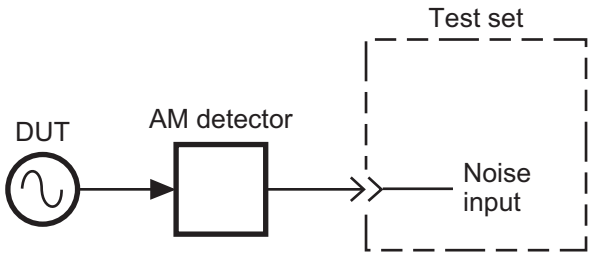


Figure 227 Double-Sided spur AM noise setup (method 2, example 1)

2 Measure the power which will be applied to the AM detector. It must be between 0 and +23 dBm.

3 Measure the carrier-to-sideband ratio of the AM at the AM detector’s input with an RF spectrum analyzer or modulation analyzer (Figure 228 on page 297). The source should be adjusted such that the sidebands are between –30 and –60 dB below the carrier with a modulation rate between 10 Hz and 20 MHz.

NOTE

The carrier-to-sideband ratio $\frac{C}{sb}$ for AM is:

$$\frac{C}{sb} = 20\log\left(\frac{percentAM}{100}\right) = 6dB$$

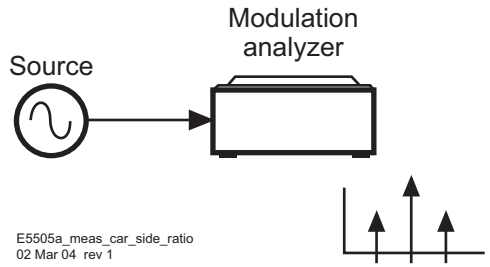


Figure 228 Measuring the carrier-to-sideband ratio

4 Reconnect the AM detector and enter the carrier-to-sideband ratio and modulation frequency.

5 Measure the AM detector calibration constant (Figure 229).

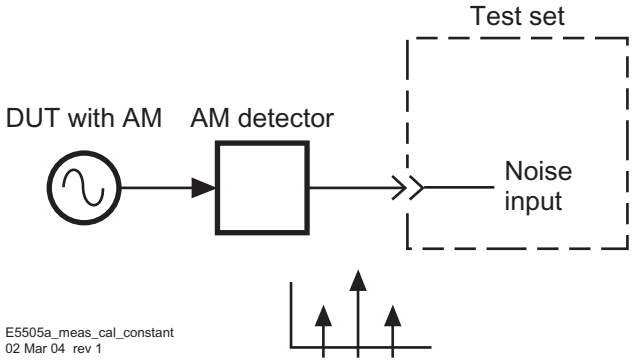


Figure 229 Measuring the calibration constant

6 Turn off AM.

7 Measure noise data and interpret the results.

NOTE

The quadrature meter should be at zero volts due to the blocking capacitor at the AM detector's output.

Method 2, example 2

Advantages

- Will measure source without modulation capability
- Calibration is done under actual measurement conditions so all non-linearities and harmonics of the AM detector are calibrated out. The double-sided spur method and the single-sided-spur method are the two most accurate methods for this reason.

Disadvantages

- Requires a second RF source with very accurate AM modulation and output power sufficient to match the DUT. If the AM modulation is not very accurate, a modulation analyzer must be used to make manual measurement of the AM sidebands.

Procedure

1 Connect circuit as shown in Figure 230, and tighten all connections. If the N5500A Option 001 or N5507A is available, use one of the connection diagrams described in "AM noise measurement block diagrams" on page 287.

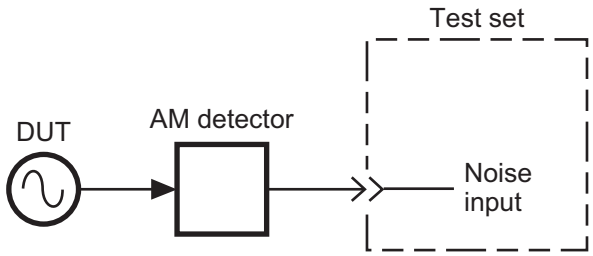


Figure 230 Double-sided spur AM noise setup (method 2, example 2)

2 Measure the power which will be applied to the AM detector (Figure 231). It must be between 0 and +23 dBm.

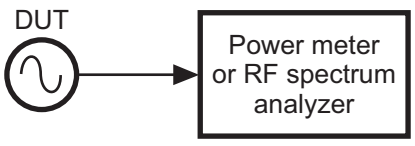


Figure 231 Measuring power at the am detector

3 Using a source with AM, set its output power equal to the power measured in step 2. The source should be adjusted such that the sidebands are

between –30 and –60 dB below the carrier with a modulation rate between 10 Hz and 20 MHz.

NOTE

The carrier-to-sideband ratio $\frac{C}{sb}$ for AM is:

$$\frac{C}{sb} = 20\log\left(\frac{percentAM}{100}\right) = 6dB$$

To check the AM performance of the source, measure the carrier-to-sideband ratio of the AM at the source output with a modulation analyzer. See Figure 232.

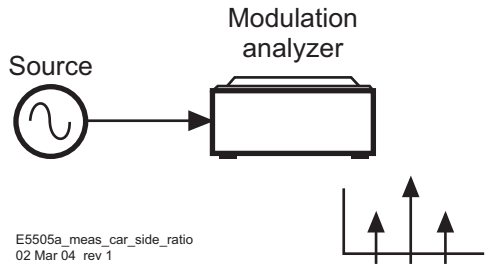


Figure 232 Measuring carrier-to-sideband ratio

4 Enter the carrier-to-sideband ratio and offset frequency, then measure the calibration constant. See Figure 233.

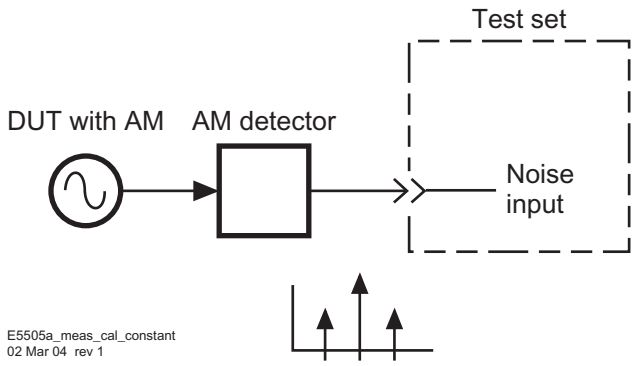


Figure 233 Measuring the calibration constant

5 Remove the AM source and reconnect the DUT.

6 Measure noise data and interpret the results.

NOTE The quadrature meter should be at zero volts due to the blocking capacitor at the AM detector's output.

Method 3: Single-Sided Spur

Advantages

- Will measure source without modulation capability.
- Calibration is done under actual measurement conditions so all non-linearities and harmonics of the AM detector are calibrated out. The double-sided spur method and the single-sided-spur method are the two most accurate methods for this reason.

Disadvantages

- Requires 2 RF sources, which must be between 10 Hz and 40 MHz apart in frequency.
- Requires an RF spectrum analyzer for manual measurement of the signal-to-spur ratio and spur offset.

Procedure

1 Connect circuit as shown in Figure 234, and tighten all connections. If the N5500A Option 001 or N5507A is available, use one of the connection diagrams described in “AM noise measurement block diagrams" on page 287.

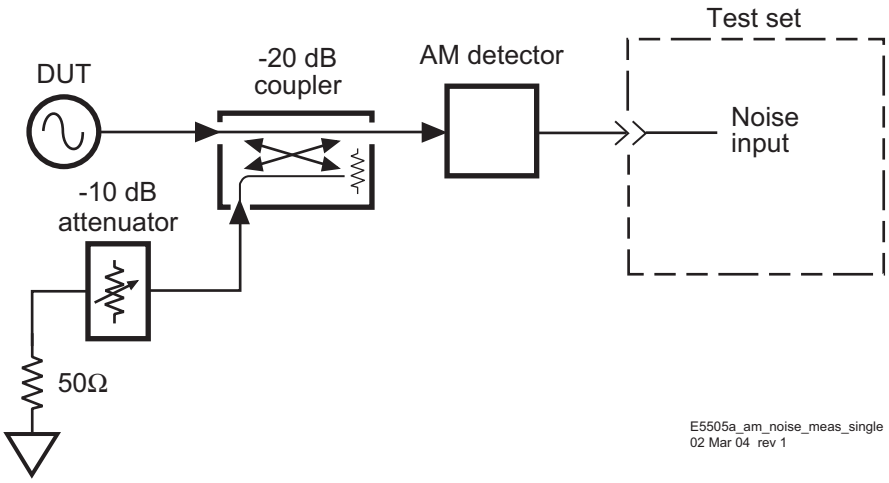


Figure 234AM noise measurement setup using single-sided spur

2 Measure the power which will be applied to the AM detector. It must be between 0 and +23 dBm.

3 Measure the carrier-to-single-sided-spur ratio and the spur offset at the input to the AM detector with an RF spectrum analyzer. See Figure 235 on

page 302. The spur should be adjusted such that it is between –30 and –60 dBc, with a carrier offset of 10 Hz to 20 MHz.

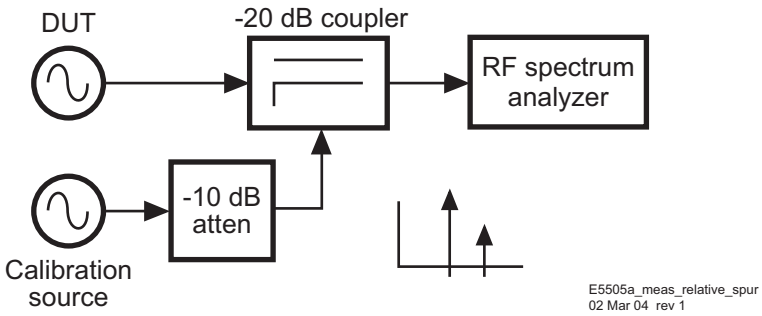


Figure 235 Measuring relative spur level

4 Reconnect the AM detector and measure the detector sensitivity. See Figure 236.

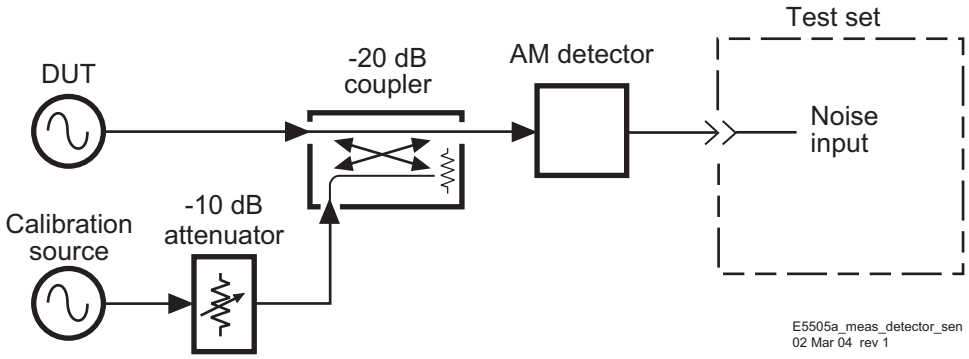


Figure 236 Measuring detector sensitivity

5 Turn off the spur source output.

6 Measure noise data and interpret the results.

NOTE The quadrature meter should be at zero volts due to the blocking capacitor at the AM detector's output.

12
AM Noise Measurement Examples

AM Noise with N5500A Option 001 304

AM Noise with N5500A Option 001

This example demonstrates the AM noise measurement of an 8662A signal generator using the AM detector in the N5500A Option 001 phase noise test set. For more information about various calibration techniques, refer to Chapter 11, “AM Noise Measurement Fundamentals.

This measurement uses the double sided spur calibration method.

The measurement of a source with amplitude modulation capability is among the simplest of the AM noise measurements. The modulation sidebands used to calibrate the AM detector are generated by the DUT. Required Equipment

CAUTION To prevent damage to the test set’s components, *do not* apply the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 47 on page 311. Apply the input signal when the connection diagram appears

Required equipment

This measurement requires an 8644B in addition to the phase noise test system and your DUT. You also need the coaxial cables and adapters necessary to connect the DUT and reference source to the test set.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Figure 237 shows the configuration used for an AM noise measurement.

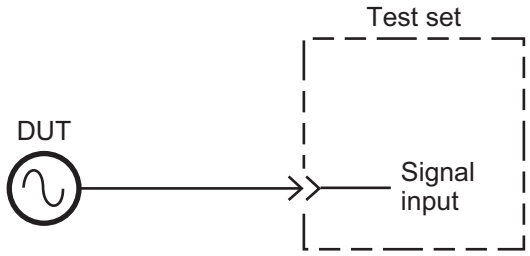


Figure 237AM noise measurement configuration

Defining the measurement

1 From the **File** menu, choose **Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, choose "**AM_noise_1ghz_8644b.pnm**." See Figure 238.

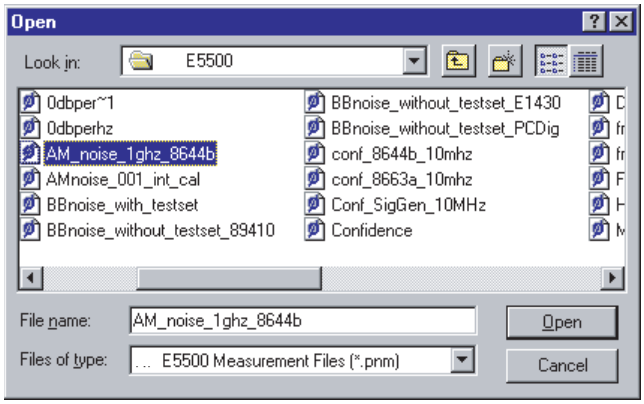


Figure 238 Select the parameters definition file

4 Click the **Open** button.

- The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 48 on page 313 lists the parameter data that has been entered for this measurement example.

NOTE

The amplitude of a source under system control, for an AM noise measurement, will automatically be set to +10 dBm. If any other amplitude is desired, the source should be placed under manual control. All other measurements set the source to +16 dBm automatically.

5 From the **Define** menu, choose **Measurement**; then choose the **Type and Range** tab from the **Define Measurement** window.

6 From the Measurement Type pull-down, select **AM Noise**. See Figure 239 on page 306

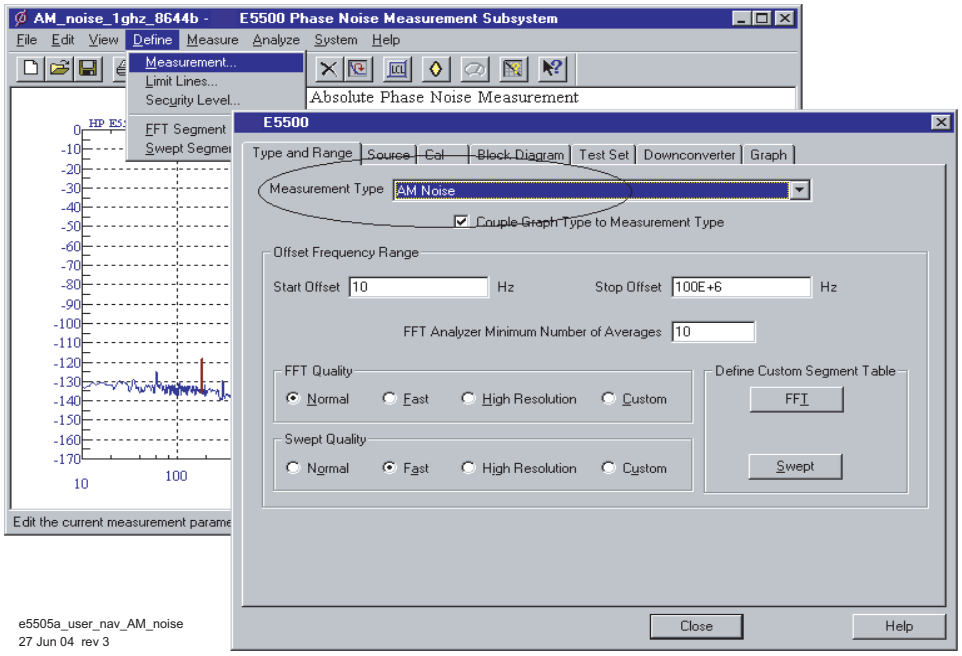


Figure 239 Navigate to AM noise

7 Choose the **Sources** tab from the **Define Measurement** window.

8 Enter the carrier (center) frequency of your DUT. Enter the same frequency for the detector input frequency. See Figure 240 on page 306.

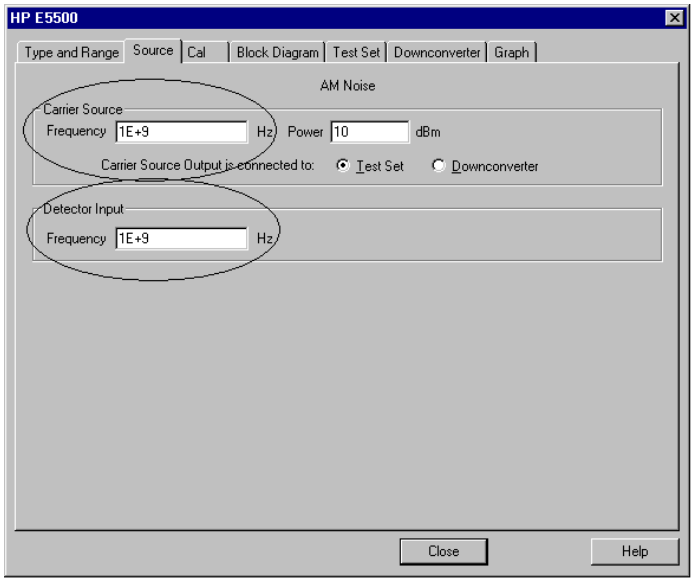


Figure 240 Enter Frequencies in Source Tab

9 Choose the **Cal** tab from the **Define Measurement** window.

10 Select **Use automatic internal self-calibration** as the calibration method. See Figure 241. For more information about various calibration techniques, refer to Chapter 11, “AM Noise Measurement Fundamentals.

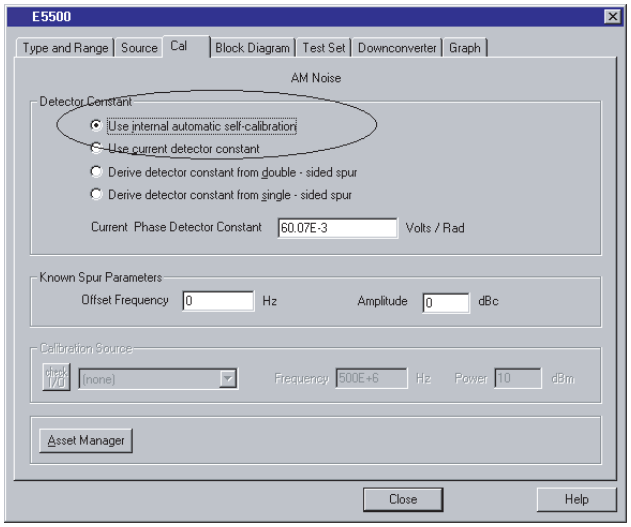


Figure 241 Enter parameters into the cal tab

11 Choose the **Block Diagram** tab from the **Define Measurement** window.

12 From the **Phase Detector** pull-down, select **AM Detector**. See Figure 242.

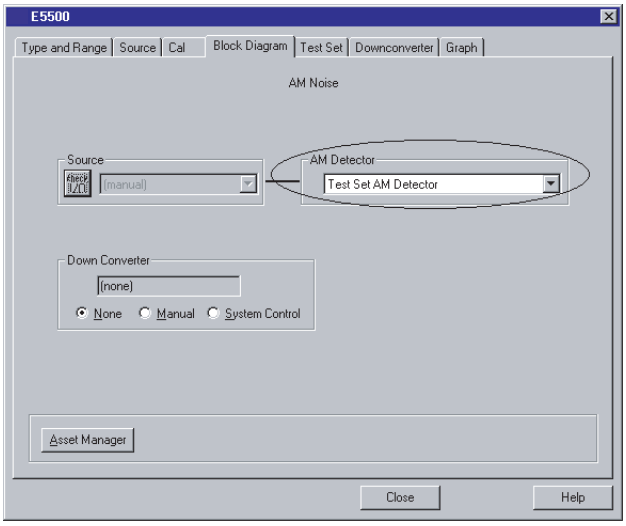


Figure 242 Select parameters in the block diagram tab

13 Choose the **Graph** tab from the **Define Measurement** window.

14 Enter a graph description of your choice. See Figure 243.

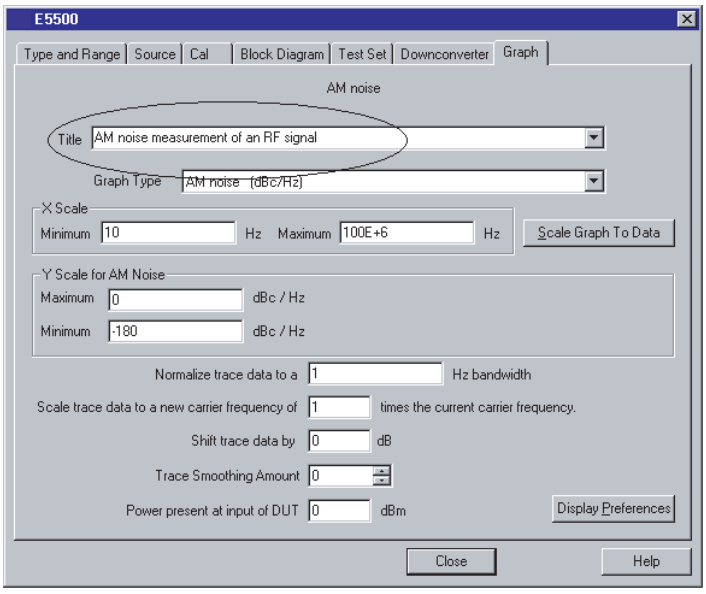


Figure 243 Select graph description on graph tab

15 When you have completed these operations, click the **Close** button.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement See** Figure 244.

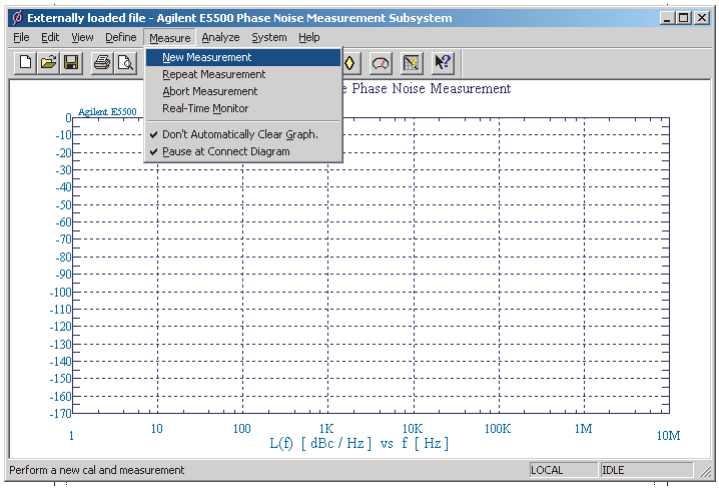


Figure 244 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

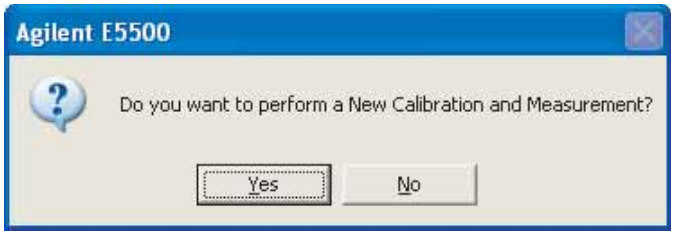


Figure 245 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select your hardware configuration from the list. See Figure 246 on page 309.

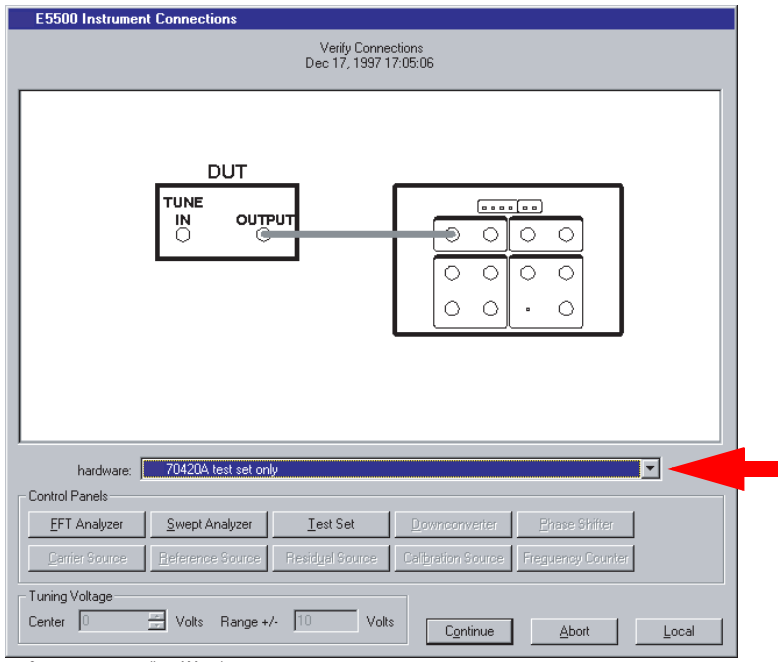


Figure 246 Connect diagram for the AM noise measurement

4 Connect your DUT and reference sources to the test set at this time. Confirm your connections as shown in the connect diagram.

- The input attenuator (Option 001 only) is now correctly configured based on your measurement definition.

CAUTION

The test set's signal input is subject to the limits and characteristics in Table 47 on page 311.

To prevent damage to the test set's hardware components, *do not* apply the input signal to the test set's signal input connector until the input attenuator (Option 001) has been set by the phase noise software, which will occur when the connection diagram appears.

Table 47 Test set signal input limits and characteristics

Limits	
Frequency	• 50 kHz to 1.6 GHz (Std.) • 50 kHz to 26.5 GHz (Option 001) • 50 kHz to 26.5 GHz (Option 201)
Maximum Signal Input Power	Sum of the reference and signal input power shall not exceed +23 dBm
At Attenuator Output, Operating Level Range: • RF Phase Detectors	• 0 to +23 dBm (Signal Input) • +15 to +23 dBm (Reference Input)
• Microwave Phase Detectors	• 0 to +5 dBm (Signal Input) • +7 to +10 dBm (Reference Input)
• Internal AM Detector	0 to +20 dBm
Downconverters:	
• Agilent N5502A/70422A	+5 to +15 dBm
• Agilent N5507A/70427A	0 to +30 dBm
Characteristics	
Input Impedance	50 Ω nominal
AM Noise	DC coupled to 50 Ω load

Figure 247 shows the system interconnections.

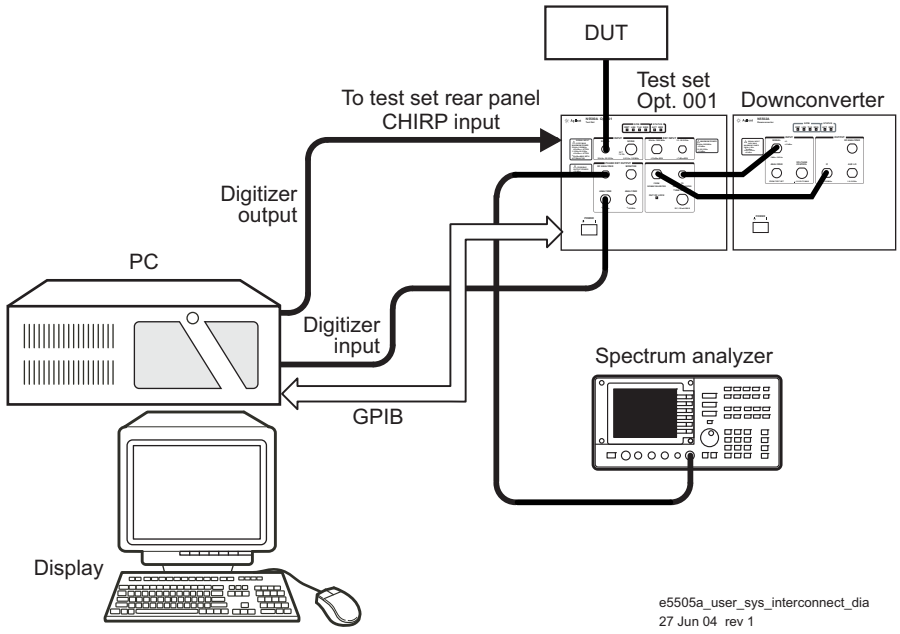


Figure 247 Connect diagram example

Making the measurement

5 Press the **Continue** button when you are ready to make the measurement.

- The system is now ready to make the measurement. The measurement results are updated on the computer screen after each frequency segment has been measured.

For more information about various calibration techniques, refer to Chapter 11, “AM Noise Measurement Fundamentals.

When the measurement is complete

When the measurement is complete, refer to Chapter 14, “Evaluating Your Measurement Results”for help with the results. Figure 248 shows a typical AM noise curve.

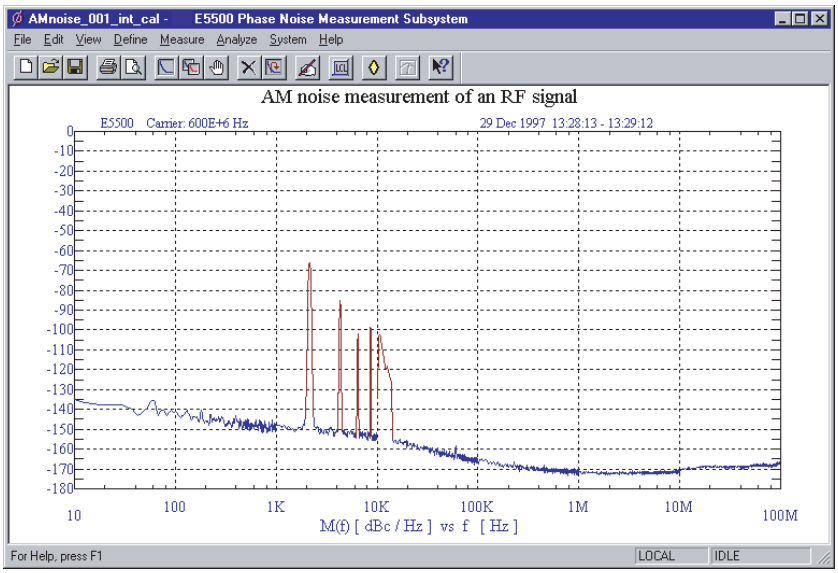


Figure 248 Typical AM noise curve

Table 48 Parameter data for the AM noise using an N5500A Option 001

Step	Parameters	Data
1	**Type and Range Tab**	
	• Measurement Type	• AM Noise
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 100 E + 6 Hz
	• Averages	• 4
	• FFT Quality	• Fast
	• Swept Quality	• Fast
2	**Sources Tab**	
	• Carrier Source Frequency	• 600 E + 6 Hz
	• Carrier Source Power	• 20 dBm
	• Carrier Source Output is connected to:	• Test Set
	• Detector Input Frequency	• 600 E +6 Hz
3	**Cal Tab**	
	• Detector Constant	• Use internal automatic self-calibration
	• Known Spur Parameters	• 1 Hz
	• Offset Frequency	• -130 dBc
	• Amplitude	
4	**Block Diagram Tab**	
	• Source	• Manual
	• AM Detector	• Test Set AM Detector
	• Down Converter	• None
5	**Test Set Tab**	
	• Input Attenuation	• Auto checked
	• LNA Low Pass Filter	• Auto checked
	• LNA Gain	• Auto Gain
	• Detector Maximum Input Levels	
	Microwave Phase Detector	• 0 dBm
	RF Phase Detector	• 0 dBm
	AM Detector	• 0 dBm
	• Ignore out-of-lock conditions	• Not checked
	• Pulsed Carrier	• Not checked
	• DC Block	• Not checked
	• Analyzer View	• Baseband
	• PLL Integrator Attenuation	• 0.00 dBm
6	**Downconverter Tab**	Does not apply to this measurement example.

Table 48 Parameter data for the AM noise using an N5500A Option 001 (continued)

Step	Parameters	Data
7	**Graph Tab**	•
	• Title	• AM Noise Measurement of an RF Signal
	• Graph Type	• AM Noise (dBc/Hz)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 100E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• - 180 dBc/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

13
Baseband Noise Measurement Examples

Baseband Noise with Test Set Measurement Example 316
Baseband Noise without Test Set Measurement Example 320

Baseband Noise with Test Set Measurement Example

This measurement example will help you measure the noise voltage of a source.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the measurement

1 From the **File** menu, select **Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, choose **"BBnoise_with_testset.pnm."** See Figure 249

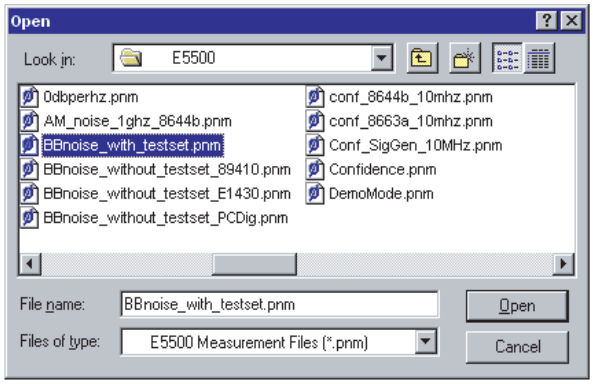


Figure 249 Select the parameters definition file

4 Click the **Open** button. The appropriate measurement definition parameters for this example have been pre-stored in this file. (Table 49 on page 319) lists the parameter data that has been entered for this measurement example.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement See** Figure 250.

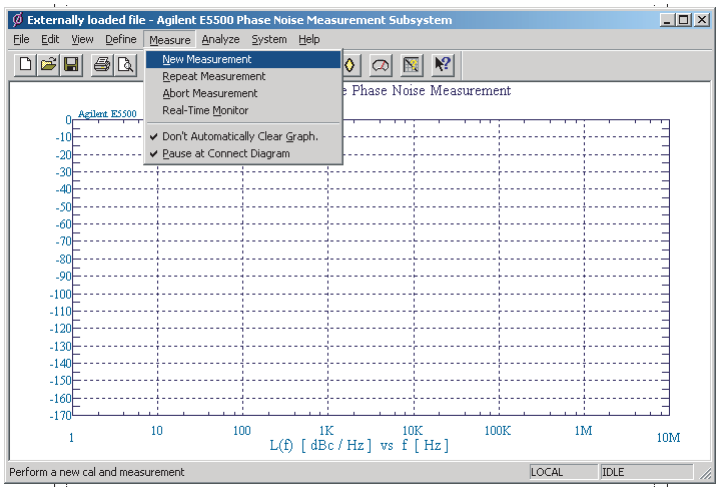


Figure 250 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

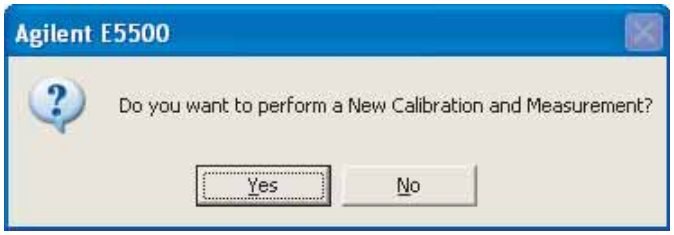


Figure 251 Confirm measurement dialog box

3 When the **Connect Diagram** dialog box appears, click on the hardware drop-down arrow and select “N5500A option 001 test set only” configuration from the list. See Figure 252 on page 318.

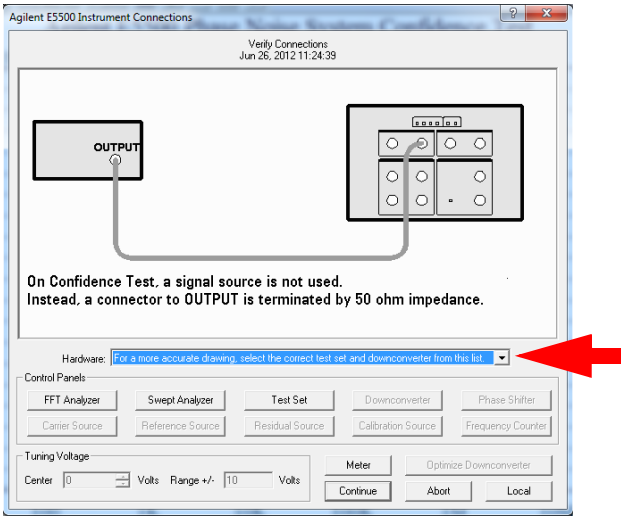


Figure 252 Connect diagram dialog box

Making the measurement

1 Press **Continue**.

- Figure 253 shows a typical phase noise curve for a baseband noise measurement using a test set.

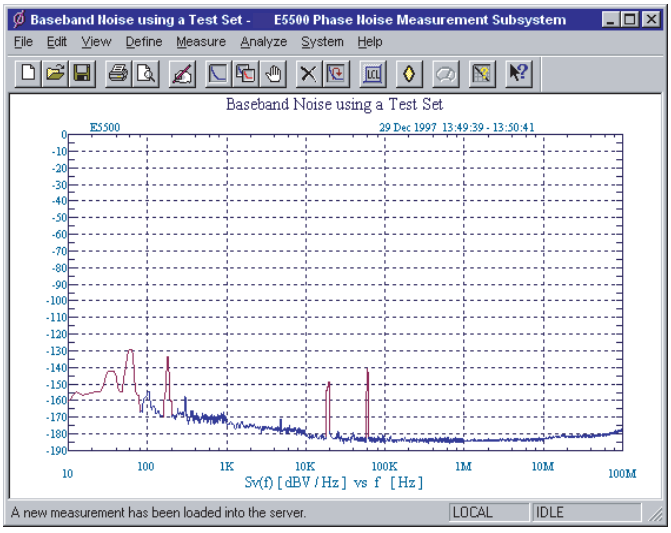


Figure 253 Typical phase noise curve for a baseband using a test set measurement.

Table 49 lists the parameter data used for this measurement example.

Table 49 Parameter data for the baseband using a test set measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	• Measurement Type	• Baseband Noise (using a test set)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 100 E + 6 Hz
	• Averages	• 4
	• Quality	• Fast
2	**Cal Tab**	
	• Gain preceding noise input	• 0 dB
3	**Block Diagram Tab**	
	• Noise Source	• Test Set Noise Input
4	**Test Set Tab**	
	• Input Attenuation	• 0 dB
	• LNA Low Pass Filter	• 20 MHz (Auto checked)
	• LNA Gain	• Auto Gain (Minimum Auto Gain –14 dB)
	• DC Block	• Not checked
	• PLL Integrator Attenuation	• 0 dBm
5	**Graph Tab**	
	• Title	• Baseband using the N5500A test set
	• Graph Type	• Baseband Noise (dBV)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 100 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –200 dBV/Hz
	• Normalize trace data to	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

Baseband Noise without Test Set Measurement Example

This measurement example will help you measure the noise voltage of a source.

NOTE To ensure accurate measurements allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the measurement

1 From the **File** menu, choose **Open**.

2 If necessary, choose the drive or directory where the file you want is stored.

3 In the **File Name** box, choose **“BBnoise_without_testset_89410.pnm.”**

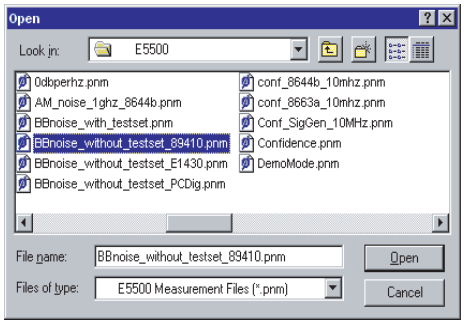


Figure 254 Select the parameters definition file

4 Click the **Open** button. The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 50 on page 323 lists the parameter data in this file.

Beginning the measurement

1 From the **Measurement** menu, choose **New Measurement See** Figure 255.

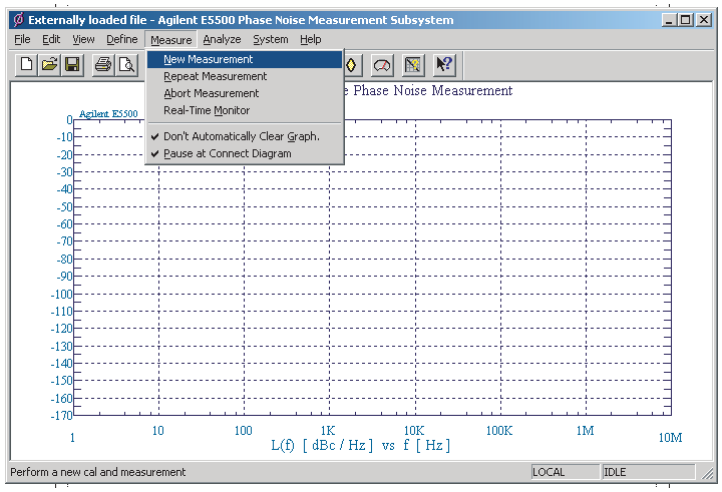


Figure 255 Selecting a new measurement

2 When the **Do you want to perform a New Calibration and Measurement?** prompt appears, click **Yes**.

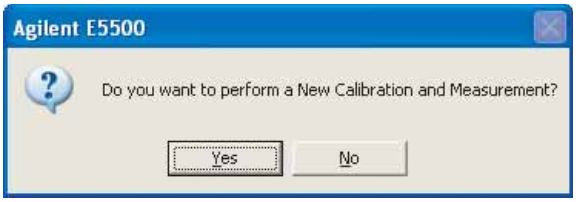


Figure 256 Confirm measurement dialog box

3 The **Instrument Connection** dialog box appears. (See Figure 258 on page 322.) At this time, connect your DUT and an FFT analyzer with the system as shown in Figure 257 on page 321.

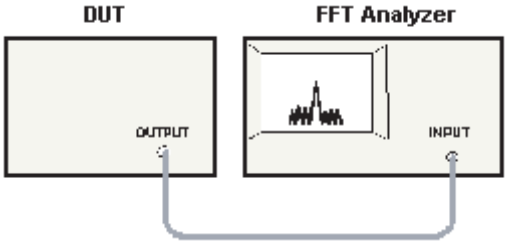


Figure 257 Connect diagram for baseband without test set measurement

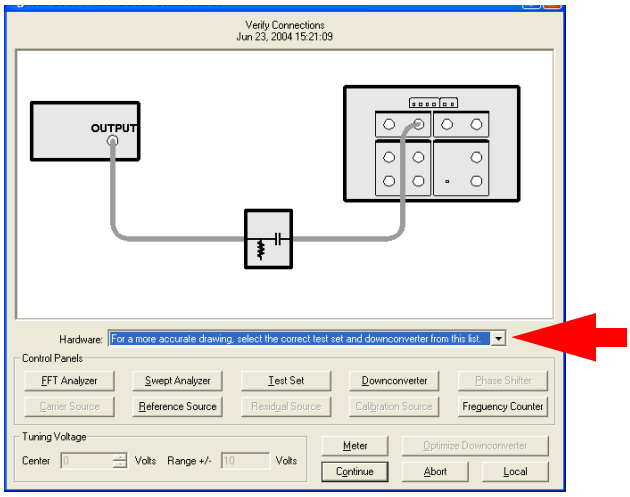


Figure 258 Instrument connection dialog box

Making the measurement

4 Press the **Continue** button. (There is no need to select a connection diagram from the drop-down list. The instrument connections for a baseband-noise-without-test-set measurement is not represented in the diagrams.)

- Figure 259 on page 322 shows a typical phase noise curve for a baseband noise measurement without using a test set.
- Table 50 on page 323 lists the parameter data for this measurement example.

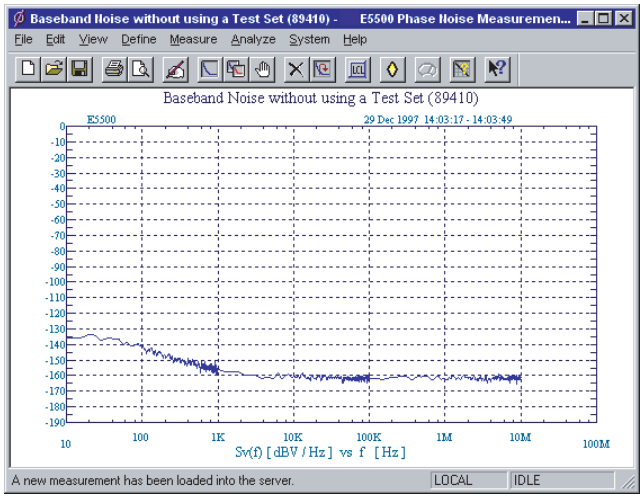


Figure 259 Typical curve for a baseband without test set measurement.

Table 50 Parameter data for the baseband without using a test set measurement

Step	Parameters	Data
1	**Type and Range Tab**	
	• Measurement Type	• Baseband Noise (without using a test set)
	• Start Frequency	• 10 Hz
	• Stop Frequency	• 100 E + 6 Hz
	• Averages	• 4
	• Quality	• Normal
2	**Cal Tab**	
	• Gain preceding noise input	• 0 dB
3	**Block Diagram Tab**	
	• Noise Source	• Test Set Noise Input
5	**Graph Tab**	
	• Title	• Baseband Noise without using a Test Set
	• Graph Type	• Baseband (dBV)
	• X Scale Minimum	• 10 Hz
	• X Scale Maximum	• 100 E + 6 Hz
	• Y Scale Minimum	• 0 dBc/Hz
	• Y Scale Maximum	• –200 dBV/Hz
	• Normalize trace data to a:	• 1 Hz bandwidth
	• Scale trace data to a new carrier frequency of:	• 1 times the current carrier frequency
	• Shift trace data DOWN by:	• 0 dB
	• Trace Smoothing Amount	• 0
	• Power present at input of DUT	• 0 dB

13 Baseband Noise Measurement Examples

14
Evaluating Your Measurement Results

Evaluating the Results 326
Gathering More Data 330
Outputting the Results 331
Graph of Results 332
Omit Spurs 334
Problem Solving 337

Evaluating the Results

This chapter contains information to help you evaluate and output the results of your noise measurements. The purpose of the evaluation is to verify that the noise graph accurately represents the noise characteristics of your DUT. To use the information in this chapter, you should have completed your noise measurement, and the computer should be displaying a graph of its measurement results. Storing the measurement results in the Result File is recommended for each measurement.

These steps provide an overview of the evaluation process.

- Look for obvious problems on the graph such as discontinuity (breaks).
- Compare the graph against known or expected data.
- If necessary, gather additional data about the noise characteristics of the DUT.

Looking for obvious problems

Some obvious problems on a graph are as follows:

- Discontinuities or breaks in the graph.
- A higher than expected noise level.
- Spurs that you cannot account for.
- Noise that exceeds the small angle criterion line on a L(f) graph).

Figure 260 provides a graphical example of these problems. If one or more of these problems appear on your graph, refer to the Problem Solving section for recommended actions.

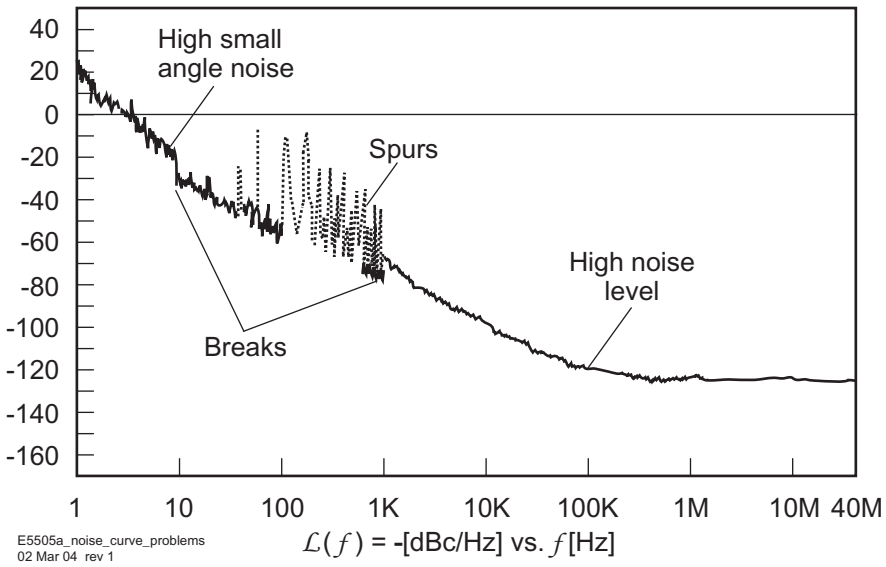


Figure 260 Noise plot showing obvious problems

Comparing against expected data

If none of the problems listed appears on your graph, there still may be problems or uncertainties that are not obvious at first glance. These uncertainties can be evaluated by comparing your measurement results against the following data:

- The noise characteristics expected for your DUT.
- The noise floor and accuracy specifications of the phase noise test system.
- The noise characteristics of the signal source used as the reference source.

The device under test

If you are testing a product for which published specifications exist, compare the measurement results against the noise and spur characteristics specified for the product. If the product is operating correctly, the noise graph provided by the phase noise system should be within the noise limits specified for the product.

If the device is a prototype or breadboard circuit, it may be possible to estimate its general noise characteristics using the characteristics of a similar type of circuit operating in a similar manner.

The reference source

It is important that you know the noise and spur characteristics of your reference source when you are making phase noise measurements. (The noise measurement results provided when using this technique reflect the sum of all contributing noise sources in the system.)

The best way to determine the noise characteristics of the reference source is to measure them. If three comparable sources are available, the Three Source Comparison technique can be used to determine the absolute noise level of each of the three sources. If you are using as your reference source, a source for which published specifications exist, compare your measurement results against the noise and spur characteristics specified for that source.

If you have obtained an actual (measured) noise curve for the reference source you are using, you can use it to determine if your measurement results have been increased by the noise of the reference source. To do this, determine the difference (in dB) between the level of the results graph and that of the reference source. Then use the graph shown in Figure 261 to determine if the measurement results need to be decreased to reflect the actual noise level of the DUT.

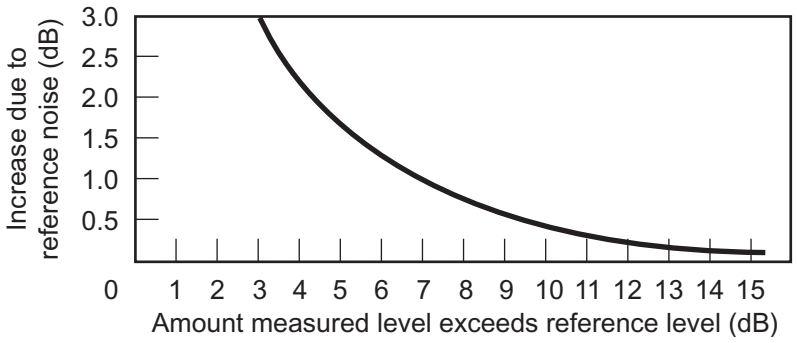


Figure 261 Compensation for added reference source noise

For example, applying to the graph the 7 dB difference in noise levels at 10 kHz, reveals that the measured results should be decreased by about 1 dB at 10 kHz to reflect the actual noise of the DUT. See Figure 262 on page 329.

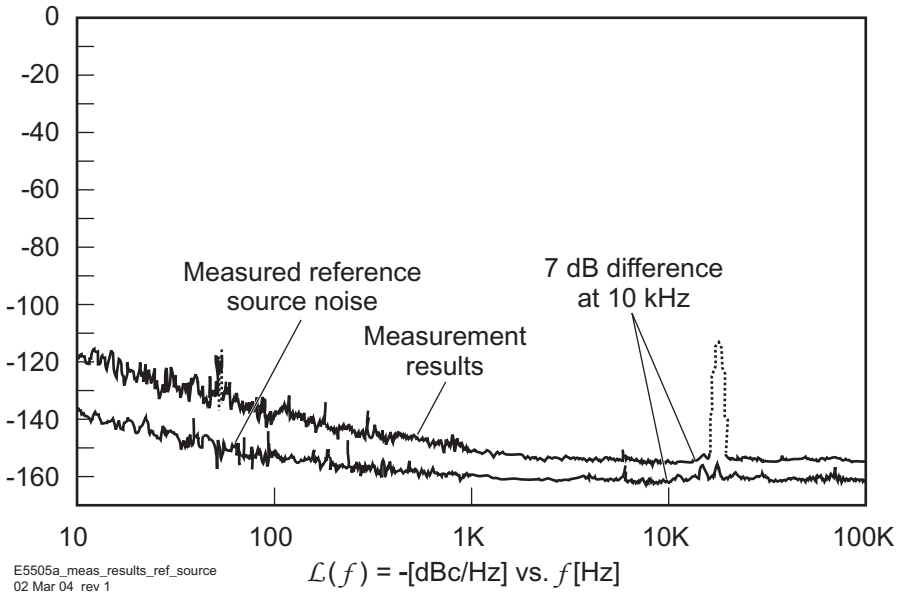


Figure 262 Measurement results and reference source noise

Gathering More Data

Repeating the measurement

Making phase noise measurements is often an iterative process. The information derived from the first measurement will sometimes indicate that changes to the measurement setup are necessary for measuring a particular device. When you make changes to the measurement setup (such as trying a different signal source, shortening cables, or any other action recommended in "Problem Solving" on page 337), repeating the measurement after each change allows you to check the effect that the change has had on the total noise graph.

To repeat a measurement, on the **Measurement** menu, click **Repeat Measurement**. See Figure 263.

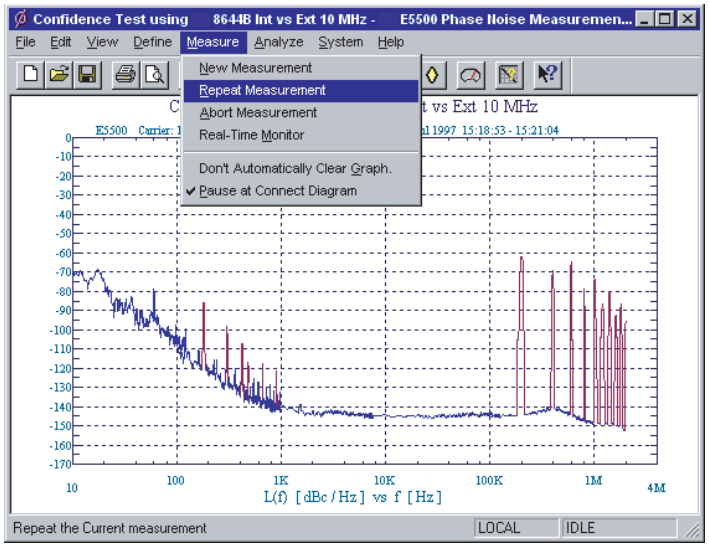


Figure 263 Repeating a measurement

Doing more research

If you are still uncertain about the validity of the measurement results, it may be necessary to do further research to find other validating data for your measurement. Additional information (such as typical noise curves for devices similar to the DUT or data sheets for components used in the device) can often provide insights into the expected performance of the DUT.

Outputting the Results

To generate a printed hardcopy of your test results, you must have a printer connected to the computer.

Using a printer

To print the phase noise graph along with the parameter summary data, select **File**/**Print** on the menu.

Graph of Results

Use the Graph of Results to display and evaluate your measurement results. The Graph of Results screen is automatically displayed as a measurement is being made. However, you can also access the Graph of Results functions from the main graph menu. You can load a result file using the File/System functions, and then display the results.

The following functions are available to help you evaluate your results:

- "Marker" on page 332
- "Omit Spurs" on page 334
- "Parameter summary" on page 335

Marker

The marker function allows you to display the exact frequency and amplitude of any point on the results graph. To access the marker function:

1 On the **View** menu, click **Markers.** See Figure 264.

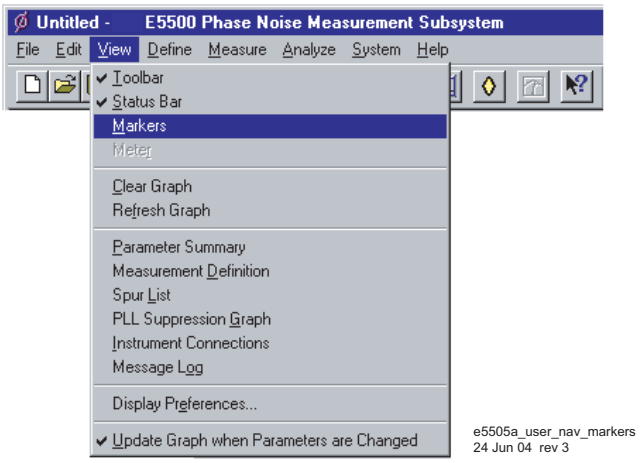


Figure 264 Navigate to marker

2 To remove the highlighted marker, click the **Delete** button. You may add as many as nine markers. See Figure 265 on page 333.

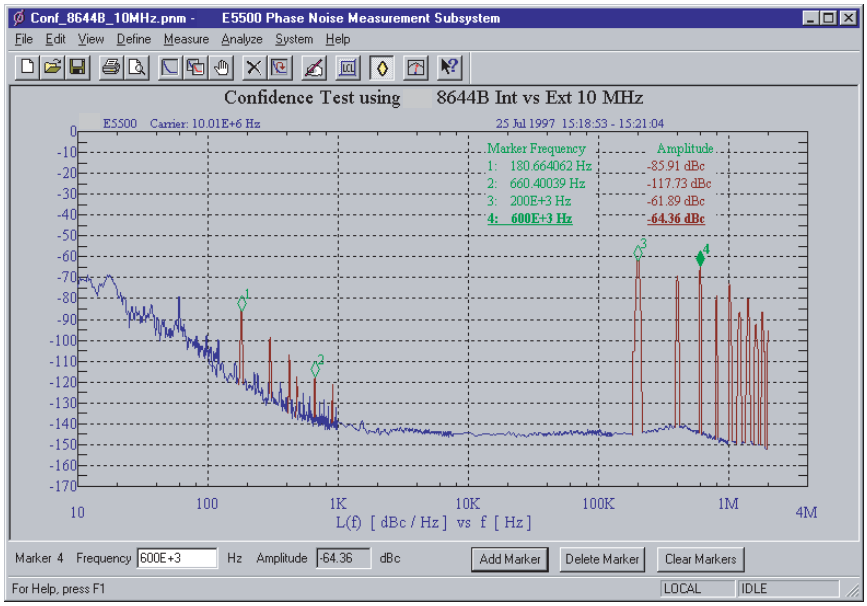


Figure 265 Add and delete markers

Omit Spurs

Omit Spurs plots the currently loaded results without displaying any spurs that may be present.

1 On the **View** menu, click **Display Preferences.** See Figure 266.

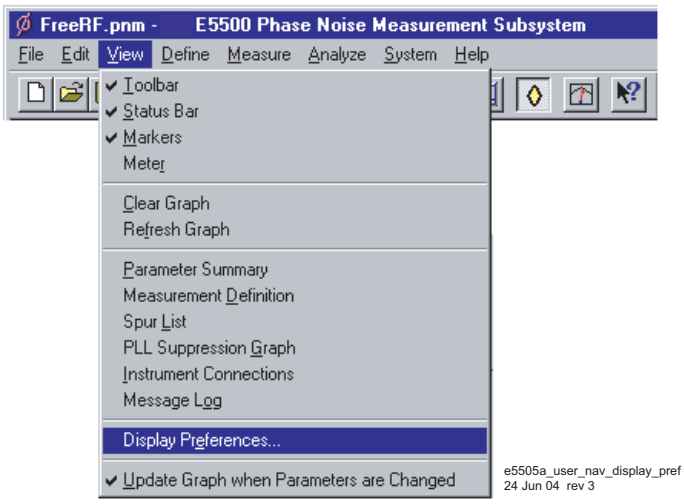


Figure 266 Select display preferences

2 In the **Display Preferences** dialog box, uncheck **Spurs**. See Figure 267. Click OK.

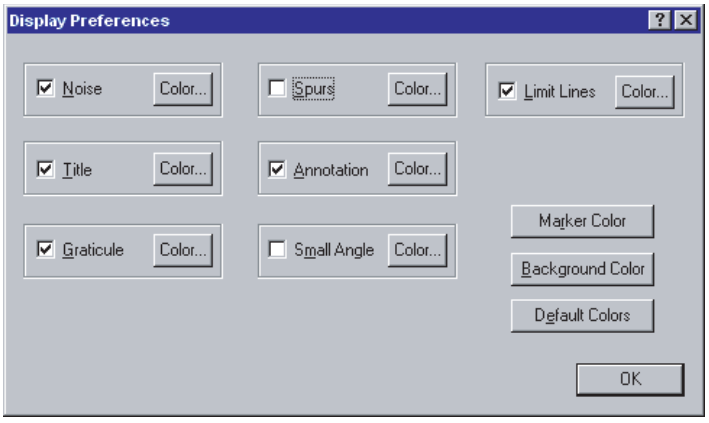


Figure 267 Uncheck spurs

3 The Graph will be displayed without spurs (Figure 268 on page 335). To re-display the spurs, check **Spurs** in the **Display Preferences** dialog box.

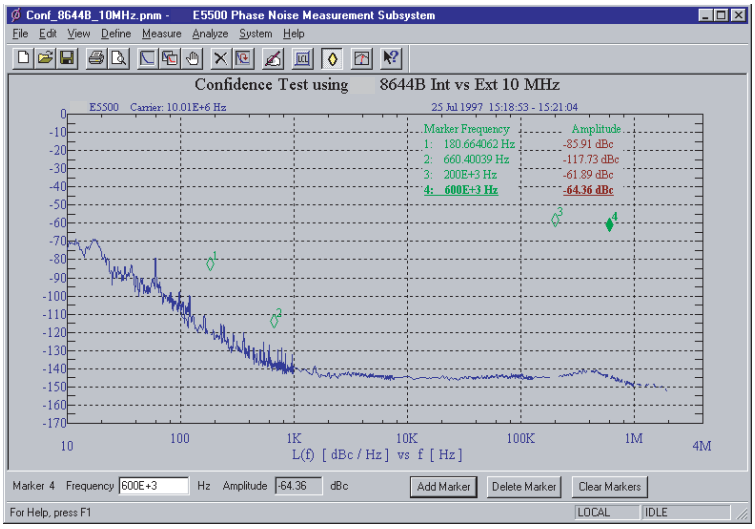


Figure 268 Graph without spurs

Parameter summary

The Parameter Summary function allows you to quickly review the measurement parameter entries that were used for this measurement. The parameter summary data is included when you print the graph.

1 On the **View** menu, click **Parameter Summary** (Figure 269).

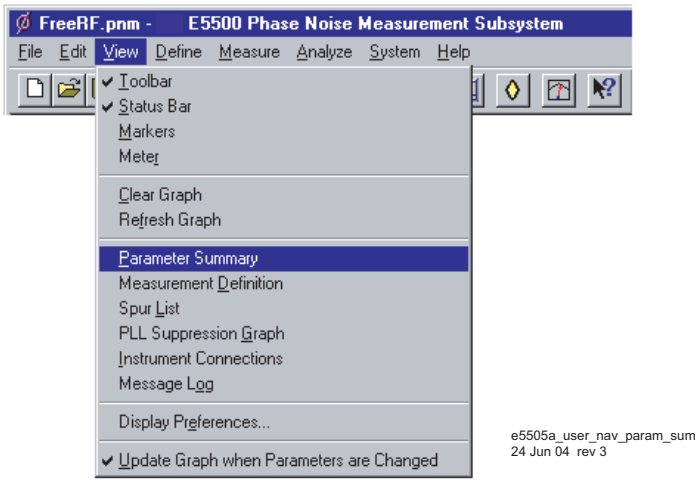


Figure 269 Navigate to parameter summary

2 The Parameter Summary Notepad dialog box appears (Figure 270). The data can be printed or changed using standard Notepad functionality.

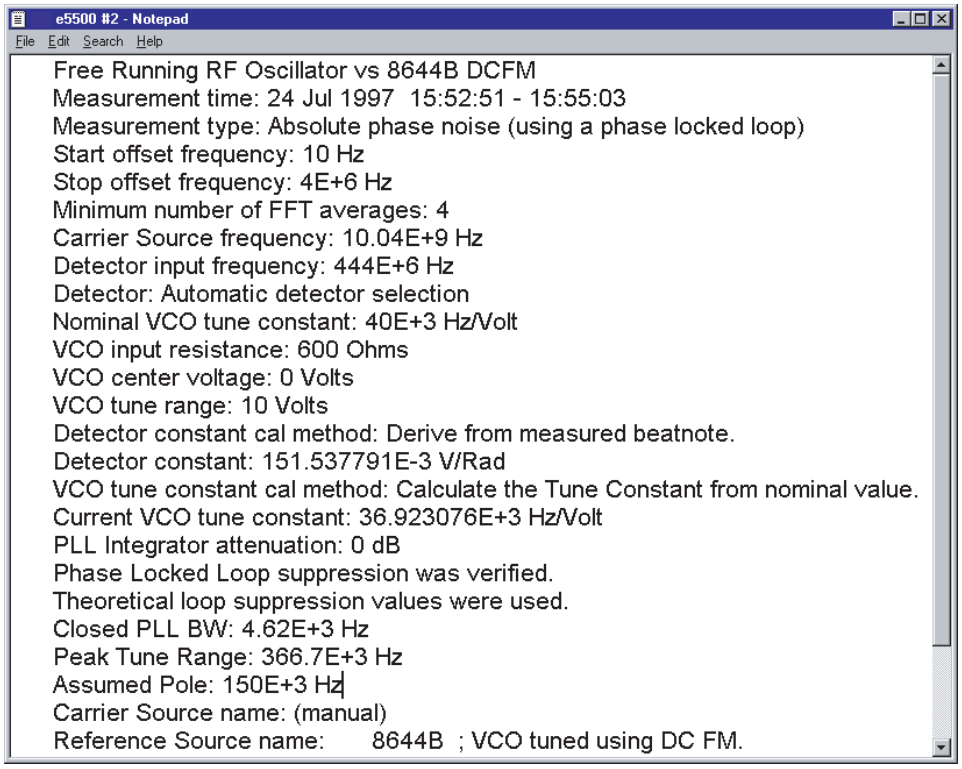


Figure 270 Parameter summary notepad

Problem Solving

Table 51 List of topics that discuss problem solving in this chapter

If you need to know:	Refer to:
What to do about breaks in the noise graph	Discontinuity in the Graph
How to verify a noise level that is higher than expected	High Noise Level
How to verify unexpected spurs on the graph	Spurs on the Graph
How to interpret noise above the small angle line	Small Angle Line

Discontinuity in the graph

Because noise distribution is continuous, a break in the graph is evidence of a measurement problem. Discontinuity in the graph will normally appear at the sweep-segment connections.

Table 52 identifies the circumstances that can cause discontinuity in the graph.

Table 52 Potential causes of discontinuity in the graph

Circumstance	Description	Recommended Action
Break between segments where closely spaced spurs are resolved in one segment but not in the next.	Closely spaced spurs that are resolved in one sweep-segment but not in the next can cause an apparent jump in the noise where they are not resolved.	Use the Real-time Monitor to evaluate the noise spectrum at the break frequency on the graph. To eliminate the break in the graph, you may find it necessary to change the Sweep-Segment Ranges so that the measurement resolution remains constant over the frequency range where the spurs are located.
Erratic Noise: One or more segments out of line with the rest of the graph.	This occurs when the noise level of the source being used is inconsistent over time. The time-varying noise level causes the overall noise present when one segment is being measured to differ from the level present during the period when the next segment is measured.	Repeat the noise measurement several times for the segment that does not match the rest of the graph, and check for a change in its overall noise level.

Table 52 Potential causes of discontinuity in the graph (continued) (continued)

Circumstance	Description	Recommended Action
Break at the upper edge of the segment below PLL Bandwidth ³ 4.	Accuracy degradation of more than 1 or 2 dB can result in a break in the graph at the internal changeover frequency between the phase detector portion of the measurement and the voltage controlled oscillator tune line measurement. The accuracy degradation can be caused by: An inaccurate Tuning or Phase Detector Constant Injection locking, or Noise near or above the small angle line at an offset equal to the PLL Bandwidth for the measurement.	Check the Parameter Summary list provided for your results graph to see if any accuracy degradation was noted. If the Tuning constant and Phase Detector constant were not measured by the phase detector system, verify their accuracy by selecting the Measured calibration method and then initiating a New Measurement. If you suspect injection locking or noise above the small angle line, refer to the Problem Solving section of Chapter 3 for specific actions.
Small Break at 100 kHz, 10 kHz, or 1 kHz		

Higher noise level

The noise level measured by the test system reflects the sum of all of the noise sources affecting the system. This includes noise sources within the system as well as external noise sources. If the general noise level measured for your device is much higher than you expected, begin evaluating each of the potential noise sources. The following table will help you identify and evaluate many of the potential causes of a high noise floor.

Spurs on the graph

Except for marked spurs, all data on the graph is normalized to a 1 Hz bandwidth. This bandwidth correction factor makes the measurement appear more sensitive than it really is. Marked spurs are plotted without bandwidth correction however, to present their true level as measured.

Refer to Table 53. The spur marking criterion is a detected upward change of more than X dB (where X is the value shown below) within 4 data points (a single data point noise peak will not be marked as a spur). Note that the effective noise floor for detecting spurs is above the plotted 1 Hz bandwidth noise by the bandwidth correction factor.

Table 53 Spurs on the graph

Offset Frequency	Number of Averages	Upward Change for Marking Spurs (dB)
< 100 kHz	<4	30
	≥4	17
	≥8	12
	≥30	6
>100 kHz	Any	4

To list the marked spurs

A list of spurs can be displayed by accessing the **Spurs List** function in the **View** menu.

Forest of spurs

A so called forest of spurs is a group of closely spaced spurs on the phase noise plot. A forest of spurs is often caused by improper shielding that allows stray RF energy to be picked up by the DUT wiring, etc. A breadboarded or prototype circuit should be well shielded from external RF fields when phase noise measurements are being made.

Table 54 shows actions to take to eliminate spurs.

Table 54 Actions to eliminate spurs

Spur Sources	Description	Recommended Action
Internal	Potential spur sources within the measurement system include the phase noise system, the DUT, and the reference source. Typical system spurs are –120 dBc, and they occur at the power line and system vibration frequencies in the range of from 25 Hz to 1 kHz, and above 10 MHz.	If you do not have a plot of the system's noise and spur characteristics, perform the system Noise Floor Test. If you suspect that the DUT or the reference source may be the spur source, check each source using a spectrum analyzer or measuring receiver (such as an Agilent 8902A). Also, if additional sources are available, try exchanging each of the sources and repeating the measurement.
External	Spur sources external to the system may be either mechanical or electrical. When using the Phase Lock Loop measurement technique, the system's susceptibility to external spur sources increases with increases in the Peak Tuning Range set by the VCO source.	Shorten coaxial cables as much as possible (particularly the Tune Voltage Output cable). Make sure all cable connections are tight. It may be possible to identify an external spur source using a spectrum analyzer with a pick-up coil or an antenna connected to it.

Table 54 Actions to eliminate spurs (continued)

Spur Sources	Description	Recommended Action
Electrical	Electrically generated spurs can be caused by electrical oscillation, either internal or external to the measurement system. The list of potential spur sources is long and varied. Many times the spur will not be at the fundamental frequency of the source, but may be a harmonic of the source signal. Some typical causes of electrical spurs are power lines, radio broadcasting stations, computers and computer peripherals (any device that generates high frequency square waves), and sum and difference products of oscillators that are not isolated from one another in an instrument such as a signal generator.	The frequency of the spur and patterns of multiple spurs are the most useful parameters for determining the source of spurs. The spur frequency can be estimated from the graph, or pinpointed using either the Marker graphic function which provides a resolution of from 0.1% to 0.2% or by using the spur listing function.
Mechanical	Mechanically generated spurs are usually at frequencies below 1 kHz. The source of a mechanically generated spur is typically external to the measurement system.	Try turning off or moving fans, motors, or other mechanical devices that oscillate at a specific frequency. (Temporarily blocking the airflow through a fan may alter its speed enough to discern a frequency shift in a spur that is being caused by the fan.)

Small angle line

Caution must be exercised where $L(f)$ is calculated from the spectral density of the phase modulation $S_\phi(f)/2$ because of the small angle criterion. Refer to Figure 271. Below the line, the plot of $L(f)$ is correct; above the line, $L(f)$ is increasingly invalid and Sf(f) must be used to accurately represent the phase noise of the signal. To accurately plot noise that exceeds the small angle line, select the Spectral Density of Phase Modulation (dB/Hz) graph type ($S_\phi(f)$). $L(f)$ raises the noise floor by 3 dB.

The –10 dB per decade line is drawn on the plot for an instantaneous phase deviation of 0.2 radians integrated over any one decade of offset frequency. At approximately 0.2 radians, the power in the higher order sideband of the phase modulation is still insignificant compared to the power in the first order sideband. This ensures that the calculation of cal L(f) is still valid.

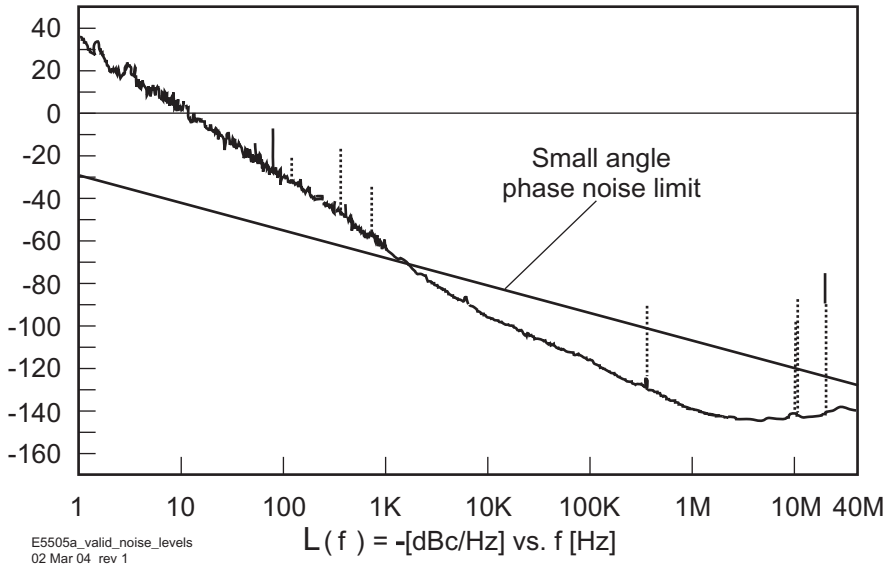


Figure 271 $L(f)$ Is only valid for noise levels below the small angle line

15
Advanced Software Features

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Introduction

The E5500 Phase Noise Measurement System software feature **Advanced Functions** allows you to manipulate the test system or to customize a measurement using the extended capabilities of the E5500 software. This chapter describes each of these advanced functions. Agilent recommends that only users who understand how the measurement and the test system are affected by each function use the **Advanced Functions** feature.

Phase-Lock-Loop Suppression

Selecting “PLL Suppression Graph” on the View menu causes the software to display the PLL Suppression Curve plot, as shown in Figure 272, when it is verified during measurement calibration. The plot appears whether or not an accuracy degradation occurs.

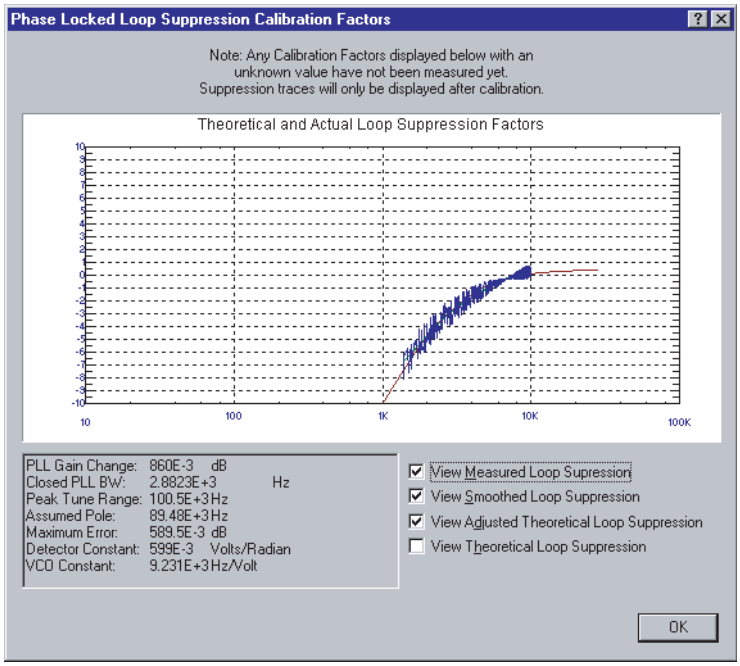

Figure 272PLL suppression verification graph

PLL suppression parameters

The following measurement parameters are displayed along with the PLL Suppression Curve.

PLL gain change

This is the amount of gain change required to fit the Theoretical Loop Suppression curve to the measured loop suppression. A PLL Gain Change of greater than 1 dB creates an accuracy degradation (ACCY. DEGRADED) error. If an accuracy degradation is detected, the amount of error is determined from either the PLL Gain Change or the Maximum Error, which ever is larger. The degradation itself is 1 dB less than the greater of these.

Max error

This is the measured error that still exists between the measured Loop Suppression and the Adjusted Theoretical Loop Suppression. The four points on the Loop Suppression graph marked with arrows (ranging from the peak down to approximately ––8 dB) are the points over which the Maximum Error is determined. An error of greater than 1 dB results in an accuracy degradation.

Closed PLL bandwidth

This is the predicted Phase Lock Loop Bandwidth for the measurement. The predicted PLL BW is based on the predicted PTR. The Closed PLL BW will not be adjusted as a result of an accuracy degradation. If an accuracy degradation is detected, the amount of error is determined from either the PLL Gain Change or the Maximum Error, which ever is larger. The degradation itself is 1 dB less than the greater of these.

Peak tune range

This is the Peak Tuning Range (PTR) for the measurement determined from the VCO Tune Constant and the Tune Range of VCO. This is the key parameter in determining the PLL properties, the Drift Tracking Range, and the ability to phase lock sources with high close in noise.

The PTR displayed should be approximately equal to the product of the VCO Tune Constant times the Tune Range of VCO. This is not the case when a significant accuracy degradation is detected (4 dB) by the Loop Suppression Verification. In this case, the PTR and Assumed Pole are adjusted when fitting the Theoretical Loop Suppression to the smoothed measured Loop Suppression, and the test system will display the adjusted PTR. If the PTR must be adjusted by more than 1 dB, as indicated by an accuracy degradation of greater than 0 dB, the Phase Detector Constant or the VCO Tune Constant is in error at frequency offsets near the PLL BW, or the PLL BW is being affected by some other problem such as injection locking.

Assumed pole

This is the frequency of the Assumed Pole required to adjust the Theoretical Loop suppression to match the smoothed measured Loop suppression. The Assumed Pole frequency is normally much greater than the Closed PLL BW. An Assumed Pole frequency of less than 10 X PLL BW is an indication of peaking on the PLL Suppression curve. For PLL BWs less than 20 kHz, an Assumed Pole of less than 10 X PLL BW indicates a delay or phase shift in the VCO Tune Port. For PLL BWs greater than 20 kHz, the Assumed Pole may be adjusted to less than 10 X PLL BW to account for phase shifts in the test set.

Detector constant

This is the phase Detector Constant (sensitivity of the phase detector) used for the measurement. The accuracy of the Phase Detector Constant is verified if the PLL suppression is verified. The accuracy of the phase Detector Constant determines the accuracy of the noise measurement.

The phase Detector Constant value, along with the LNA In/Out parameter, determines the Agilent E5505A system noise floor, exclusive of the reference source. “VCO CONSTANT” is the VCO Tune Constant used for the measurement. The accuracy of the VCO Tune Constant determines the accuracy of the PLL noise measurement for offset frequencies in segments where the entire plotted frequency range is less than the PLL BW / 4. The accuracy of the VCO Tune Constant is verified if the PLL Suppression is verified. The VCO Tune Constant times the Tune Range of VCO determines the Peak Tune Range (PTR) value for the measurement. The PTR sets the drift tracking and close-in noise suppression capabilities of the test system.

Ignore-Out-Of-Lock Mode

The Ignore Out Of Lock test mode enables all of the troubleshooting mode functions, plus it causes the software to not check for an out-of-lock condition before or during a measurement. This allows you to measure sources with high close-in noise that normally would cause an out-of-lock condition and stop the measurement. When Ignore Out Of Lock is selected, the user is responsible for monitoring phase lock. This can be accomplished using an oscilloscope connected to the test set Aux. Monitor port to verify the absence of a beatnote and monitor the dc output level.

- When Ignore Out Of Lock is selected, the test system does not verify the phase lock of the measurement. The user must ensure that the measurement maintains phase lock during the measurement.

PLL Suppression Verification Process

When “Verify calculated phase locked loop suppression” is selected, it is recommended that “Always Show Suppression Graph” also be selected. Verifying phase locked loop suppression is a function which is very useful in detecting errors in the phase detector constant or tune constant, the tune constant linearity, limited VCO tune port bandwidth conditions, and injection locking conditions. If the DUT is well behaved (injection locking issues do not exist or have been eliminated) and the reference source is well behaved (well known tuning characteristics or a system controlled RF signal generator) then the need to select PLL suppression verification is minimal.

To verify PLL suppression, a stimulus source is required for the FFT analyzer. This stimulus signal is connected to the CHIRP INPUT port on the rear panel of the test set. The PC digitizer, when used as the FFT analyzer, provides a companion D/A output for this purpose. When an Agilent 89410A vector signal analyzer is the system FFT analyzer, the 89410A’s companion source output is used.

PLL suppression information

The PLL Suppression View graph has been updated to allow measured, calculated (adjusted), and theoretical information to be examined more closely. When the “Always Show Suppression Graph” is selected, the following graph (Figure 273) is provided.

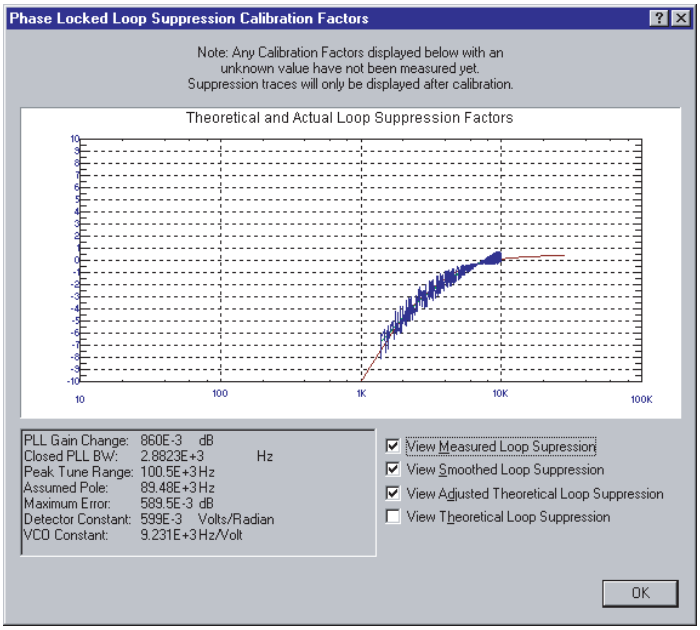

Figure 273 Default PLL suppression verification graph

There are four different curves available for this graph:

a "Measured" loop suppression curve (Figure 274 on page 350)—this is the result of the loop suppression measurement performed by the E5505A system.

b "Smoothed" measured suppression curve (Figure 275 on page 351)—this is a curve-fit representation of the measured results, it is used to compare with the "theoretical" loop suppression.

c "Theoretical" suppression curve (Figure 276 on page 351)—this is the predicted loop suppression based on the initial loop parameters defined/selected for this particular measurement (kphi, kvco, loop bandwidth, filters, gain, etc.).

d "Adjusted" theoretical suppression curve (Figure 277 on page 352 through Figure 279 on page 353) —this is the new "adjusted" theoretical value of suppression for this measurement. It is based on changing loop parameters (in the theoretical response) to match the "smoothed" measured curve as closely as possible.

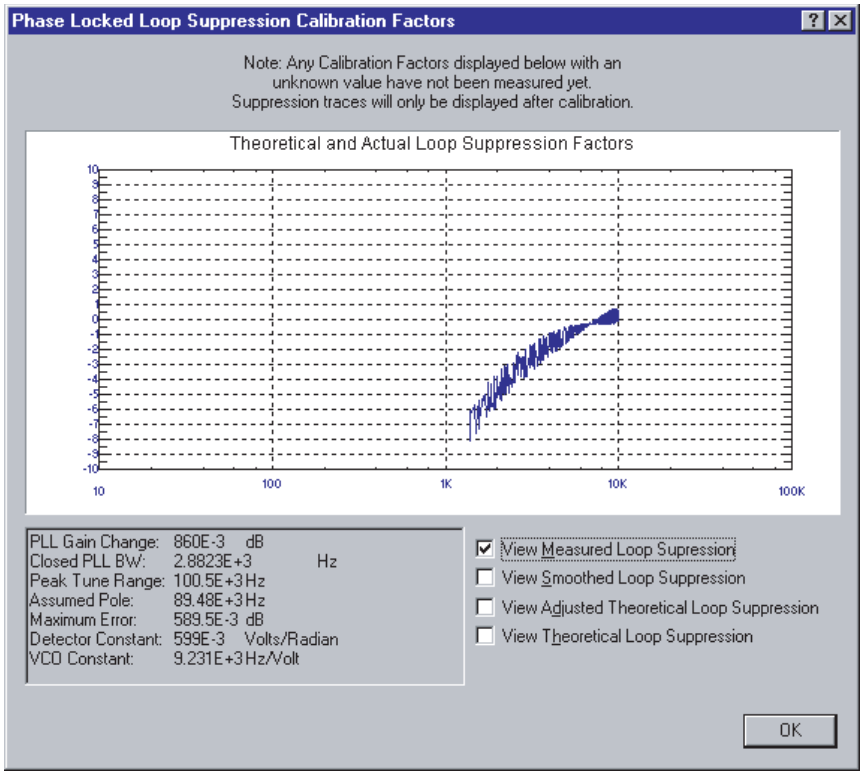

Figure 274 Measured loop suppression curve

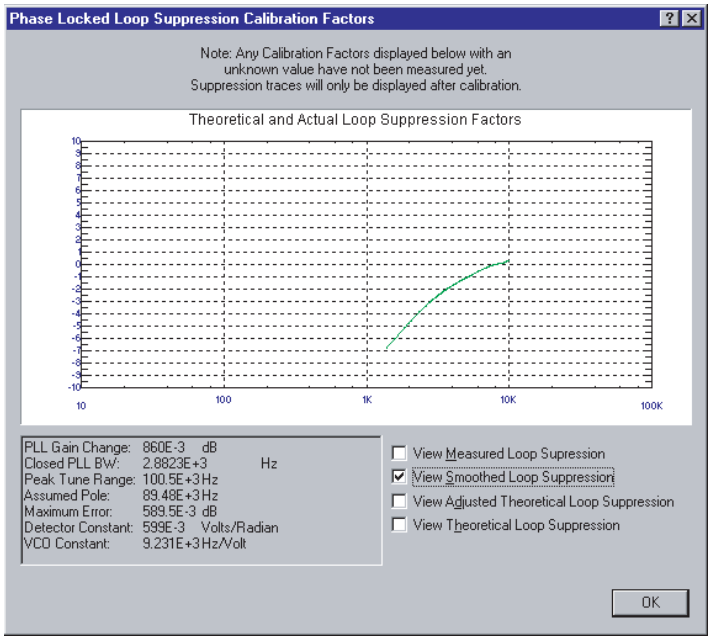

Figure 275 Smoothed loop suppression curve

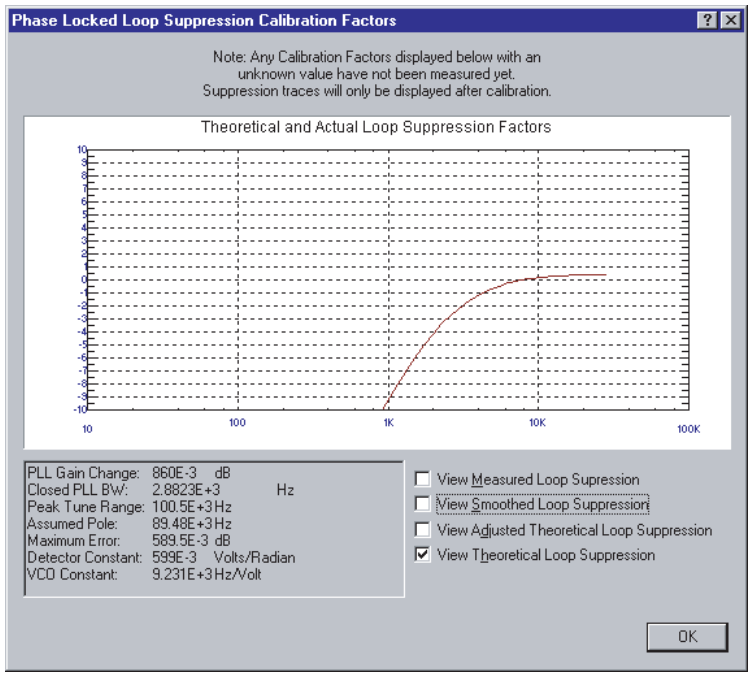

Figure 276 Theoretical loop suppression curve

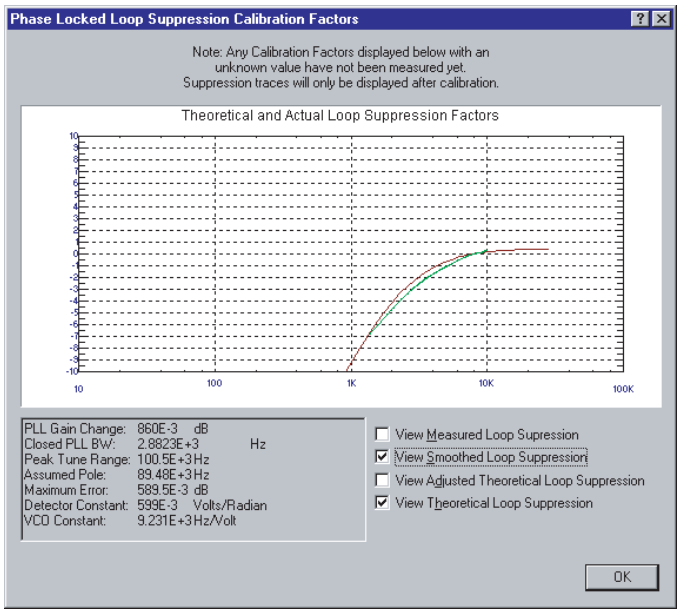

Figure 277 Smoothed vs. theoretical loop suppression curve

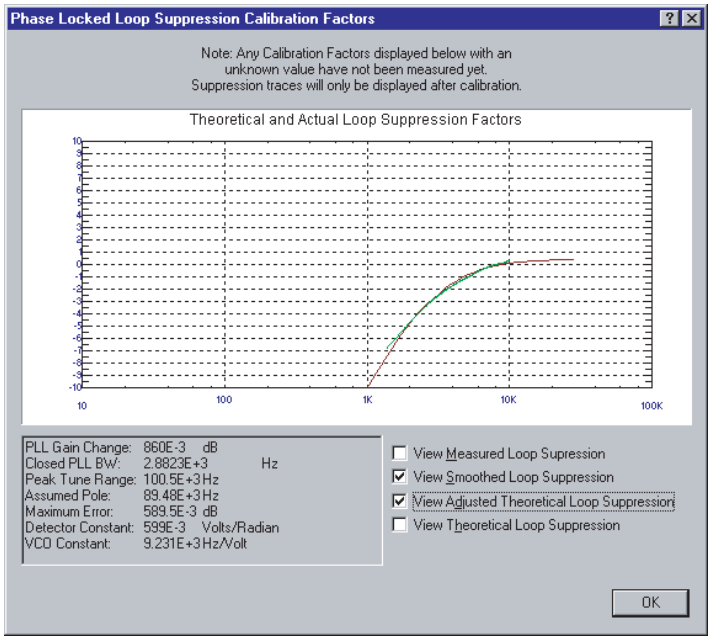

Figure 278 Smoothed vs. Adjusted theoretical loop suppression curve

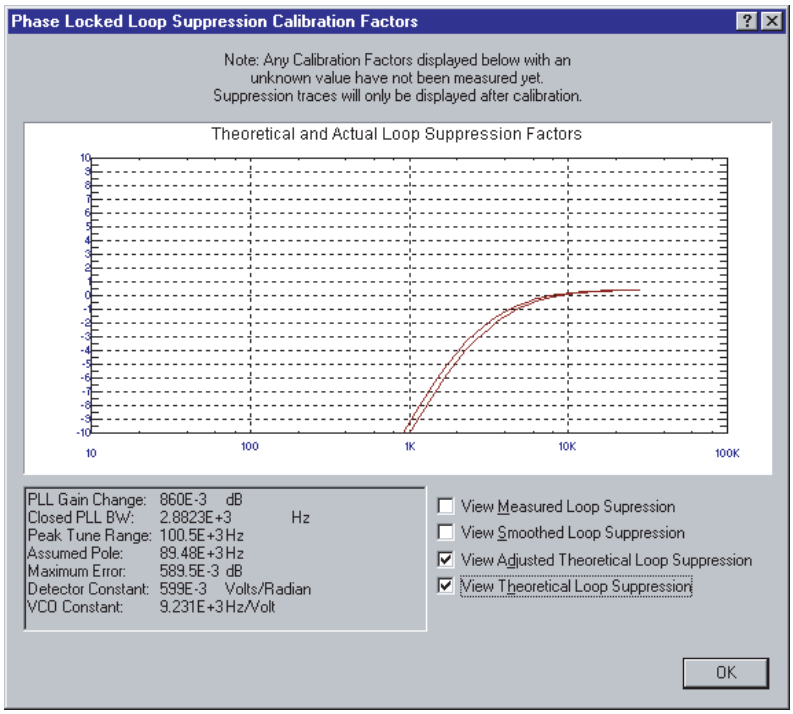

Figure 279 Adjusted theoretical vs. theoretical loop suppression curve

PLL gain change

PLL gain change is the amount in dB by which the theoretical gain of the PLL must be adjusted to best match the smoothed measured loop suppression. The parameters of the theoretical loop suppression that are modified are Peak Tune Range (basically open loop gain) and Assumed Pole (for example a pole on the VCO tune port that may cause peaking).

Maximum error

Maximum Error is the largest difference between the smoothed measured loop suppression and the adjusted theoretical loop suppression in the frequency range plotted for the smoothed measured loop suppression.

The frequency of the assumed pole is normally much greater than the Closed PLL BW and there is no loop peaking. If the smoothed measured PLL suppression shows peaking, the assumed pole is shifted down in frequency to simulate the extra phase shift that caused the peaking. If the peaking is really due to a single pole at a frequency near the Closed PLL BW, the adjusted theoretical loop suppression and smoothed measured loop suppression will show a good match and the maximum error will be small.

Accuracy degradation

Accuracy specification degradation is determined by taking the larger of Maximum Error and magnitude of PLL Gain Change and then subtracting 1 dB.

Blanking Frequency and Amplitude Information on the Phase Noise Graph

CAUTION Implementing either of the “secured” levels described in this section is not reversible. **Once the frequency or frequency/amplitude data has been blanked**, **it can not be recovered**. If you need a permanent copy of the data, you can print out the graph and parameter summary before you secure the data and store the printed data to a secured location

NOTE An alternate method of storing classified data is to save the measurement test file (*.pnm), including the real frequency/amplitude data onto a floppy diskette and securing the diskette. It can then be recalled at a later data

Security level procedure

1 From the Define Menu, choose Security Level. See Figure 280.

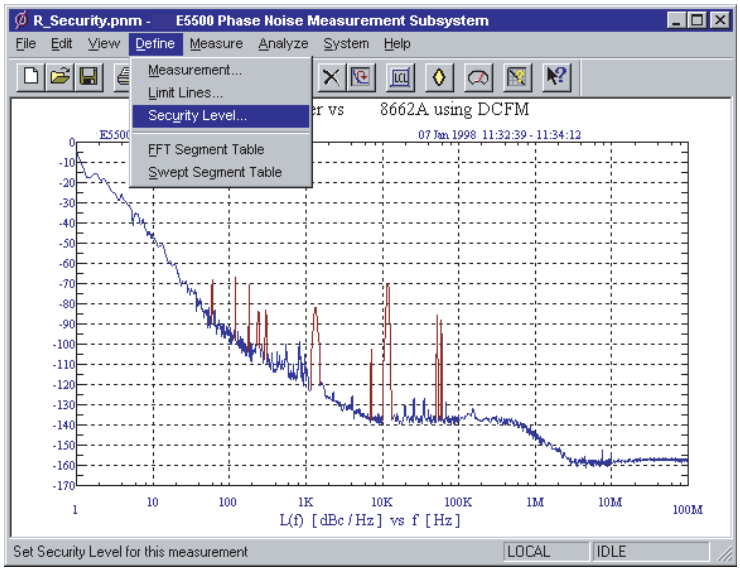

Figure 280 Navigate to security level

2 Choose one of the security options provided:

- Unsecured: all data is viewable
- Secured: Frequencies cannot be viewed
- Secured: Frequencies and amplitudes cannot be viewed

Unsecured: all data is viewable

When “Unsecured all data is viewable” is selected, all frequency and amplitude information is displayed on the phase noise graph. See Figure 281 and Figure 282.

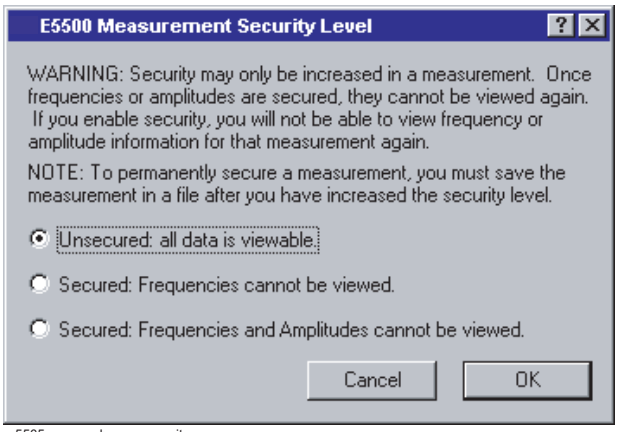

Figure 281 Choosing levels of security

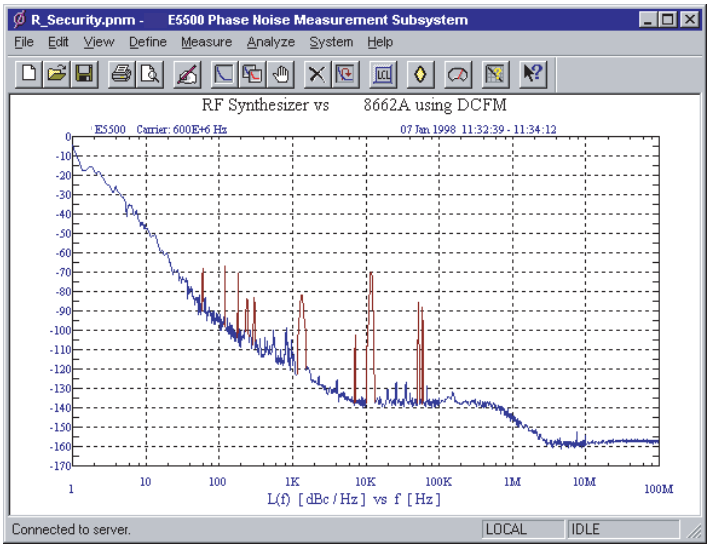

Figure 282 Unsecured: all data is viewable

Secured: Frequencies Cannot be Viewed

When “Secured: Frequencies cannot be viewed” is selected, all frequency information is blanked on the phase noise graph. See Figure 283 through Figure 285.

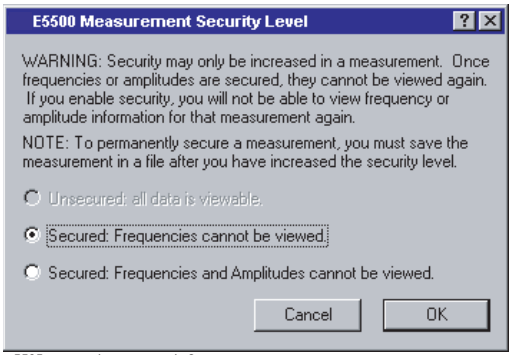

Figure 283 Choosing levels of security

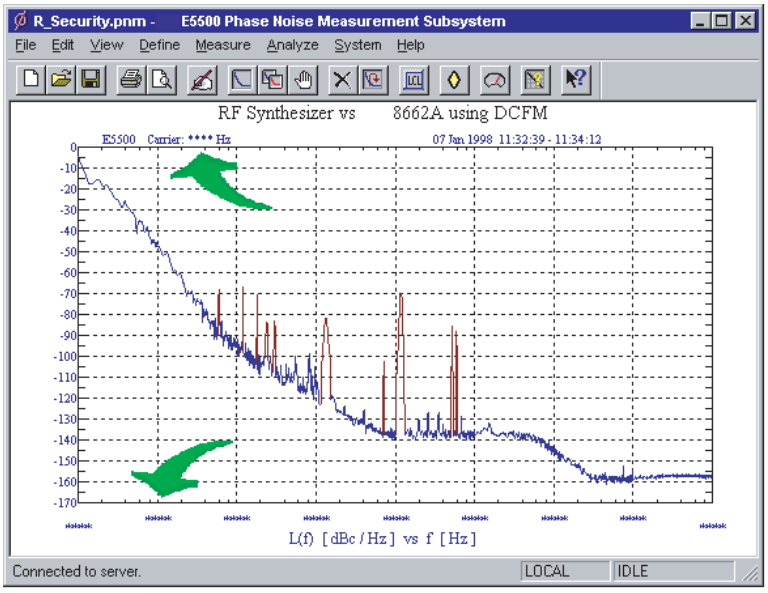

Figure 284 Secured: frequencies cannot be found-1

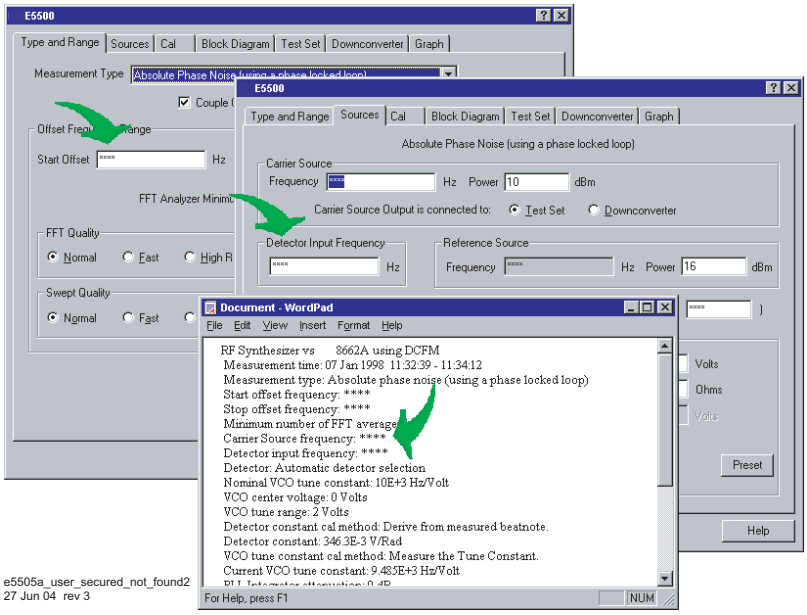

Figure 285 Secured: frequencies cannot be found-2

Secured: Frequencies and Amplitudes cannot be viewed

When “Secured: Frequencies and Amplitudes cannot be viewed” is selected, all frequency and amplitude information is blanked on the phase noise graph. See Figure 286 and Figure 287.

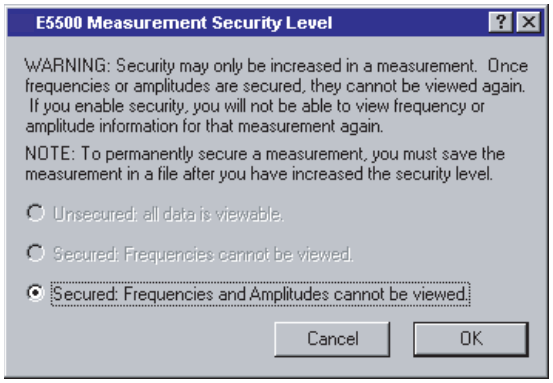

Figure 286 Choosing levels of security

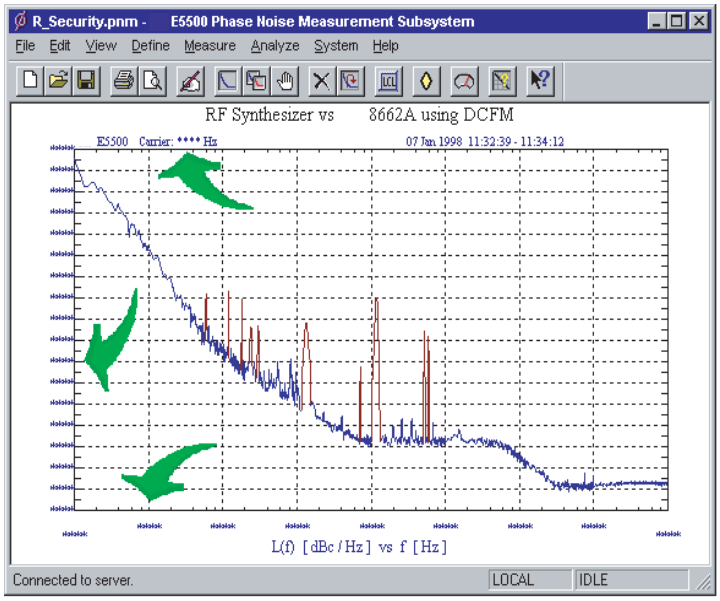

Figure 287 Secured: frequencies and amplitudes cannot be viewed

16
Reference Graphs and Tables

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Approximate System Noise Floor vs. R Port Signal Level

The sensitivity of the phase noise measurement system can be improved by increasing the signal power at the R input port (Signal Input) of the phase detector in the test set. Figure 288 illustrates the approximate noise floor of the N5500A test set for a range of R input port signal levels from –15 dBm to +15 dBm. These estimates of sensitivity assume the signal level at the L port is appropriate for either the microwave or the RF mixer that is used (+7 dBm or +15 dBm, respectively). The approximate phase detector calibration constant that results from the input signal level at the R port is shown on the right side of the graph.

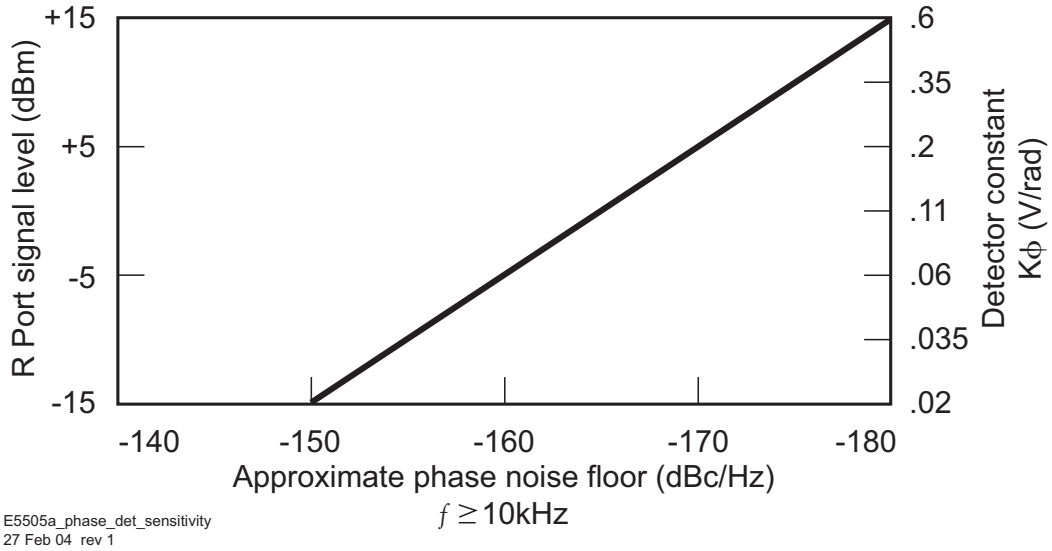

Figure 288 Noise floor for R input port

Phase Noise Floor and Region of Validity

Caution must be exercised when $L(f)$ is calculated from the spectral density of the phase fluctuations, $S_\phi(f)$ because of the small angle criterion. The –10 dB/decade line is drawn on the plot for an instantaneous phase deviation of 0.2 radians integrated over any one decade of offset frequency. At approximately 0.2 radians, the power in the higher order sidebands of the phase modulation is still insignificant compared to the power in the first order sideband which ensures the calculation of $L(f)$ is still valid. As shown in Figure 289, the line plot of $L(f)$ is correct; above the line, $L(f)$ is increasingly invalid and $S_\phi(f)$ must be used to represent the phase noise of the signal. ($S_\phi(f)$ is valid both above and below the line. When using the $L(f)$ graph to compute $S_\phi(f)$, add 3 dB to the Level.

$$S_\phi(f) = 2\,(L(f))\ or\ S_\phi(f)_{dB} = L(f)_{dBc} + 3\ dB$$

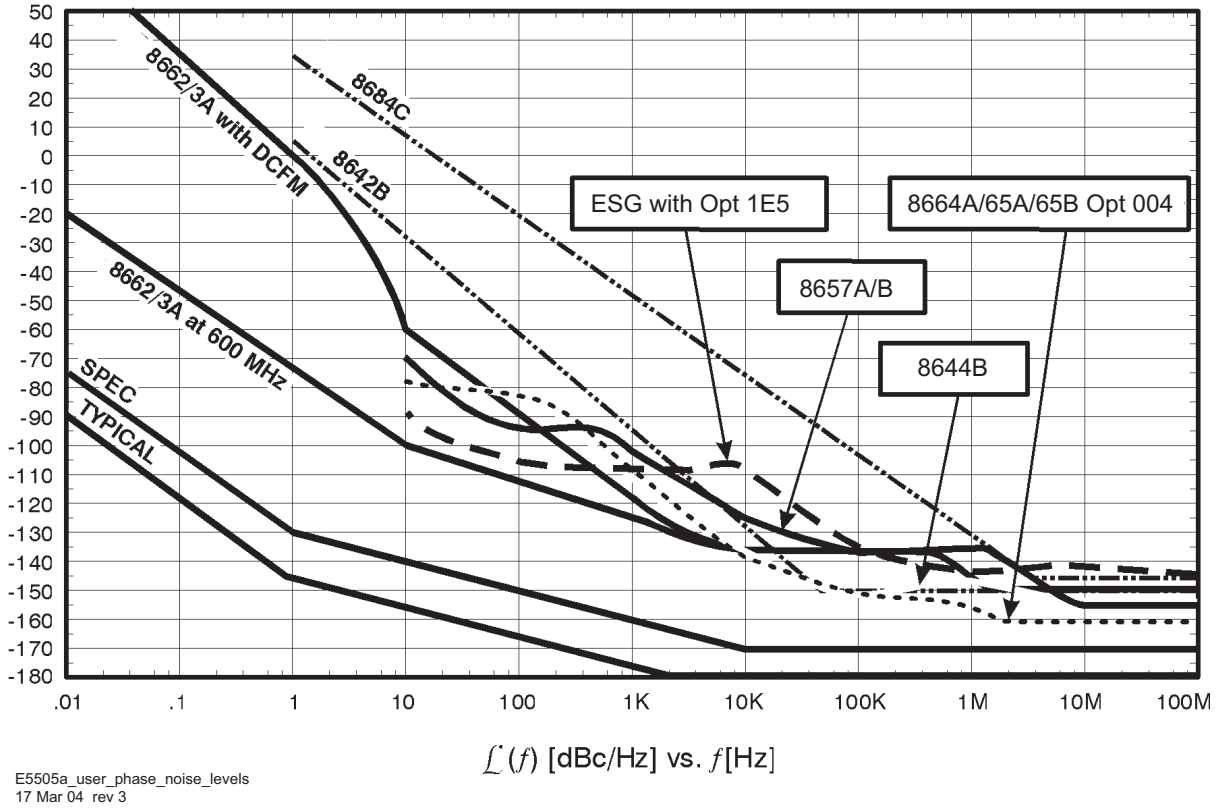

Figure 289 Region of validity

Phase Noise Level of Various Agilent Sources

The graph in Figure 290 indicates the level of phase noise that has been measured for several potential reference sources at specific frequencies. Depending on the sensitivity that is required at the offset to be measured, a single reference source may suffice or several different references may be needed to achieve the necessary sensitivity at different offsets.

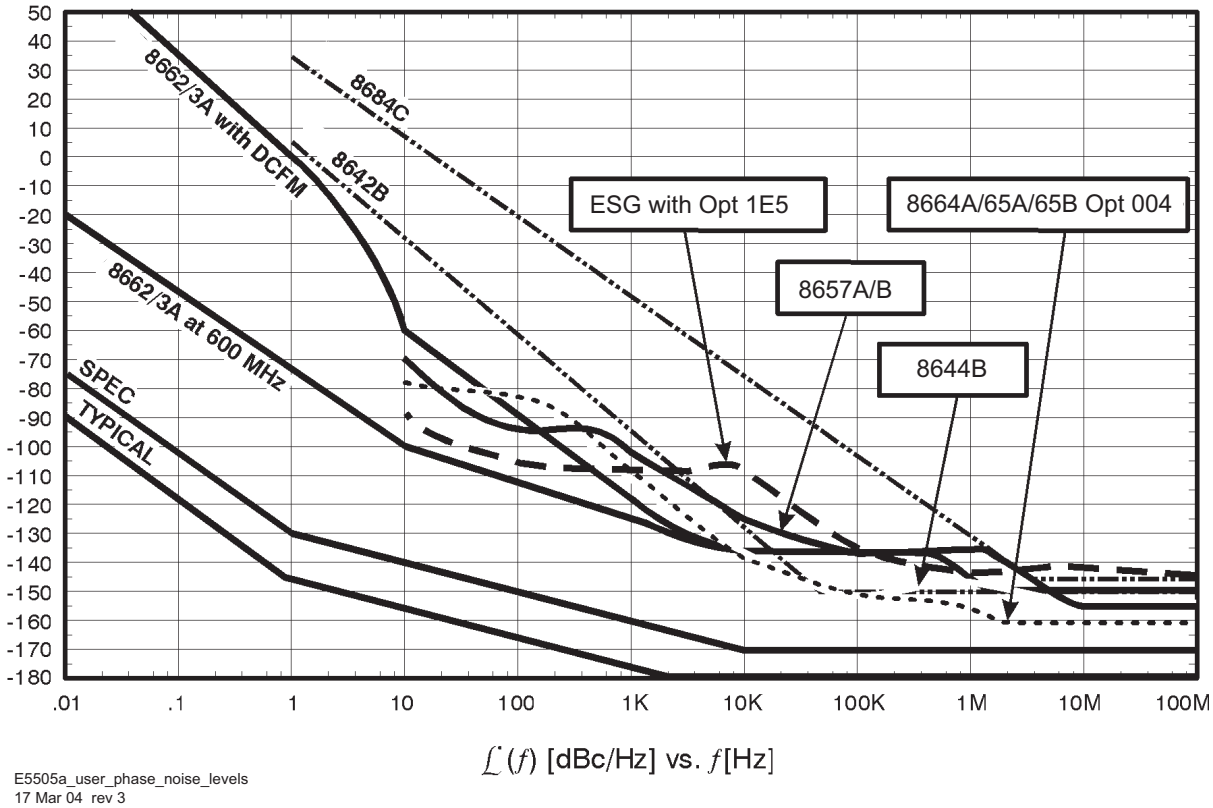

Figure 290 Noise level for various reference sources

Increase in Measured Noise as Ref Source Approaches DUT Noise

The graph shown in Figure 291 demonstrates that as the noise level of the reference source approaches the noise level of the DUT, the level measured by the software (which is the sum of all sources affecting the test system) is increased above the actual noise level of the DUT.

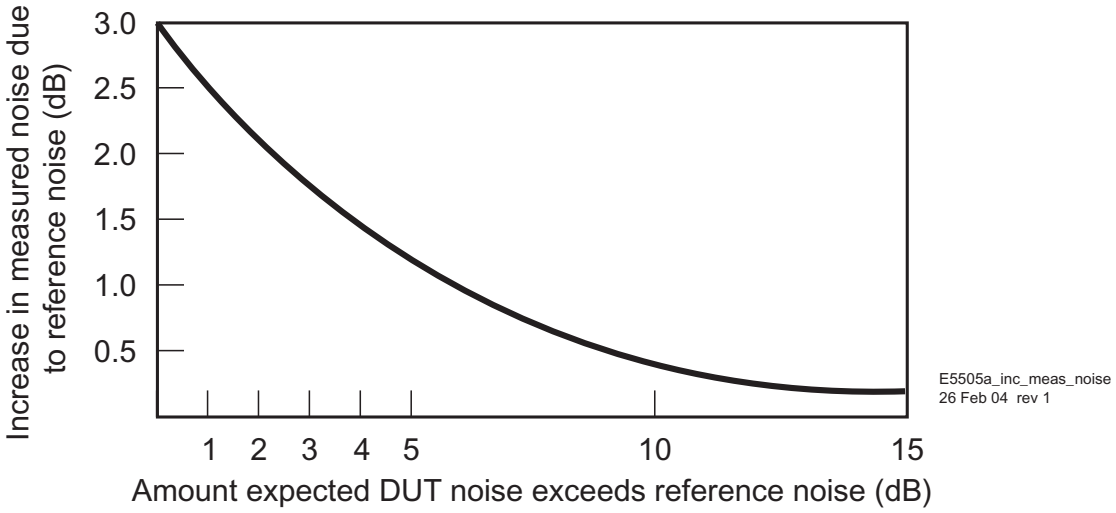

Figure 291 Reference source and DUT noise levels

Approximate Sensitivity of Delay Line Discriminator

The dependence of a frequency discriminator's sensitivity on the offset frequency is obvious in the graph in Figure 292. By comparing the sensitivity specified for the phase detector to the delay line sensitivity, it is apparent the delay line sensitivity is “tipped up” by 20 dB/decade beginning at an offset of $1/2\pi\tau$. The sensitivity graphs indicate the delay line frequency discriminator can be used to measure some types of sources with useful sensitivity. Longer delay lines improve sensitivity, but eventually the loss in the delay line will exceed the available power of the source and cancel any further improvement. Also, longer delay lines limit the maximum offset frequency that can be measured.

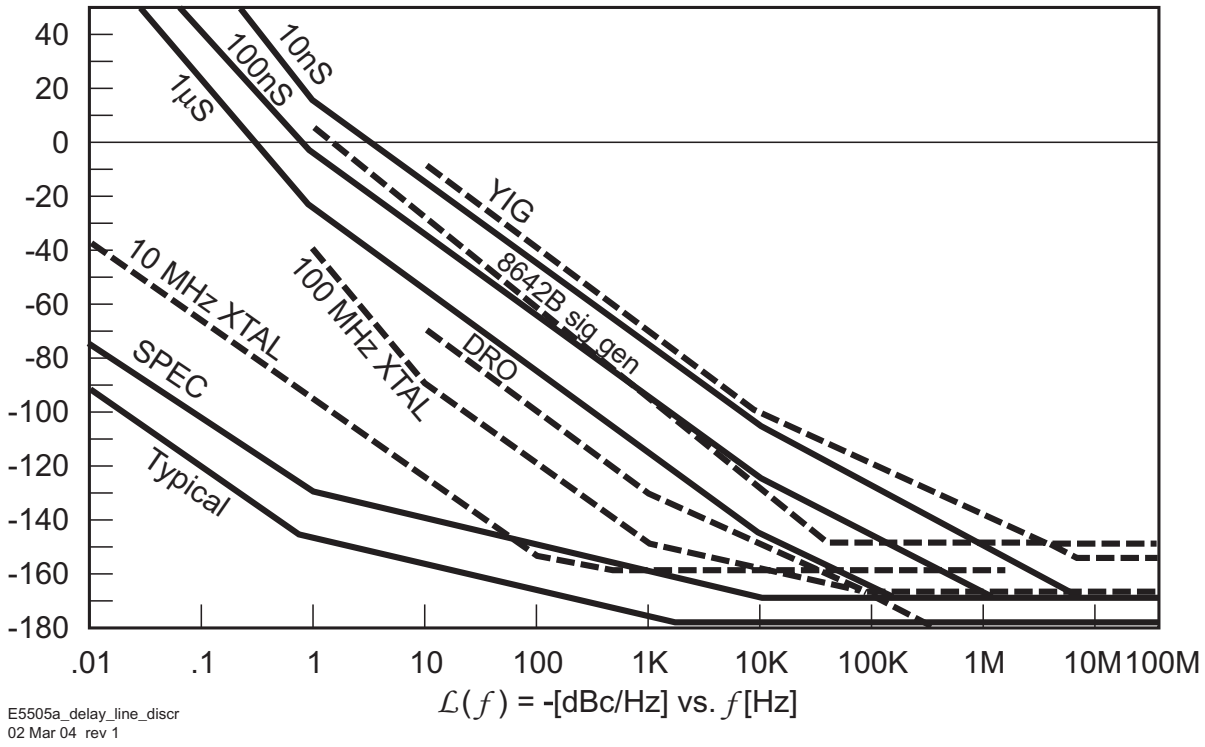

Figure 292 Delay line discriminator sensitivity

AM Calibration

The AM detector sensitivity graph in Figure 293 is used to determine the equivalent phase Detector Constant from the measured AM Detector input level or from the diode detector's DC voltage. The equivalent phase detector constant (phase slope) is read from the left side of the graph while the approximate detector input power is read from the right side of the graph.

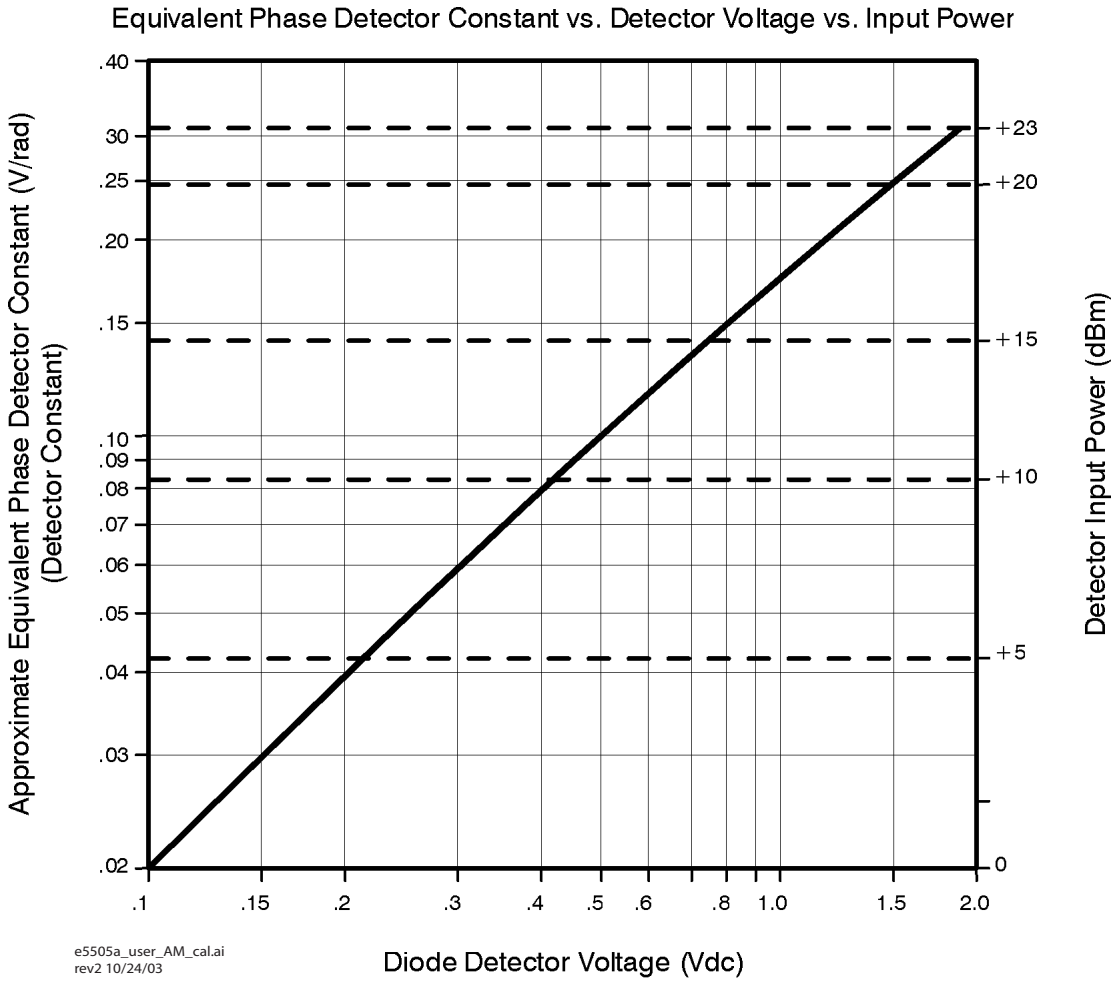

Figure 293AM detector sensitivity

Voltage Controlled Source Tuning Requirements

Peak Tuning Range (PTR) ≈ Tune Range of VCO x VCO Tune Constant.

Min. PTR = 0.1 Hz

Max. PTR = Up to 200 MHz, depending on analyzer and phase detector LPF.

Drift Tracking Range = Allowable Drift During Measurement

The tuning range that the software actually uses to maintain quadrature is limited to a fraction of the peak tuning range (PTR) to ensure that the tuning slope is well behaved and the VCO Tune Constant remains accurate. After phase lock is established, the test system monitors the tuning voltage required to maintain lock. If the tuning voltage exceeds 5% of the PTR during the measurement, the test system again informs the user and requests the oscillator be retuned or the problem be otherwise corrected before proceeding with the measurement. These limits have been found to guarantee good results. Refer to Figure 294.

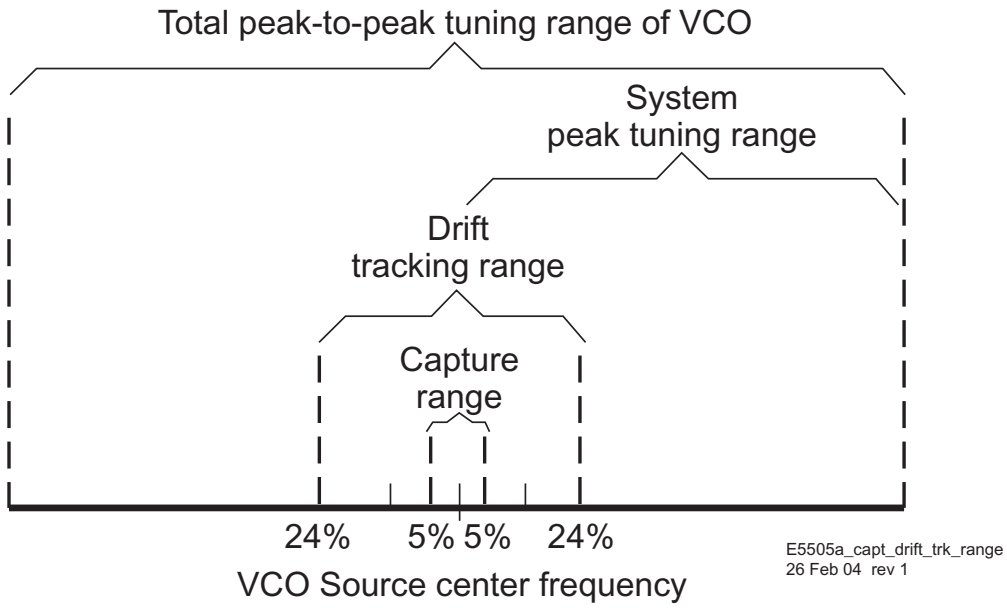

Figure 294 Tuning voltage required for phase lock

Tune Range of VCO for Center Voltage

The graph in Figure 295 outlines the minimum to maximum Tune Range of VCO that the software provides for a given center voltage. The Tune range of VCO decreases as the absolute value of the center voltage increases due to hardware limitations of the test system.

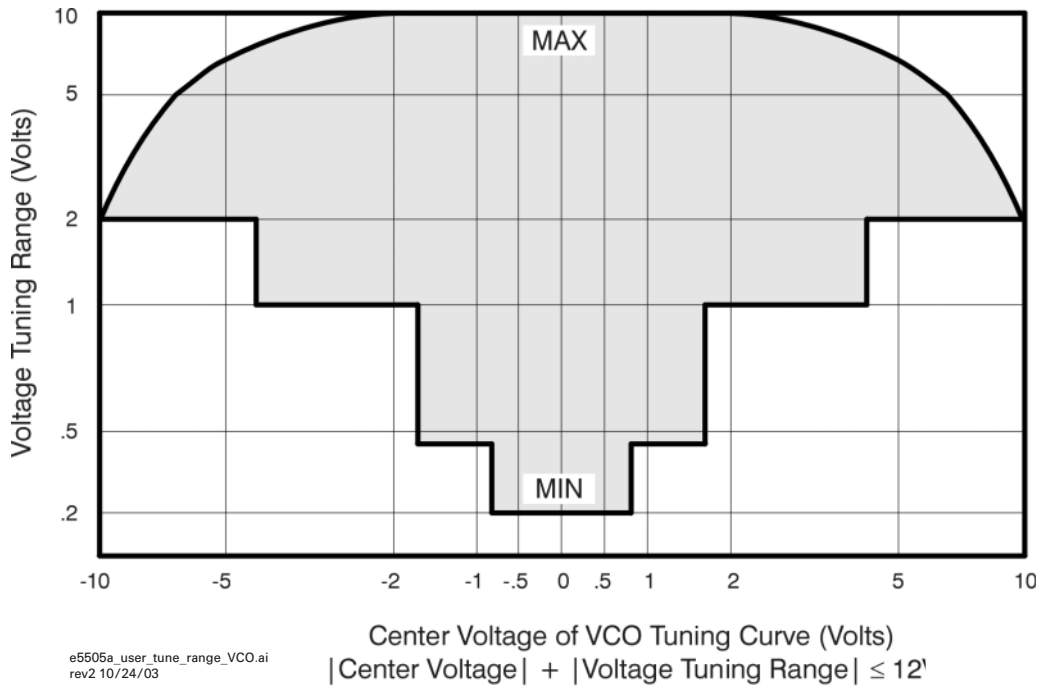

Figure 295 Tune range of VCO for center voltage

Peak Tuning Range Required by Noise Level

The graph in Figure 296 provides a comparison between the typical phase noise level of a variety of sources and the minimum tuning range that is necessary for the test system to create a phase lock loop of sufficient bandwidth to make the measurement. Sources with higher phase noise require a wider Peak Tuning Range.

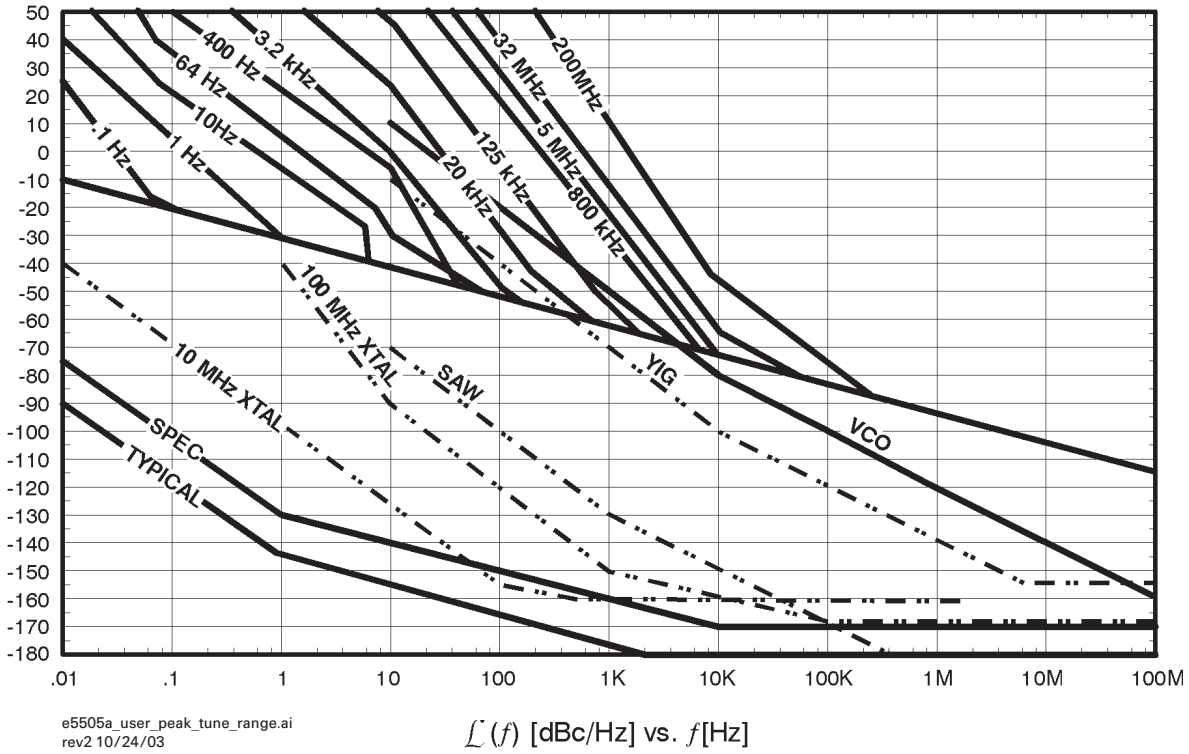

Figure 296 Typical source noise level vs. minimum tuning range

Phase Lock Loop Bandwidth vs. Peak Tuning Range

The graph in Figure 297 illustrates the closed Phase Lock Loop Bandwidth (PLL BW) chosen by the test system as a function of the Peak Tuning Range of the source. Knowing the approximate closed PLL BW allows you to verify that there is sufficient bandwidth on the tuning port and that sufficient source isolation is present to prevent injection locking.

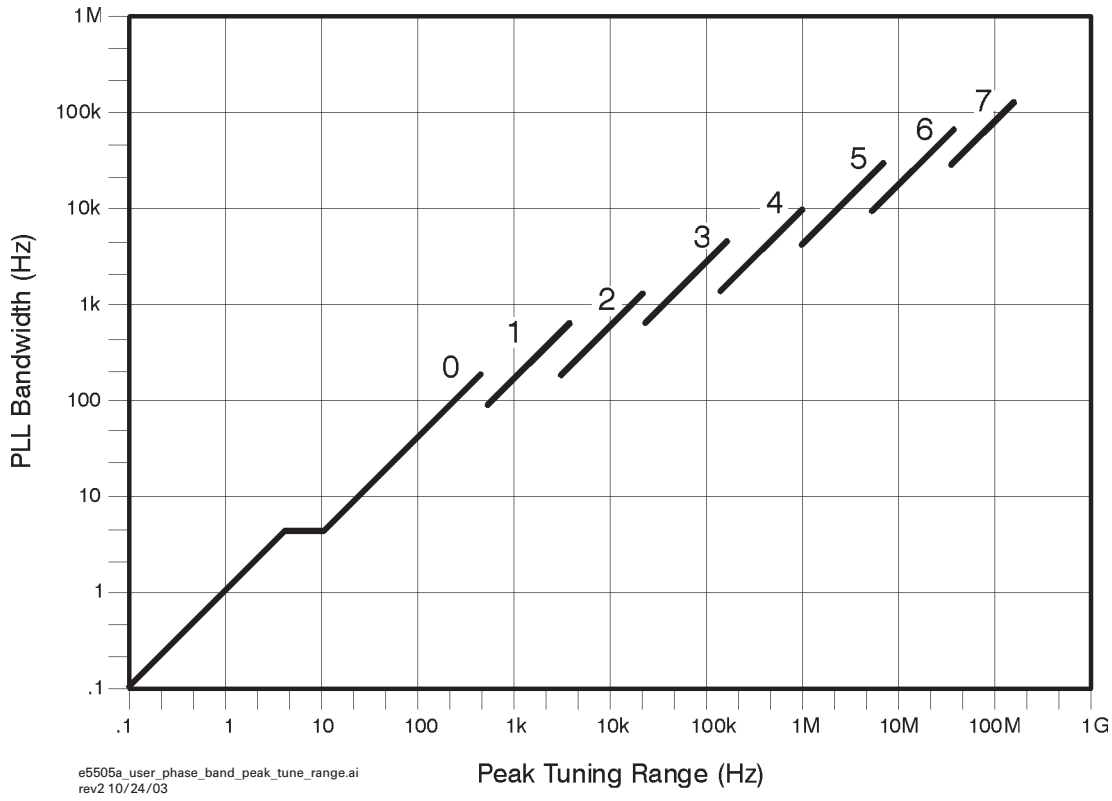

Figure 297PLL BW vs. peak tuning range

Noise Floor Limits Due to Peak Tuning Range

The graph in Figure 298 illustrates the equivalent phase noise at the Peak Tuning Range entered for the source due to the inherent noise at the test set Tune Voltage Output port. (A Tune Range of VCO ±10 V and phase Detector Constant of 0.2V/Rad is assumed.)

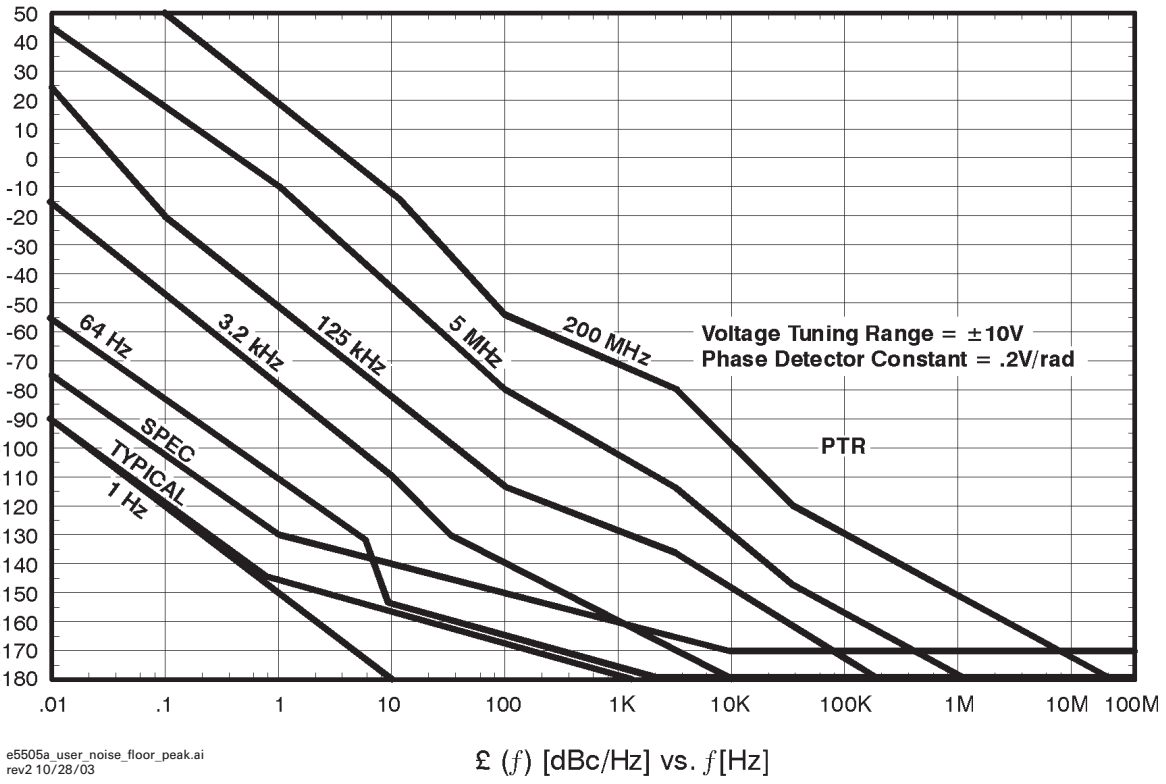

Figure 298 Noise at source’s peak tuning range

Tuning Characteristics of Various VCO Source Options

Table 55 Tuning parameters for several VCO options

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range (± V)	Input Resistance (Ω)	Tuning Calibration Method
Agilent 8662/3A • EFC • DCFM	υ_0	5 E – 9 x υ_0 FM Deviation	0 0	10 10	1E + 6 1 k (8662) 600 (8663)	Measure Calculate Calculate
Agilent 8642A/B		FM Deviation	0	10	600	Calculate
Agilent 8643A/44B		FM Deviation	0	10	600	Calculate
Agilent 8664A **Agilent 8665A/B**		FM Deviation	0	5 (*See Caution Below*)	600	Calculate
Other Signal Generator DCFM Calibrated for ±1V		FM Deviation	0	10	R_{in}	Calculate
Other User VCO Source		Estimated within a factor of 2	–10 to +10	See "Tune Range of VCO for Center Voltage" on page 369	1 E + 6	Measure

CAUTION Exceeding 5 volts maximum voltage tuning range for the 8664A and 8665A/B may damage equipment.

8643A Frequency Limits

Table 56 8643A frequency limits

Note: Special Function 120 must be enabled for DCFM				**Minimum Recommended PTR (Peak Tune Range) PTR =FM Deviation x VTR[1]**	
Model Number	**Option**	**Band Minimum (MHz)**	**Band Maximum (MHz)**	**Mode 2[2]**	**Mode 1[3]**
8643A	002	1030	2060	2000000	20000000
8643A	002	515	1029.99999999	1000000	10000000
8643A	Standard	515	1030	1000000	10000000
8643A	Both	257.5	514.99999999	500000	5000000
8643A	Both	128.75	257.49999999	250000	2500000
8643A	Both	64.375	128.74999999	125000	1250000
8643A	Both	32.1875	64.37499999	62500	625000
8643A	Both	16.09375	32.18749999	31200	312000
8643A	Both	8.046875	16.09374999	15600	156000
8643A	Both	4.0234375	8.04687499	7810	78100
8643A	Both	2.01171875	4.02343749	3900	39000
8643A	Both	1.005859375	2.01171874	1950	19500
8643A	Both	0.5029296875	1.005859365	976	9760
8643A	Both	0.25146484375	0.5029296775	488	4880

1 Takes into account limited tuning resolution available in linear FM (Special Function 120, refer to "How to access special functions" on page 375.

2 The 8643A defaults to Mode 2 operation.

3 Wideband FM: Use Special Function 125 (refer to "How to access special functions" on page 375.

8643A mode keys

- The **[Mode 1]** key provides the maximum FM deviation and minimum RF output switching time. Noise level is highest in this mode, as shown in Table 57 on page 375.
- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 57 on page 375. The 8643A defaults to Mode 2 operation.

Table 57 Operating characteristics for 8643A modes 1, 2, and 3

Characteristic	Synthesis Mode	
	Mode 1	**Mode 2**
RF Frequency Switching Time	90 ms	200 ms
FM Deviation at 1 GHz	10 MHz	1 MHz
Phase Noise (20 kHz offset at 1 GHz)	–120 dBc	–130 dBc

How to access special functions

Press the Special key and enter the special function number of your choice. Access the special function key by pressing the Enter key. Press the [ON] (ENTER) key to terminate data entries that do not require specific units (kHz, mV, rad, for example)

Example:

[Special], [1], [2], [0], [ON] (Enter).

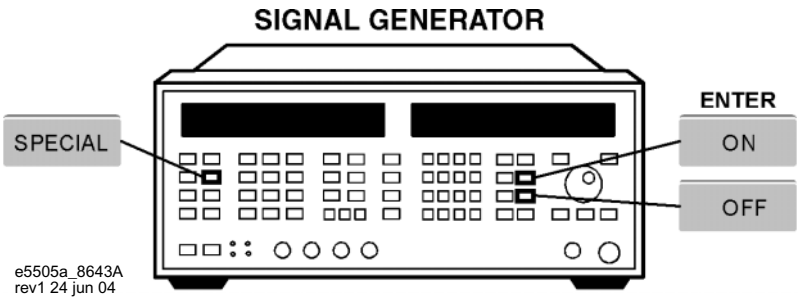

Figure 2998643A special function keys

Description of special functions 120 and 125

120: FM synthesis

This special function allows you to have the instrument synthesize the FM signal in a digitized or linear manner. Digitized FM is best for signal-tone modulation and provides very accurate center frequency at low deviation rates. Linear FM is best for multi-tone modulation and provides a more constant group delay than the Digitized FM.

125: Wide FM deviation (8643A only)

Mode 1 operation can be selected using this special function, which allows you to turn on wide FM deviation. The 8643 defaults to Mode 2 operation. Wide FM deviation provides the maximum FM deviation and minimum RF output switching time. In this mode, the maximum deviation is increased, by a factor of 10, to 10 MHz (for a 1 GHz carrier). The noise level of the generator is also increased in this mode, however.

8644B Frequency Limits

Table 58 8644B frequency limits

Note: Special Function 120 must be enabled for DCFM				**Minimum Recommended PTR (Peak Tune Range) PTR =FM Deviation x VTR[1]**		
Model Number	**Option**	**Band Minimum (MHz)**	**Band Maximum (MHz)**	**Mode 3**	**Mode 2**	**Mode 1**
8644B	002	1030	2060	200000	2000000	20000000
8644B	002	515	1029.99999999	100000	1000000	10000000
8644B	Standard	515	1030	100000	1000000	10000000
8644B	Both	257.5	514.99999999	50000	500000	5000000
8644B	Both	128.75	257.49999999	25000	250000	2500000
8644B	Both	64.375	128.74999999	12500	125000	1250000
8644B	Both	32.1875	64.37499999	6250	62500	625000
8644B	Both	16.09375	32.18749999	3120	31200	312000
8644B	Both	8.046875	16.09374999	1560	15600	156000
8644B	Both	4.0234375	8.04687499	781	7810	78100
8644B	Both	2.01171875	4.02343749	390	3900	39000
8644B	Both	1.005859375	2.01171874	195	1950	19500
8644B	Both	0.5029296875	1.005859365	97.6	976	9760
8644B	Both	0.25146484375	0.5029296775	48.8	488	4880

1 Takes into account limited tuning resolution available in linear FM (Special Function 120, refer to "How to access special functions" on page 375.

8644B mode keys

- The **[Mode 1]** key provides the maximum FM deviation and minimum RF output switching time. Noise level is highest in this mode, as shown in the following table.
- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 59 on page 378.
- The **[Mode 3]** key provides the lowest noise level at the RF output, FM deviation bandwidth is narrower, and the RF switching time is slower than in either Modes 1 or 2.

Table 59 Operating characteristics for 8644B modes 1, 2, and 3

Characteristic	Synthesis Mode		
	Mode 1	**Mode 2**	**Mode 3**
RF Frequency Switching Time	90 ms	200 ms	350 ms
FM Deviation at 1 GHz	10 MHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-120 dBc	-130 dBc	-136 dBc

How to access special functions

Press the Special key and enter the special function number of your choice. Access the special function key by pressing the Enter key. Press the [ON] (ENTER) key to terminate data entries that do not require specific units (kHz, mV, rad, for example)

Example:

[Special], **[1]**, **[2]**, **[0]**, **[ON]** (Enter).

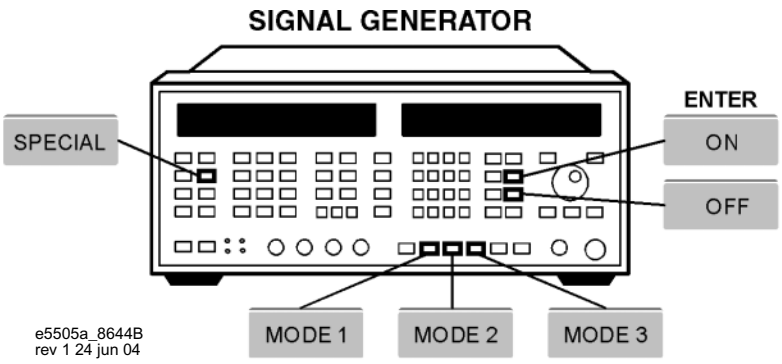

Figure 3008644B special functions keys

Description of special function 120

120: FM synthesis

This special function allows you to have the instrument synthesize the FM signal in a digitized or linear manner. Digitized FM is best for signal-tone modulation and provides very accurate center frequency at low deviation rates. Linear FM is best for multi-tone modulation and provides a more constant group delay than the Digitized FM.

8664A Frequency Limits

Table 60 8664A frequency limits

Note: Special Function 120 must be enabled for the DCFM				[1] Minimum Recommended PTR (Peak Tune Range) PTR =FM Deviation x VTR	
Model Number	**Option**	**Band Minimum (MHz)**	**Band Maximum (MHz)**	**Mode 3**	**Mode 2**
8664A		2060	3000	400000	10000000
8664A		1500	2059.99999999	200000	10000000
8664A		1030	1499.99999999	200000	5000000
8664A		750	1029.99999999	100000	5000000
8664A		515	749.99999999	100000	2500000
8664A		375	514.99999999	50000	2500000
8664A		257.5	374.99999999	50000	1250000
8664A		187.5	257.49999999	25000	1250000
8664A		30	187.49999999	200000	5000000
8664A		5	29.99999999	100000	5000000
8664A		0.05	4.99999999	Max FM = MIN (Above, Carrier frequency –9 kHz)	

1 Takes into account limited tuning resolution available in linear FM (Special Function 120, refer to "How to access special functions" on page 375).

8664A mode keys

- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 61.
- The **[Mode 3]** key provides the lowest noise level at the RF output, FM deviation bandwidth is narrower, and the RF switching time is slower than in either Modes 1 or 2.

Table 61 Operating characteristics for 8664A modes 2 and 3

Characteristic	**Synthesis Mode**	
	Mode 2	**Mode 3**
RF Frequency Switching Time	200 ms	350 ms
FM Deviation at 1 GHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-130 dBc	-136 dBc

How to access special functions

Press the Special key and enter the special function number of your choice. Access the special function key by pressing the Enter key. Press the [ON] (ENTER) key to terminate data entries that do not require specific units (kHz, mV, rad, for example)

Example:

[Special], **[1]**, **[2]**, **[0]**, **[ON]** (Enter)

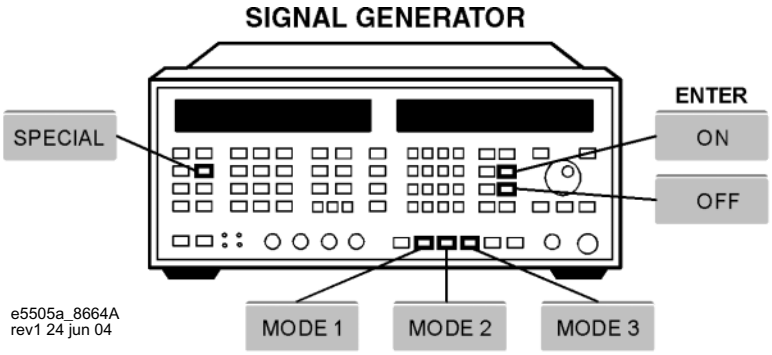

Figure 301 Special functions keys

Description of special functions 120

120: FM synthesis

This special function allows you to have the instrument synthesize the FM signal in a digitized or linear manner. Digitized FM is best for signal-tone modulation and provides very accurate center frequency at low deviation rates. Linear FM is best for multi-tone modulation and provides a more constant group delay than the Digitized FM.

8665A Frequency Limits

Table 62 8665A frequency limits

Note: Special Function 120 must be enabled for DCFM			**Minimum Recommended PTR (Peak Tune Range)** **PTR =FM Deviation x VTR[1]**	
Model Number **Option**	**Band Minimum (MHz)**	**Band Maximum (MHz)**	**Mode 3**	**Mode 2**
8665A	4120	4200	800000	20000000
8665A	3000	4119.99999999	400000	20000000
8665A	2060	2999.99999999	400000	10000000
8665A	1500	2059.99999999	200000	10000000
8665A	1030	1499.99999999	200000	5000000
8665A	750	1029.99999999	100000	5000000
8665A	515	749.99999999	100000	2500000
8665A	375	514.99999999	50000	2500000
8665A	257.5	374.99999999	50000	1250000
8665A	187.5	257.49999999	25000	1250000
8665A	30	187.49999999	200000	5000000
8665A	5	29.99999999	100000	5000000
8665A	0.05	4.99999999	Max FM = MIN (Above, Carrier frequency –9 kHz)	

1 Takes into account limited tuning resolution available in linear FM (Special Function 120, refer to "How to access special functions" on page 375.

8665A mode keys

- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 63 on page 383.
- The **[Mode 3]** key provides the lowest noise level at the RF output, FM deviation bandwidth is narrower, and the RF switching time is slower than in either Modes 1 or 2.

Table 63 Operating characteristics for 8665A modes 2 and 3

Characteristic	Synthesis Mode	
	Mode 2	**Mode 3**
RF Frequency Switching Time	200 ms	350 ms
FM Deviation at 1 GHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-130 dBc	-136 dBc

How to access special functions

Press the Special key and enter the special function number of your choice. Access the special function key by pressing the Enter key. Press the [ON] (ENTER) key to terminate data entries that do not require specific units (kHz, mV, rad, for example)

Example:

[Special], **[1]**, **[2]**, **[0]**, **[ON]** (ENTER).

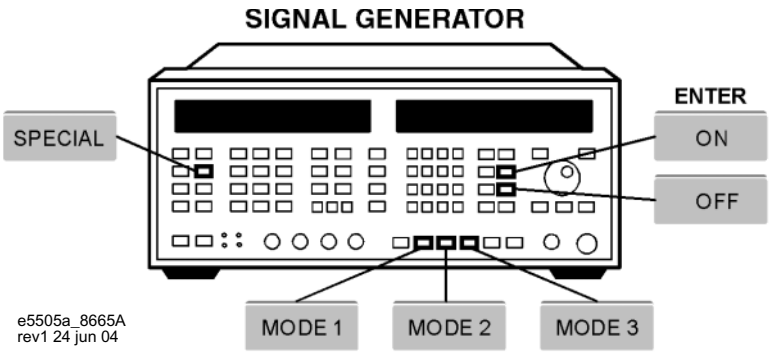

Figure 3028665A special functions keys

Description of Special Functions 120 and 124

120: FM synthesis

This special function allows you to have the instrument synthesize the FM signal in a digitized or linear manner. Digitized FM is best for signal-tone modulation and provides very accurate center frequency at low deviation rates. Linear FM is best for multi-tone modulation and provides a more constant group delay than the Digitized FM. The preset condition is FM Digitized.

124: FM Dly equalizer

This special function allows you to turn off FM delay equalizer circuitry. When [ON] (The preset condition), 30 µsec of group delay is added to the FM modulated signal to get better FM frequency response.

You may want to turn [OFF] the FM Delay Equalizer circuitry when the signal generator is used as the VCO in a phase-locked loop application to reduce phase shift, of when you want to extend the FM bandwidth to 200 kHz. When [OFF], FM Indicator Accuracy is worse for rates of 1-5 kHz and better beyond 30 kHz. Refer to the 8643A/8644B User's Guide for specific details.

8665B Frequency Limits

Table 64 8665B frequency limits

Note: Special Function 120 must be enabled for DCFM				Minimum Recommended PTR (Peak Tune Range) PTR =FM Deviation x VTR[1]	
Model Number	**Option**	**Band Minimum (MHz)**	**Band Maximum (MHz)**	**Mode 3**	**Mode 2**
8665B		4120	6000	800000	20000000
8665B		3000	4119.99999999	400000	20000000
8665B		2060	2999.99999999	400000	10000000
8665B		1500	2059.99999999	200000	10000000
8665B		1030	1499.99999999	200000	5000000
8665B		750	1029.99999999	100000	5000000
8665B		515	749.99999999	100000	2500000
8665B		375	514.99999999	50000	2500000
8665B		257.5	374.99999999	50000	1250000
8665B		187.5	257.49999999	25000	1250000
8665B		30	187.49999999	200000	5000000
8665B		5	29.99999999	100000	5000000
8665B		0.05	4.99999999	Max FM = MIN (Above, Carrier frequency –9 kHz)	

1 Takes into account limited tuning resolution available in linear FM (Special Function 120, refer to "How to access special functions" on page 375).

8665B mode keys

- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 65.
- The **[Mode 3]** key provides the lowest noise level at the RF output, FM deviation bandwidth is narrower, and the RF switching time is slower than in either Modes 1 or 2.

Table 65 Operating characteristics for 8665B modes 2 and 3

Characteristic	Synthesis Mode	
	Mode 2	**Mode 3**
RF Frequency Switching Time	200 ms	350 ms
FM Deviation at 1 GHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-130 dBc	-136 dBc

How to access special functions

Press the Special key and enter the special function number of your choice. Access the special function key by pressing the Enter key. Press the [ON] (ENTER) key to terminate data entries that do not require specific units (kHz, mV, rad, for example)

Example:

[Special], **[1]**, **[2]**, **[0]**, **[ON]** (Enter).

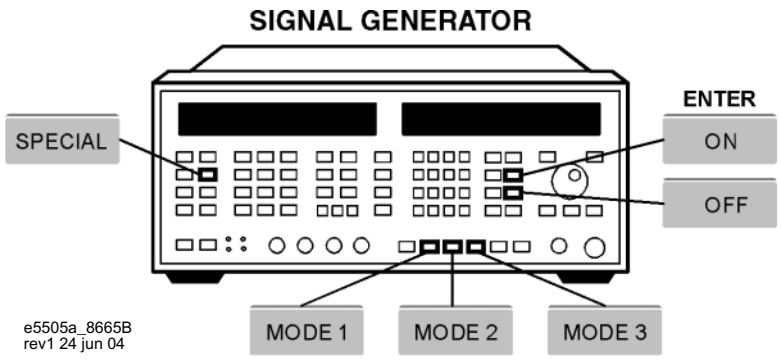

Figure 3038665B Special functions keys

Description of special functions 120 and 124

120: FM synthesis

This special function allows you to have the instrument synthesize the FM signal in a digitized or linear manner. Digitized FM is best for signal-tone modulation and provides very accurate center frequency at low deviation rates. Linear FM is best for multi-tone modulation and provides a more constant group delay than the Digitized FM.

124: FM Dly equalizer

This special function allows you to turn off FM delay equalizer circuitry. When [ON] (The preset condition), 30 µsec of group delay is added to the FM modulated signal to get better FM frequency response.

You may want to turn [OFF] the FM Delay Equalizer circuitry when the signal generator is used as the VCO in a phase-locked loop application to reduce phase shift, of when you want to extend the FM bandwidth to 200 kHz. When [OFF], FM Indicator Accuracy is worse for rates of 1-5 kHz and better beyond 30 kHz. Refer to the 8665B User's Guide for specific details.

17
System Specifications

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Specifications

This section contains mechanical and environmental specifications, operating characteristics, power requirements, and PC requirements for the system. It also provides specifications for accuracy, measurement qualifications, and tuning.

Table 66 contains the mechanical and environmental specifications for a system. Table 67 shows the system's operating characteristics.

Table 66 Mechanical and environmental specifications

Specifications	Values		
Temperature:			
Operating	0 °C to 40 °C (32 °F to 131 °F)		
Non-operating/storage	-40 °C to 70 °C (-40 °F to 158 °F)		
Altitude	type tested from 0 to 3000 m (9,842 ft) - operating 4600 m (15,000 ft) - non-operating		
Relative humidity	type tested at 95%, +40°C (non-condensing)		
Air flow space required	102 mm (4 in) on all sides		
System weight:	**Benchtop**	**1.6 Meter Rack**	**2 Meter Rack**
Approximate, typical	210 lbs (95.5 kg)	431 lbs (195.5 kg)	465 lbs (211 kg)
System dimensions:			
Height	711 to 915 mm (28 to 36 in)	1,620 mm (64 in)	2,020 mm (79.5 in)
Width	432 mm (17 in)	600 mm (23.6 in)	600 mm (23.6 in)
with rack-mounted flat-panel display	n/a	1438 mm (56.7 in)	1438 mm (56.7 in)
with benchtop PC and display	1,016 mm (40 in)	n/a	n/a
Depth	711 mm (28 in)	905 mm (35.7 in)	905 mm (35.7 in)

Table 67 Operating characteristics

Warm up time required	30 minutes
Carrier frequency ranges	50 KHz to 1.6 GHz 50 KHz to 6 GHz 50 KHz to 18 GHz 50 KHz to 26.5 GHz
Offset frequency ranges	0.01 Hz to 2 MHz 0.01 Hz to 100 MHz
System noise response	–180 dBc/Hz typically (>10 kHz offsets)
System spurious response	≤120 dBc typically

Table 67 Operating characteristics (continued)

Phase detector input power	(<1.6 GHz carrier frequency) R input = 0 to +23 dBm L input = +15 to +23 dBm
Downconverter input range	1 GHz to 6 GHz 1 GHz to 18 GHz 1.5 GHz to 26.5 GHz
External noise input port	0.01 Hz to 100 MHz
Measurement accuracy	±2 dB (<1.0 MHz offsets) ±4 dB (<100 MHz offsets)

Reliable accuracy

The E5505A phase noise system minimizes measurement uncertainty by assuring you of accurate and repeatable measurement results.

Table 68 Phase noise measurement accuracy

RF Phase Detector Accuracy	
Frequency Range	**Offset from Carrier**
.01 Hz to 1 MHz	± 2 dB
1 MHz to 100 MHz	± 4 dB

Table 69 AM noise measurement accuracy

AM Detector Accuracy	
Frequency Range	**Offset from Carrier**
.01 Hz to 1 MHz	± 3 dB
1 MHz to 100 MHz	± 5 dB

Measurement qualifications

In order for the E5505A to meet its accuracy specifications for any measurement‘, these qualifications must be met by the signal sources you are using:

- Source Return Loss: 9.5 dB (<2:1 SWR)
- Source Harmonic Distortion <–20 dB (or a square wave)
- Nonharmonic spurious ≤ –26 dBc (except for phase modulation close to the carrier.

If either of these conditions are not met, system measurement accuracy may be reduced.

NOTE

In addition, if you have a **know** source, the source's uncertainties **must bee added** to the system specifications.

Tuning

The tuning range of the voltage controlled oscillator (VCO) source must be commensurate with the frequency stability of the sources being used. If the tuning range is too narrow, the system will not properly phase lock, resulting in an aborted measurement. If the tuning range of the VCO source is too large, noise on the control line may increase the effective noise of the VCO source.

Computer

The minimum requirements for the E5505A phase noise measurement system CPU are:

- Pentium® microprocessor (2.4 GHz or higher recommended)
- 1 GB of memory (RAM)
- 40 GB hard disk
- Microsoft® Windows 7
- Super Video Graphics Array (SVGA)
- Two GPIB Interface Cards
- At least three available PCI slots (for GPIB interface card and PC digitizer card)

Power Requirements

The flexibility of the E5505A system configuration results in a significant range of power requirements, depending on the type and number of instruments in a system. Table 70 provides the maximum requirements for individual instruments so that you can determine the requirements of your specific system. It also provides the maximum current drawn by an E5505A system that contains one of each type of instrument listed in the table.

Table 70 E5505A maximum AC power requirements

Component	115 VAC	230 VAC
System maximum (one of each type of instrument below)	27 A	17 A
PC	9 A	4.5 A
Display (LCD)	1.2 A	1.2 A
N5500A test set (Opt. 001)	3 A	2 A
Downconverter	3 A	2 A
Source	~ 6 A	~ 4 A
Spectrum analyzer	~ 2.5 A	~ 1.5 A
Frequency counter	1.5 A	~ 1 A
Oscilloscope	~ 1 A	~ 0.7 A

The E5505A system is shipped with AC power cords appropriate for your location.

For information on an instrument's power line module, see the instrument's separate user's guide.

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System Interconnections

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This chapter contains information and diagrams for connecting the instruments in a racked or benchtop E5505A system.

Making Connections

Use the information in this section to connect your system hardware. It contains cable and connector tables, connection diagrams, and guidelines for making connections.

CAUTION Make all system hardware connections without AC power applied. Failure to do so may result in damage to the hardware. GPIB connections are an exception; they may be connected with power applied.

Make connections in a properly grounded environment. Agilent recommends wearing grounding wrist or foot straps. Failure to do so may result in damage to the hardware.

CAUTION *Do not* make a GPIB connection with an oscilloscope. Doing so causes the E5505A system to malfunction and may result in damage.

System Connectors

Table 71 contains the connectors and adapters for the main E5505A system instruments. It includes the type and quantity for each instrument and option. (You receive the devices specific to the instruments in your system with your shipment; you may not receive every device shown in the table.)

Table 71 E5505A connectors and adapters

Part Number	Description	N5500A Standard	N5500A Opt. 001	N5500A Opt. 201	N5501A N5502A	N5507A	N5508A	N5508A Opt. 002
0960-0053	Termination, coaxial SMA (male), 50 Ω					4	3	3
1250-0207	Termination, BNC, 50 Ω	1	1	1				
1250-0780	Adapter, Type N (male) to BNC (female)	3	2	3	1			
1250-0839	Termination, coaxial SMC (female), 50 Ω					1	1	1
1250-1200	Adapter, SMA (male) to BNC (female)		2					
1250-1250	Adapter, N (male) to SMA (female)		1		2	1		
1250-2015	Adapter, SMA (female) to BNC (male)				1			
1250-2076	Termination, coaxial SMB (female), 50 Ω					1	1	1
5061-5311	Adapter/Connector saver, 3.5 mm (female) to 3.5mm (female)		2	2		3	1	2
5813-0803	GPIB extension	1	1	1	1	1	1	1
E5505-60001	Digitizer adapter for PC	1 with E5505A system						

System Cables

Table 72 shows the E5505A system cables and their connections. Some cables are used only with specific system options; you may not receive all cables in the table. An additional GPIB cable is shipped with each optional instrument ordered.

Table 72 E5505A cables and connections

Part Number	Description	Qty	From	To
8120-2582	BNC (male) to BNC (male), coaxial, 4 feet	3	Varies with configuration and function	
8120-5370	BNC (male) to BNC (male), coaxial, 8 feet	2	Varies with configuration and function	
8120-3445	GPIB, 10834A, 1 meter	1	Test set rear panel GPIB	Downconverter rear panel GPIB
8120-3446	GPIB, 10834B, 2 meter	1	PC rear panel GPIB	Test set rear panel GPIB
E5505-80001	RF, SMA (male) to BNC (male), yellow	1	PC digitizer card adapter IN	Test set front panel ANALYZER <100 MHz OUT
E5505-80002	RF, SMA (male) to BNC (male), green	1	PC digitizer card adapter OUT	Test set rear panel CHIRP SOURCE IN
For Test Set, Opt 001				
E5505-20001	RF, semi-rigid, N-Type (male) to N-Type (male)	1	Test set front panel FROM DOWNCONVERTER	Downconverter front panel IF OUTPUT
E5505-20002	RF, semi-rigid, N-Type (male) to SMA (male)	1	Test set front panel TO DOWNCONVERTER	N5501A/2A Downconverter front panel SIGNAL
E5505-20003	RF, semi-rigid, SMA (male) to SMA (male)	1	Test set front panel TO DOWNCONVERTER	N5507A Downconverter front panel SIGNAL

Connecting Instruments

This section provides guidelines for connecting your phase noise system instruments. When reconnecting all system instruments, first connect the PC, test set, and downconverter(s). Then connect the spectrum analyzer and remaining system instruments. Add any additional asset next. Lastly, connect power cords and apply power.

1 *Without* power applied, connect the digitizer adapter to the back of the PC digitizer card, as shown in Figure 304.

Figure 304 Connect adapter to PC digitizer card

2 Connect a GPIB extension to the GPIB connector on the PC to provide adequate clearance for the cable.

3 Connect the following cables between the PC Digitizer card adapter and the test set (see Figure 305 on page 400 and Figure 306 on page 401):

- SMA (male) to BNC (male) cable between the PC digitizer card adapter's **IN** connector and the test set's front-panel connector **ANALYZER <100 MHz OUT**.
- SMA (male) to BNC (male) cable between the PC digitizer card adapter's **OUT** connector and the test set's rear-panel connector **CHIRP SOURCE IN**.

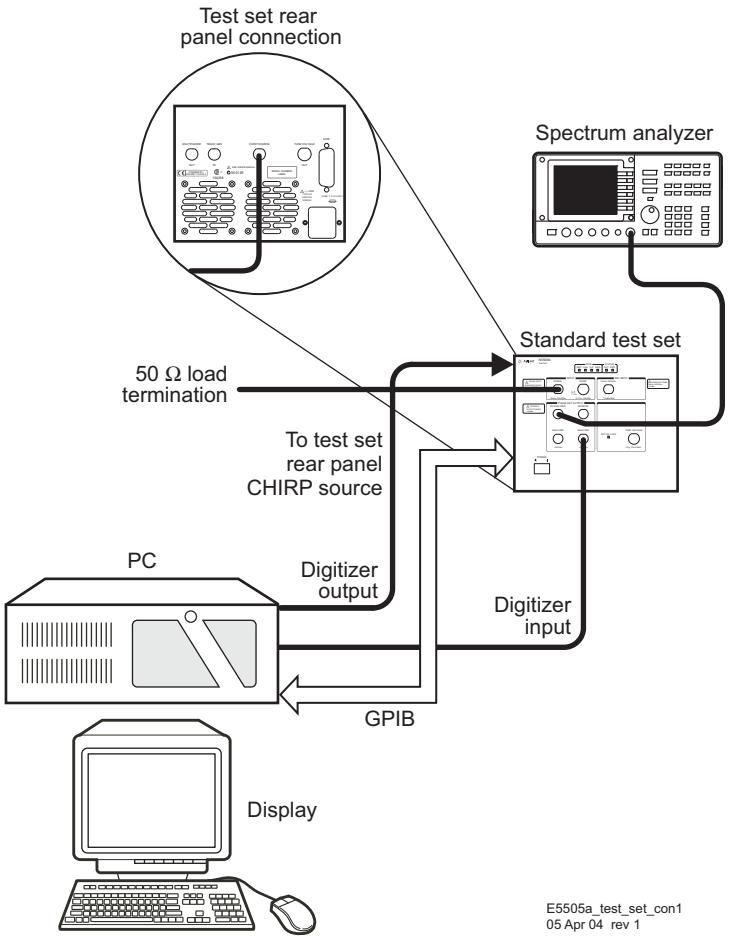

Figure 305 PC to test set connection, standard model

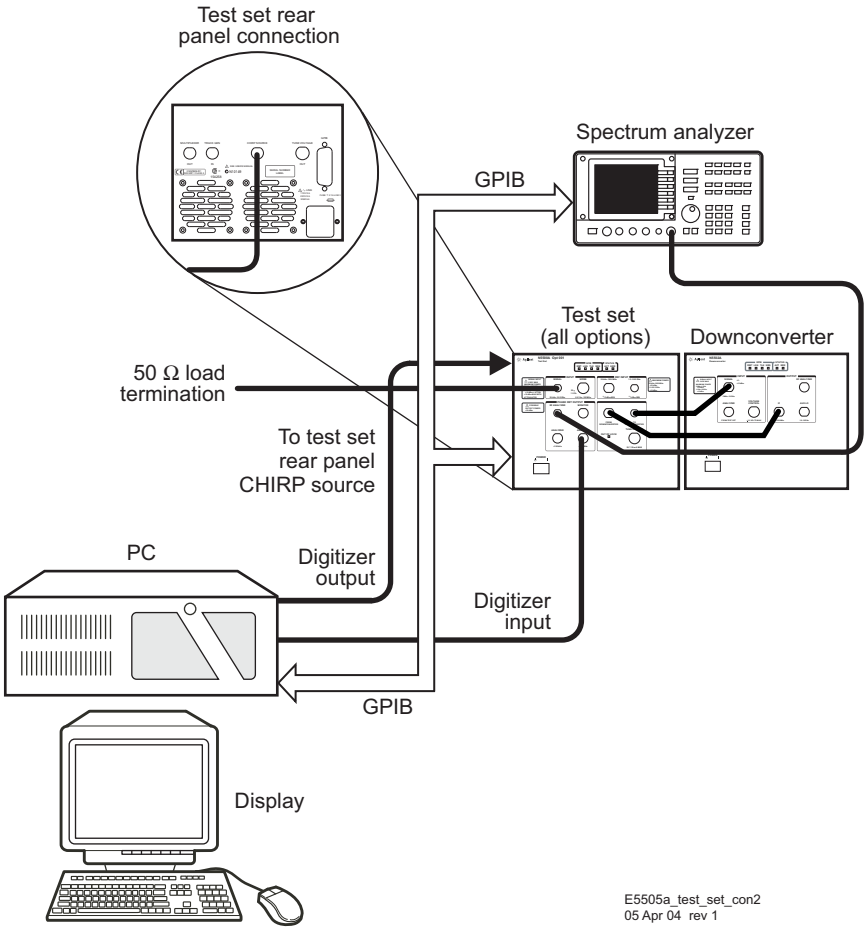

Figure 306 PC to test set (options 001 and 201) and downconverter connection

4 Connect cables to other instruments with the appropriate connectors and adapters, using the tables and diagrams in this section. (Refer to Figure 307 on page 403 through Figure 309 on page 405.)

- Install a GPIB extension on these system instruments before connecting the GPIB cable: N5500A/01A/02A/07A/08A.

CAUTION *Do not* make a GPIB connection with an oscilloscope. Doing so causes the E5505A system to malfunction and may result in damage.

NOTE For easy re-installation, label each end of each cable with the corresponding instrument connector names.

5 You may connect other assets (in addition to those supplied with the system) either at this time or after running the confidence test.

6 Lastly, connect the power cord(s) to the AC power supply.

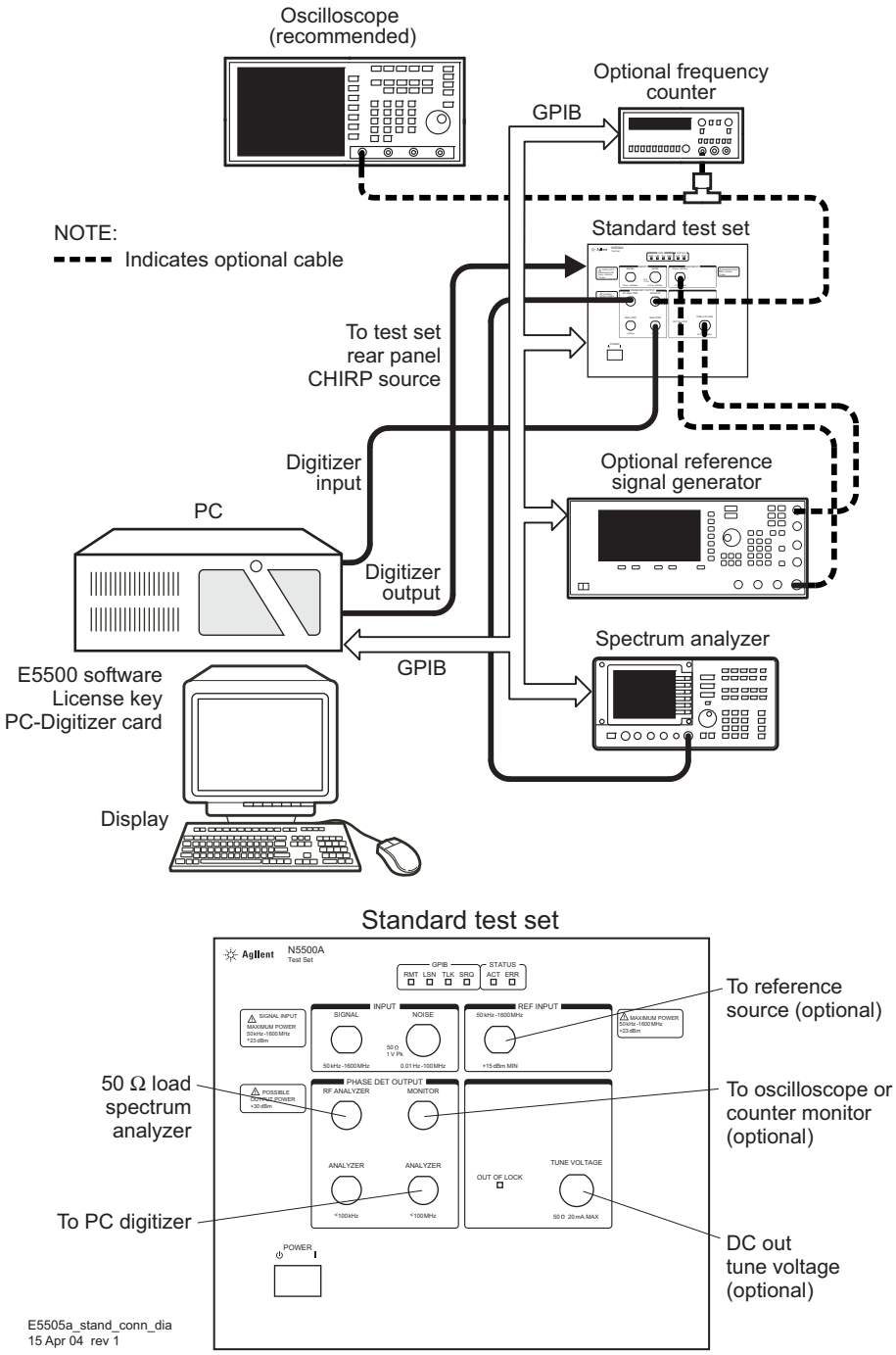

Figure 307E5505A system connections with standard test set

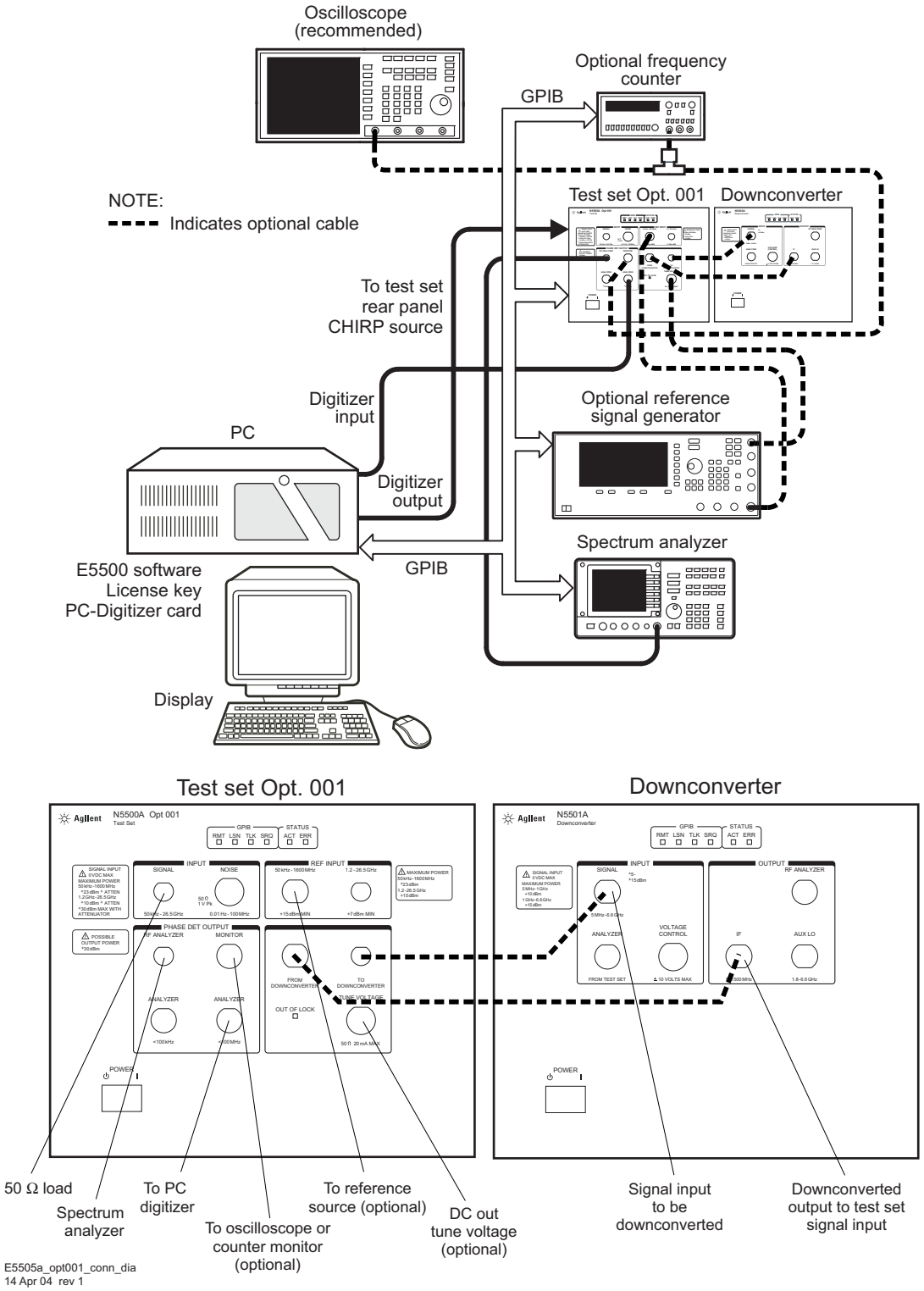

Figure 308E5505A system connections with test set option 001

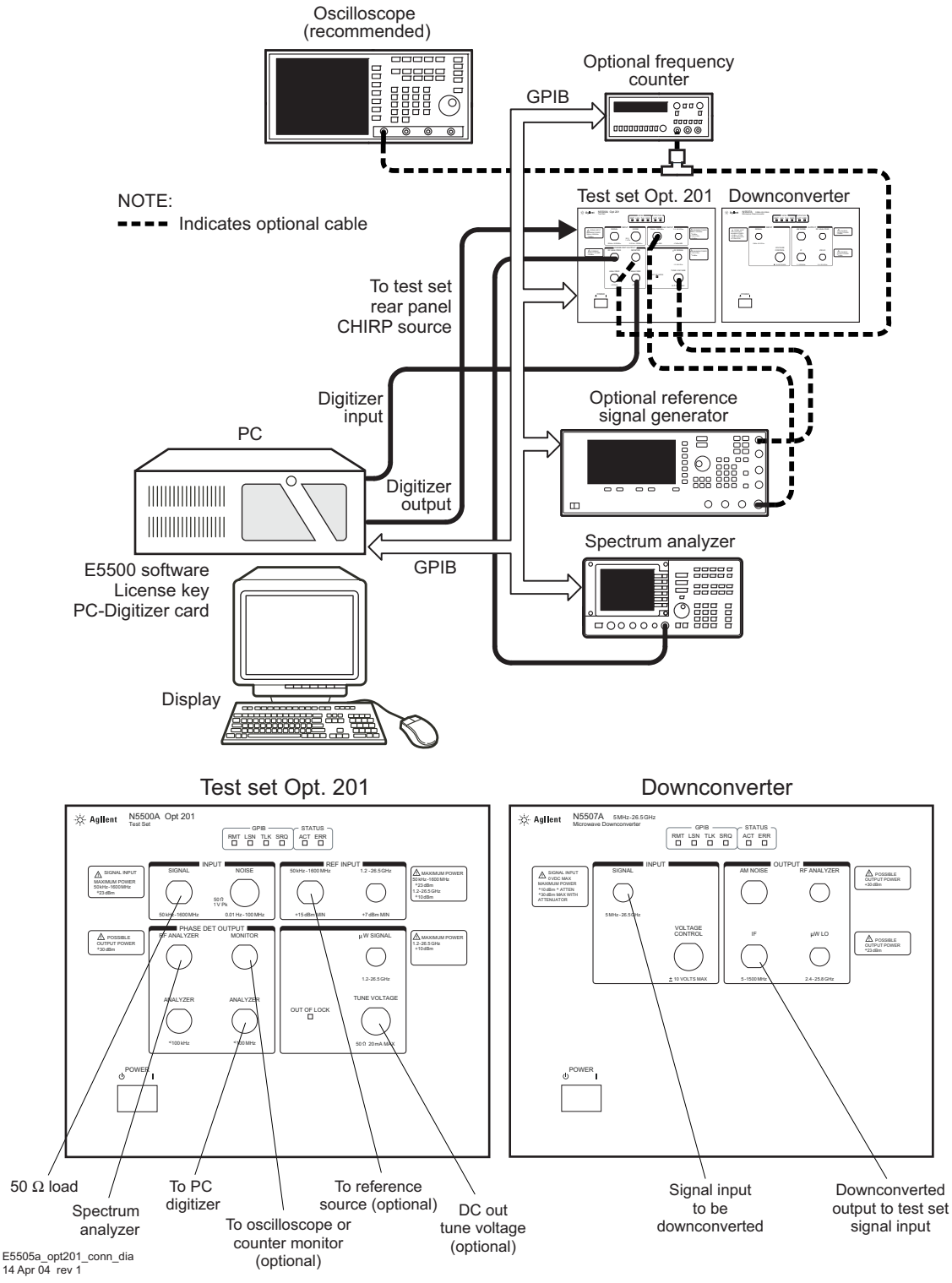

Figure 309E5505A system connections with test set option 201

19
PC Components Installation

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This chapter contains information and procedures for installing or re-installing the necessary phase noise hardware and software in an E5505A Phase Noise Measurement System PC.

Overview

Your E5505A Phase Noise Measurement System system arrives with all necessary phase noise components installed in the system PC. However, if you need to re-install the phase noise hardware and/or software in your E5505A system PC for any reason, use the procedures in this chapter. The chapter leads you through the process step-by-step. *To prevent errors in the installation process, it is important to complete the tasks in the order presented, and to complete each one before proceeding to the next.*

Installing the required phase noise software and hardware in the system PC involves the following tasks, in the order listed:

Step 1: Uninstall the current version of Agilent Technologies IO libraries

Step 2: Uninstall all National Instruments products.

Step 3: Install the National Instruments VXI software.

- Instructions: as per "Install software for the NI Data Acquisition Software."
- Accept All default settings.

Step 4: Install the National Instruments VISA runtime.

- Instructions: as per "Install software for the NI Data Acquisition Software."
- Accept All default settings.

Step 5: Install software for the NI Data Acquisition Software.

NOTE Install Windows 7 operating system, and all necessary PC-specific software and drivers, before beginning the procedures in this section. See the PC and software manufacturers' documentation for their installation requirements and procedures.

This procedure applies specifically to the PC digitizer card supplied with the N5505A system. For this and any other PC digitizer card, always follow the manufacturer's instructions.

To install the PC digitizer software

Step	Action
1 Make sure your PC and display are on.	
2 Place the manufacturer's installation DVD-R in the DVD-R drive of the PC.	• The installation wizard dialog box should automatically appear after a few seconds. If it doesn't, start it this way: • From the Start menu, select My Computer and the DVD-R drive. • Find and select the file **setup.exe.** Click OK.
3 Follow the instructions in the installation wizard.	• Accept the defaults.
4 Shutdown and power off the PC and its peripherals. Proceed to the phase noise hardware installation procedures.	• Leave the DVD-R in the drive. Once you have installed the necessary hardware and powered on the PC again, the installation wizard will lead you through completing the PC digitizer software installation process.

NOTE If you're re-installing any of the phase noise hardware and software components in the list, be sure to uninstall *all* components, then reinstall them in the order shown above.

NOTE If you encounter any problems with the installation, contact your Agilent Technologies Service Center. Contact information is in Appendix A, "Service, Support, and Safety Information."

Step 6: Hardware Installation

WARNING **Disconnect all power before removing the cover to your PC. Failure to disconnect power could result in serious injury.**

CAUTION Refer to your computer's documentation for installation safety instructions and specific instructions for opening your computer. Be sure to perform these procedures in a properly grounded environment. Agilent recommends wearing grounding wrist or foot straps. Failure to do so may result in damage to the computer.

Step 6a: Taking ESD precautions

CAUTION

The PC Digitizer and GPIB interface cards are static-sensitive devices. Wear a properly grounded wrist or foot strap while handling the cards and performing the procedures in this section. Failure to do so can result in damage to the electronic devices and assemblies involved.

While inserting the cards, be sure to hold them by the edges.

Step 6b: Preparing for Installation

You need a #1 POZIDRIV screwdriver to install hardware in the system PC.

1 Make sure that your PC and all its peripherals are powered off.

2 Disconnect the power cord from the PC.

3 Remove the cover from the PC to access the PC's expansion slots. See the PC manufacturer's documentation for instructions.

To remove the cover of the N5505A system Advantech or Kontron PC:

a Remove the top two screws on the left and right sides of the PC.

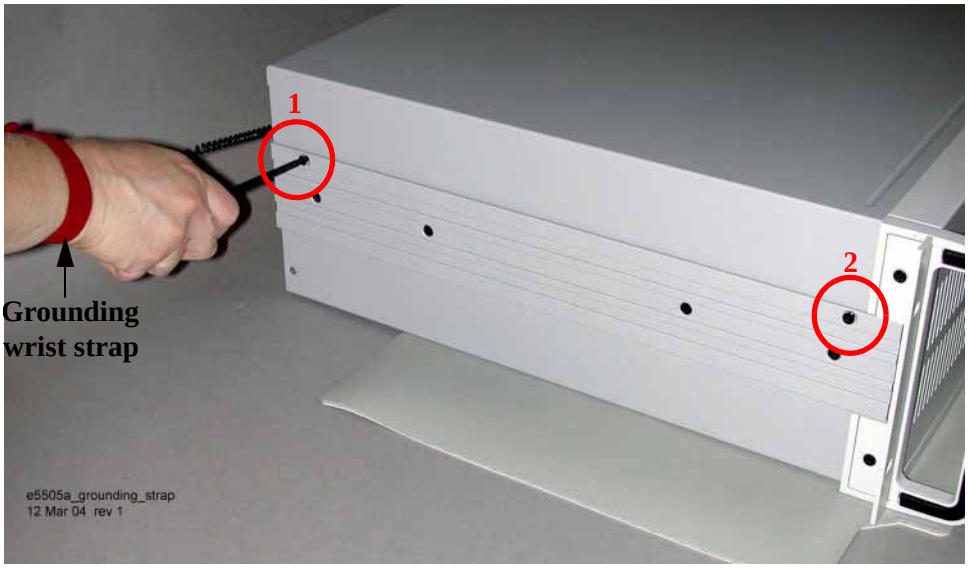


Figure 310 Remove screws from side of CPU

b Carefully slide the cover away from the front of the unit then lift it off.

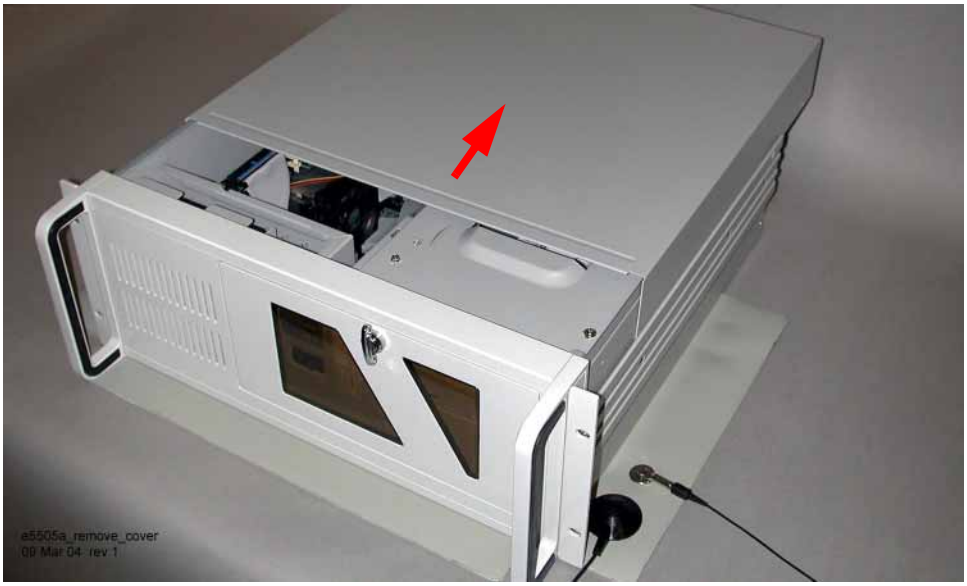


Figure 311 Slide cover off

c Uninstall the internal hold-down bar by removing the two screws that attach it and lift the bar out of the unit.

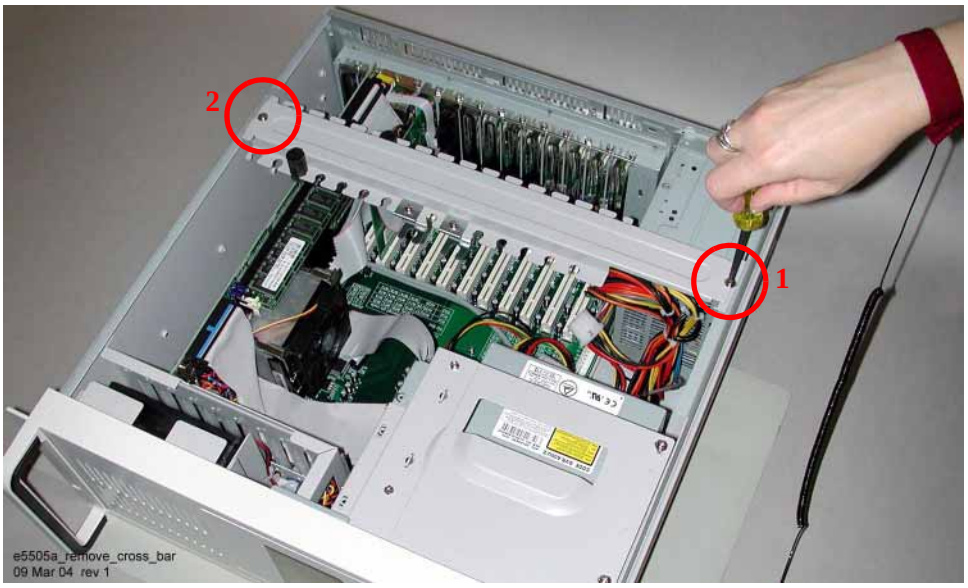


Figure 312 Remove hold-down bar

Step 6c: Accessing PC expansion slots

Figure 313 shows a view of the expansion slots vertically mounted; your computer's expansion slots may be horizontally mounted, but the process is the same.

1 Look for suitable expansion slots for both the PC digitizer card and the GPIB interface card. Choose slots that provide good external access to the PC Digitizer and GPIB interface connectors. You may want to leave an empty expansion slot between the cards for easier internal access.

2 Remove their cover plates by unscrewing the securing screw and lifting them off the slot. (Save the blank cover plates for use if the cards are removed later.)

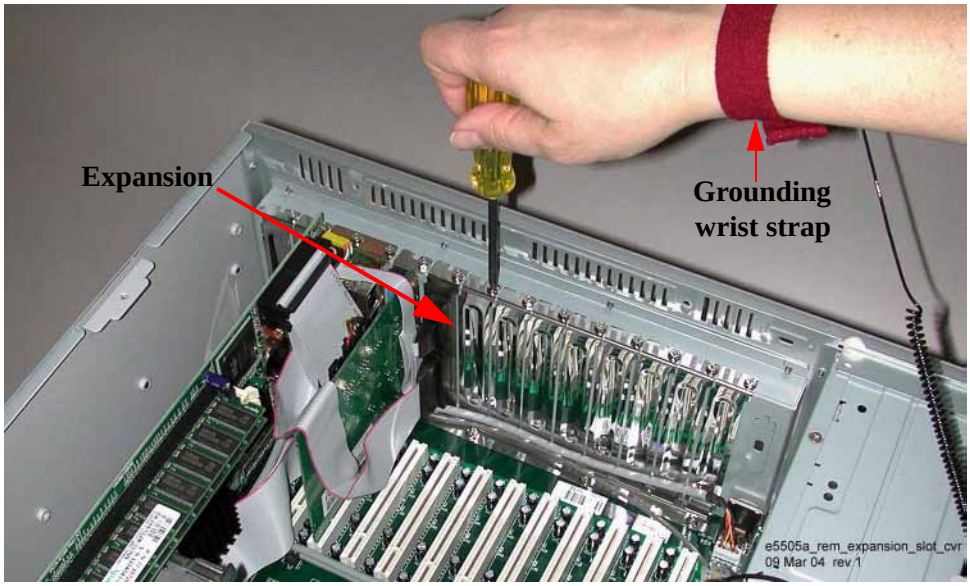


Figure 313 Vertically-Mounted expansion slots

Step 6d: Installing the PC digitizer card (PCB)

Perform this installation with the system PC disconnected from AC power. Figure 314 shows a PC digitizer card.

Figure 314 PC digitizer card

1 Insert the PC digitizer card edge connector into the PCI connector. Gently rock the card into place; do not force it. Make sure the card is fully seated by pushing firmly on the edge of the card with the palm of your hand.

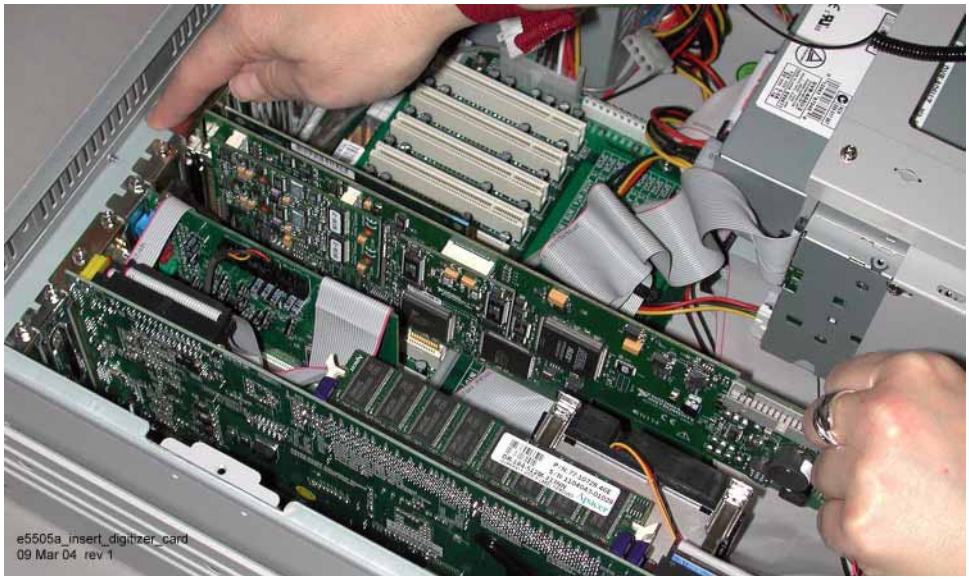


Figure 315 Insert PC digitizer card

2 Screw the mounting bracket to the PC back-rail panel to secure the card.

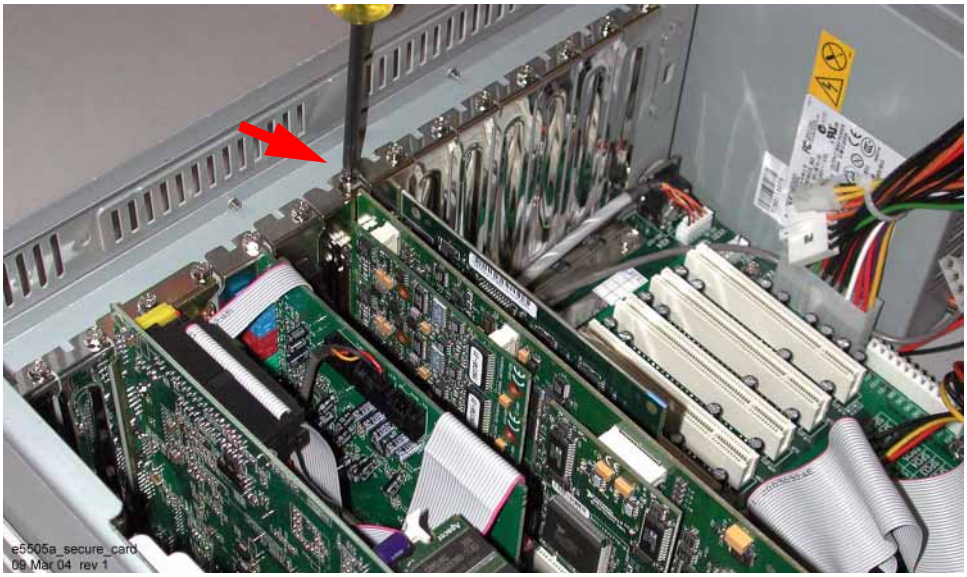


Figure 316 Secure card with screw

3 Connect the digitizer adapter to the back of the PC digitizer card, as shown in Figure 317.

Figure 317 Connect adapter to PC digitizer card

While you have access to the expansion slots, also install the second piece of phase noise system hardware, the GPIB interface card.

Step 6e: Installing the GPIB interface card (PCB)

NOTE Only Agilent Technologies PCI GPIB cards, 82350, are supported.

Perform this installation with the PC disconnected from AC power. Figure 318 shows a GPIB interface card.

Figure 318GPIB interface card

1 Insert the GPIB card in the PCI connector. Gently rock the card into place; do not force it. Make sure the card is fully seated by pushing firmly on the edge of the card with the palm of your hand.

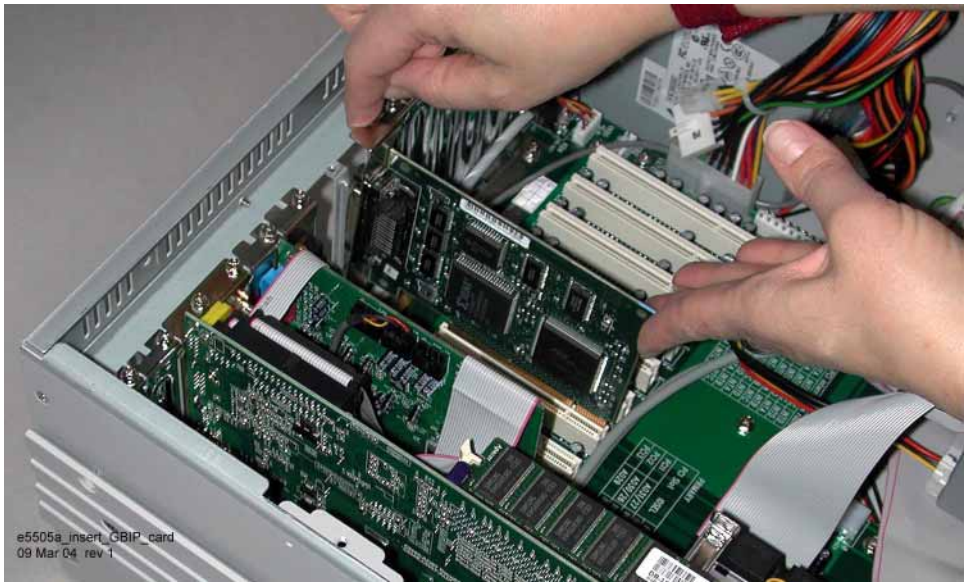


Figure 319 Insert GPIB card

NOTE You may need a GPIB connector extender to provide adequate clearance between the GPIB cable and the computer chassis.

2 Screw the mounting bracket to the PC back-rail panel to secure the card.

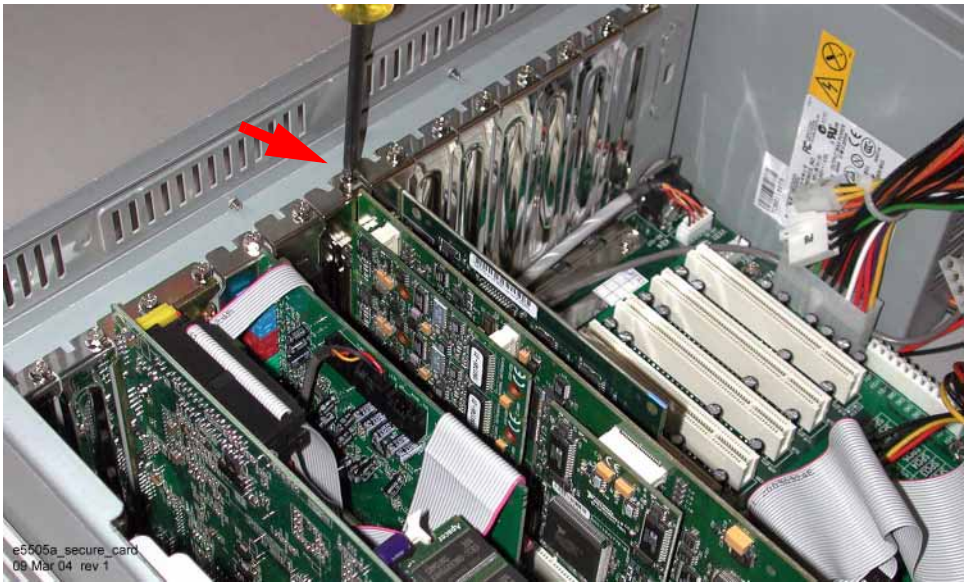


Figure 320 Secure card with screw

3 Replace the PC cover as described in the manufacturer's documentation. For the system's Advantech or Kontron PC, re-install the hold-down bar (with additional rubber bumpers if desired), then replace the cover.

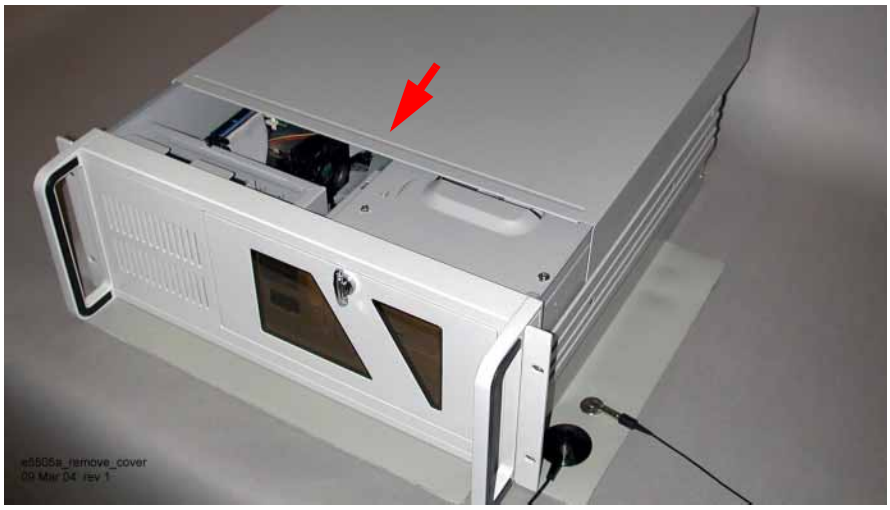


Figure 321 Replace cover

Step 7. Finalize National Instruments Software Installation.

When you power on the PC again, the installation wizard leads you through a few last steps of installing the National Instruments software.

To finish the National Instruments software installation:

1 Reconnect the power cord to the PC and the AC power supply.

2 Power on the PC and the display.

3 Follow the instructions in the installation wizard.

4 *Do **NOT*** restart the PC at this time.

Step 8: System Interconnections

Use the information in this section to make connections between the system PC and the N5500A test set.

Connectors

Table 73 contains the connectors on the main N5505A system instruments.

Table 73 E5505A connectors and adapters

Part Number	Description	N5500A Standard	N5500A Opt. 001	N5500A Opt. 201	N5501A N5502A	N5507A	N5508A	N5508A Opt. 002
0960-0053	Termination, coaxial SMA (male), 50 Ω					4	3	3
1250-0207	Termination, BNC, 50 Ω	1	1	1				
1250-0780	Adapter, Type N (male) to BNC (female)	3	2	3	1			
1250-0839	Termination, coaxial SMC (female), 50 Ω					1	1	1
1250-1200	Adapter, SMA (male) to BNC (female)		2					
1250-1250	Adapter, N (male) to SMA (female)		1		2	1		
1250-2015	Adapter, SMA (female) to BNC (male)				1			
1250-2076	Termination, coaxial SMB (female), 50 Ω					1	1	1
5061-5311	Adapter/Connector saver, 3.5 mm (female) to 3.5mm (female)		2	2		3	1	2
5813-0803	GPIB extension	1 with E5505A System, or 2 for use with Agilent Technologies E5500 SCPI Remote Interface GPIB slave Port						
E5505-60001	Digitizer adapter for PC	1 with E5505A system						

Making Connections

1 Connect the following cables between the PC Digitizer card adapter and the test set:

- SMA (male) to BNC (male) cable between the PC digitizer card adapter's **IN** connector and the test set's front-panel connector **ANALYZER <100 MHz OUT**.
- SMA (male) to BNC (male) cable between the PC digitizer card adapter's **OUT** connector and the test set's rear-panel connector **CHIRP SOURCE IN**.

2 Refer to Figure 322 below and Figure 323 on page 420 for examples of system interconnections.

NOTE For easy re-installation, label each end of the cables with the corresponding instrument connectors.

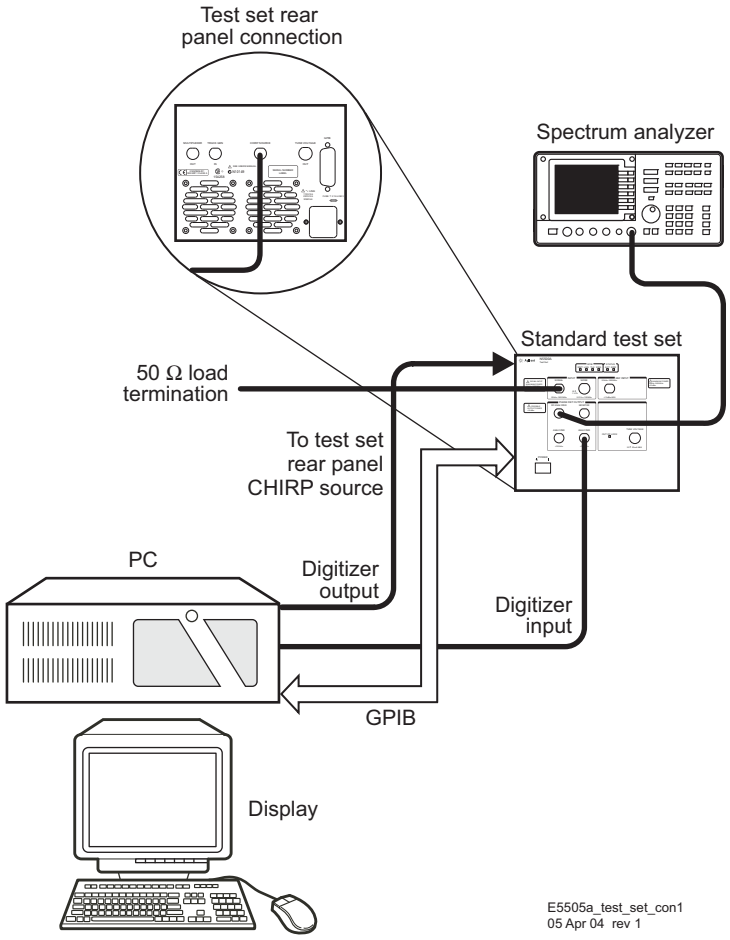


Figure 322 Test set connection, standard model

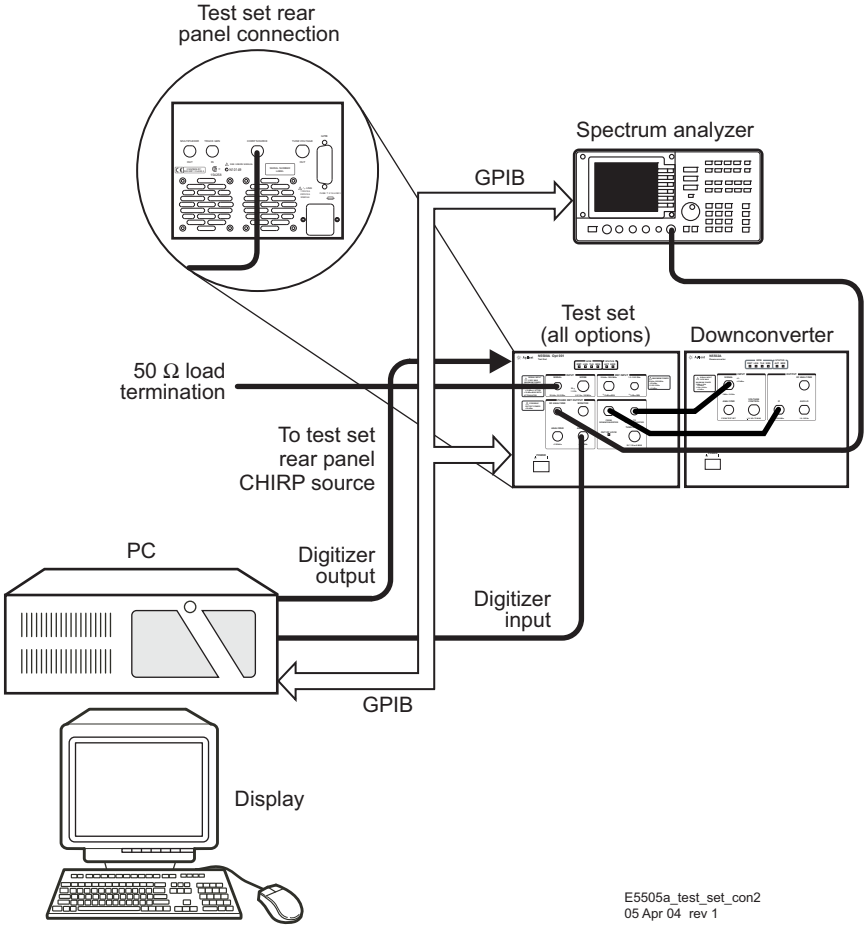


Figure 323 Test set (options 001 and 201) and downconverter connection

Step 9: Install Microsoft Visual C++ 2008 Redistributable Package use default settings

Step 9a: Install Agilent IO Libs

Step 9b: Run Agilent Connection Expert

Step 10: Install the Agilent I/O Libraries

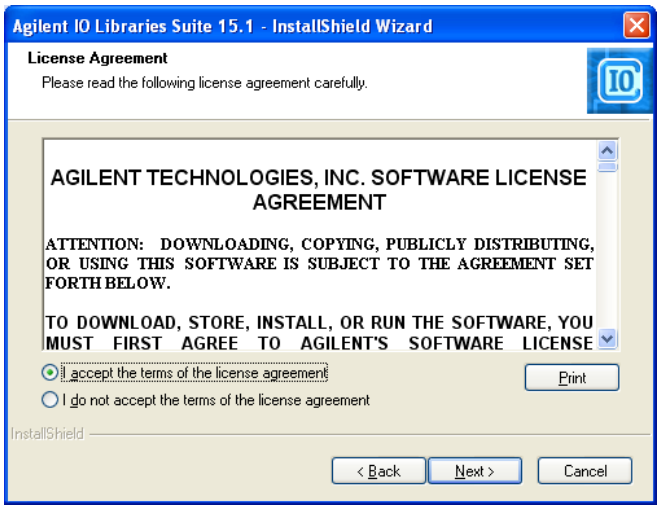
Step 10a: Install Agilent IO Libs

The Agilent I/O libraries are on the E5500 Phase Noise Measurement software DVD-R. Use this procedure to install them on the PC.

NOTE If you re-install or upgrade the Agilent I/O Libraries at a later date, you must also re-install the E5500 Phase Noise Measurement Software *after* the I/O Library installation.

To install the Agilent I/O libraries

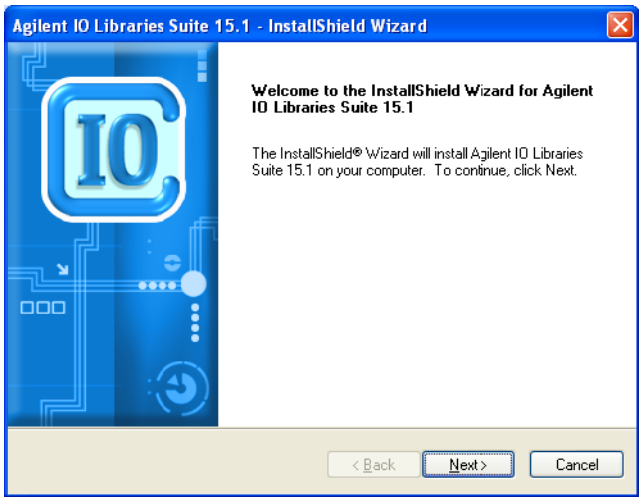
Step	Notes
1 Make sure your PC and display are on.	
2 Place the E5500 Phase Noise Measurement System software DVD-R in the PC's DVD-R drive.	• A window appears with the contents of the CD. If the window doesn't appear, navigate to the folder using the menu selections Start/Run/Browse.
3 Double-click on the folder IO_Libraries.	



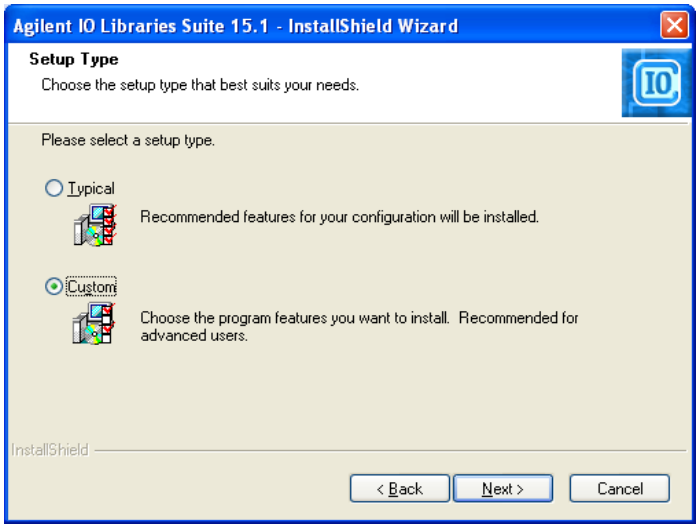
4 After double clicking the execute file, the install wizard shield should appear.	
a Read and review Agilent Terms and conditions. If you accept them, then select Accept, followed by Next	

To install the Agilent I/O libraries (continued)

Step	Notes



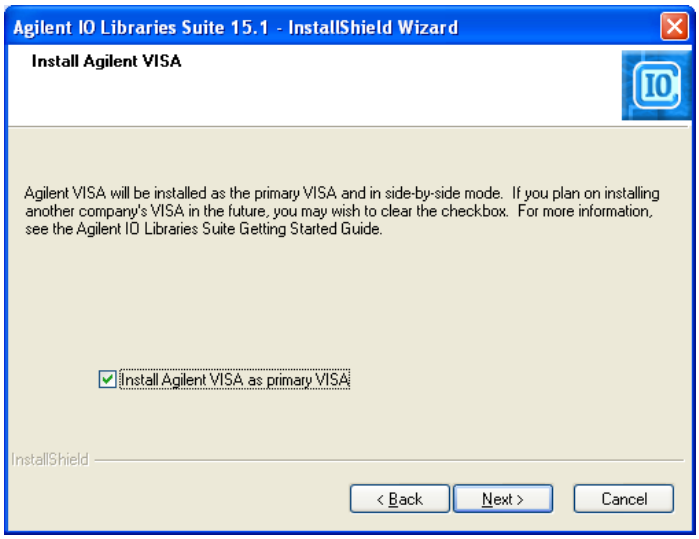
5 Select Custom Installation and follow the instructions in the **Setup.exe** wizard.



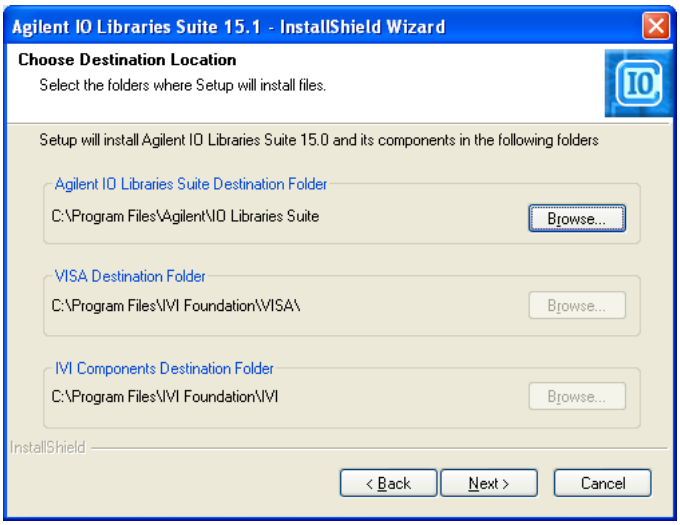
To install the Agilent I/O libraries (continued)

Step	Notes

6 Select Agilent VISA as the Primary VISA

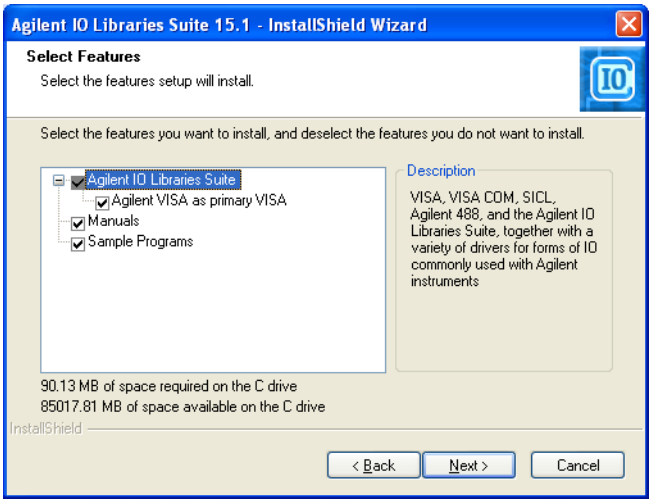


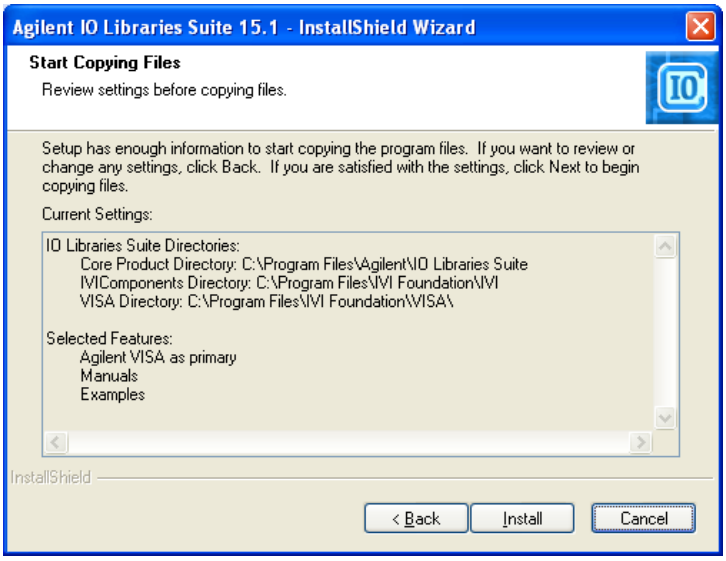
7 Accept Default settings for the remainder of the screens.



To install the Agilent I/O libraries (continued)

Step	Notes





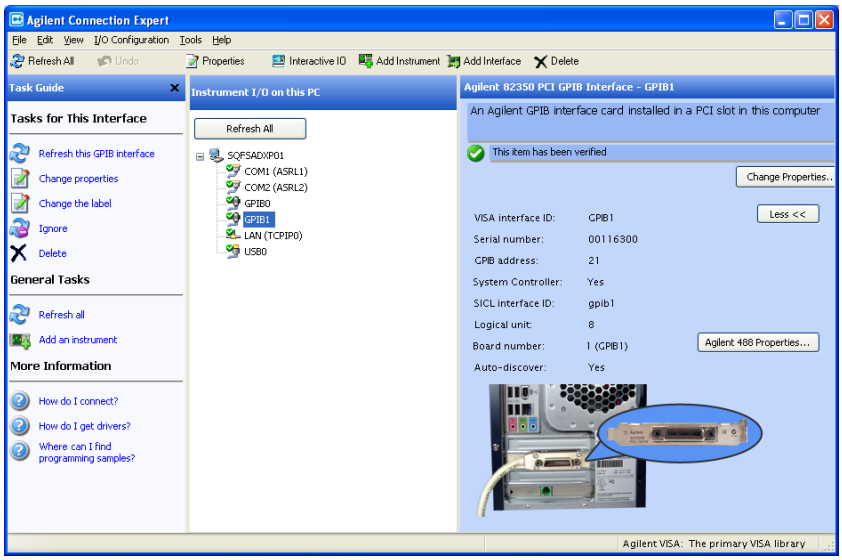
8 This will rename the current visa file in "C:\WINDOWS\system32" to "visa32.dll.bak" Continue with the installation.

9 If the PC has not gone through a reboot, then reboot it.

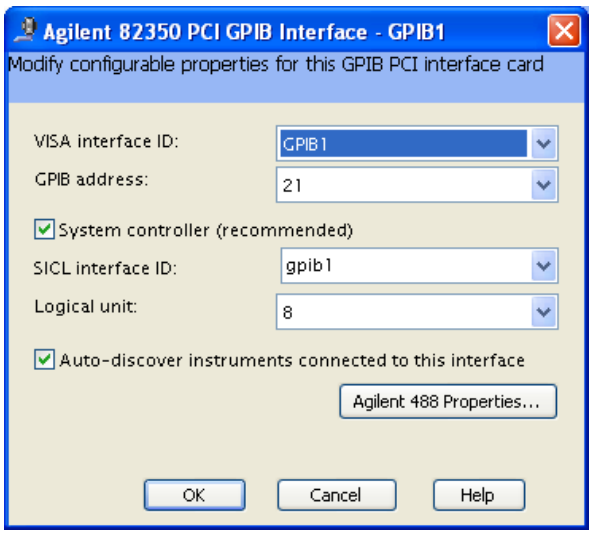
10 Navigate to the "C:\WINDOWS\system32" directory and rename the "visa32.dll.bak" file to "nivisa32.dll".

Step 10b: Run the Agilent Connection Expert

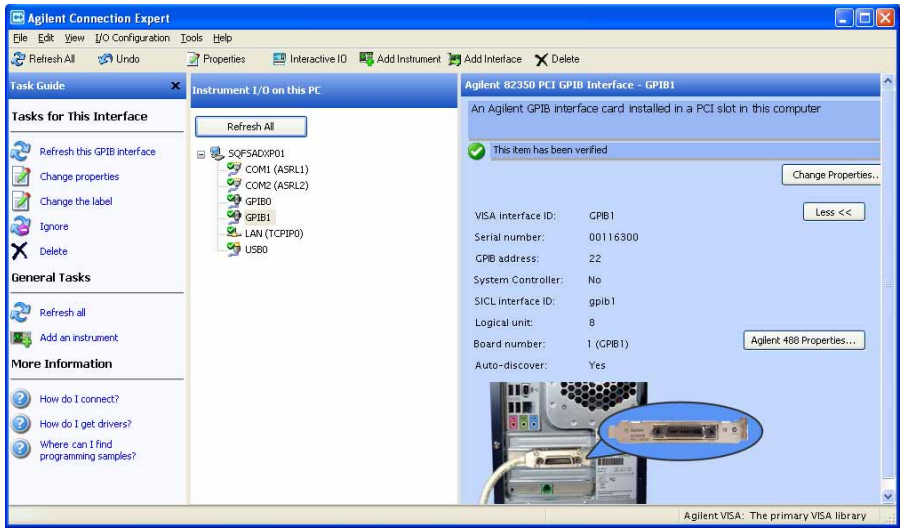
Step	Notes



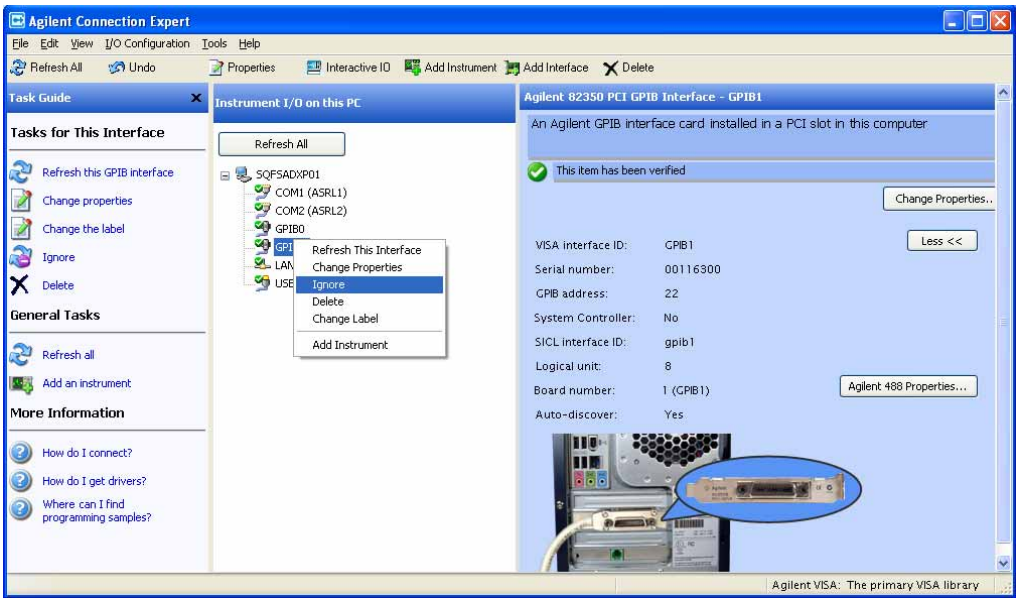
1 Select the second of the two GPIB Cards, "GPIB1". Click the "Change Properties" button. The following screen will appear:



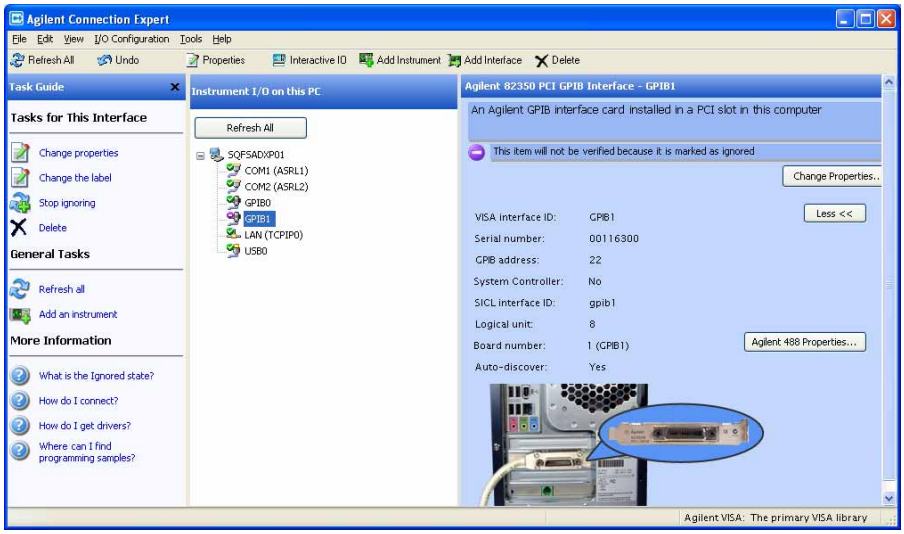
Step	Notes
2 Change the GPIB address to “22”, and unselect the “System Controller” tick box. Then click the “OK” button. You may be asked to re-boot the PC.	



3 Right click the second of the two GPIB Cards, “GPIB1”, and select the “Ignored” state.



Step	Notes
4 The ACE display should now look like…	



Step 11: Install the E5500 Phase Noise Measurement software.

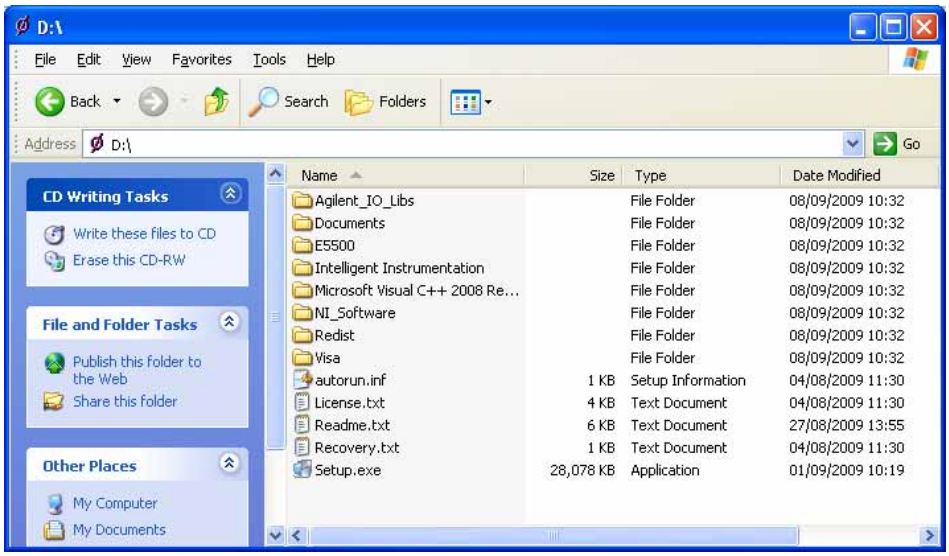
Use this procedure to re-install the E5500 software on your system PC.

To install the E5500 software

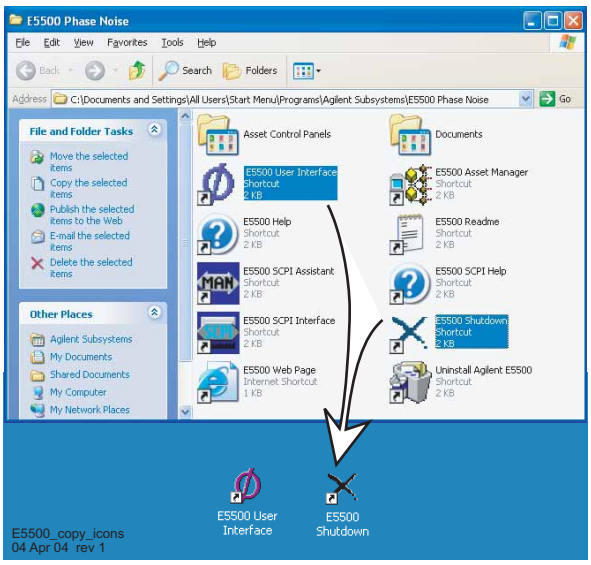
Step	Note
1 Make sure your PC and display are on and the E5500 Phase Noise Measurement System software DVD-R is in the PC's DVD-R drive.	
2 Navigate to the DVD-R contents folder using the menu selections Start/Run/Browse, and select the DVD-R drive.	• You can also open and close the DVD-R drive to cause a window with the DVD-R contents folder to appear.
3 Double-click on Setup.exe.	

To install the E5500 software (continued)

Step	Note



4	Follow the instructions in the installation wizard.	• Accept the default settings.
5	When finished, double-click the **E5500 Phase Noise** folder now on the PC desktop to open it.	• The software places the **E5500 Phase Noise** folder on the desktop as part of the installation process.
6	Copy the **E5500 User Interface** (UI) shortcut and the **E5500 Shutdown** shortcut to the PC desktop.	• This provides easy access to the E5500 software and the Shutdown utility.



To install the E5500 software (continued)

Step	Note
7 Restart the PC.	

Step 12: Asset Configuration

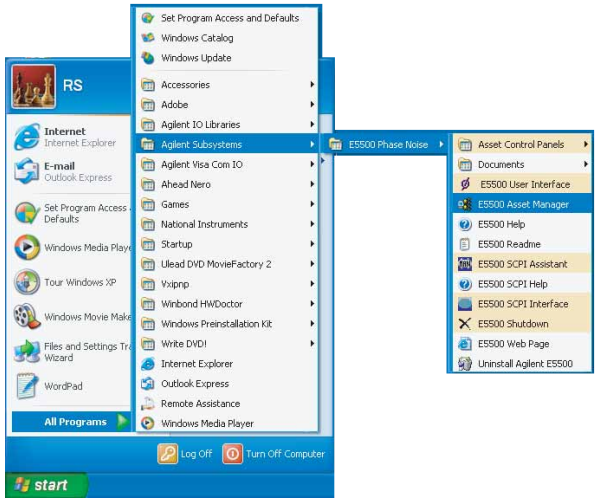
An *asset* is any piece of hardware that you want to configure for system use (N5500A, for example). An *asset role* is the general category of the hardware (test sets, downconverters, counters, and so on.) In the E5505A phase noise system, the Asset Manager serves to configure the system instruments. This section describes how to set up and use the Asset Manager.

Setting Up Asset Manager

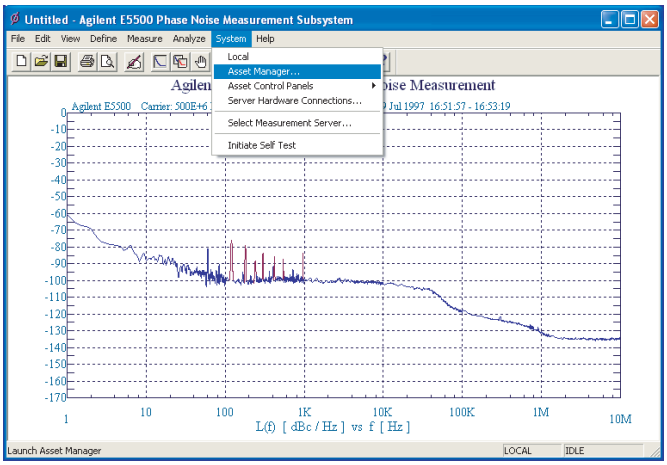
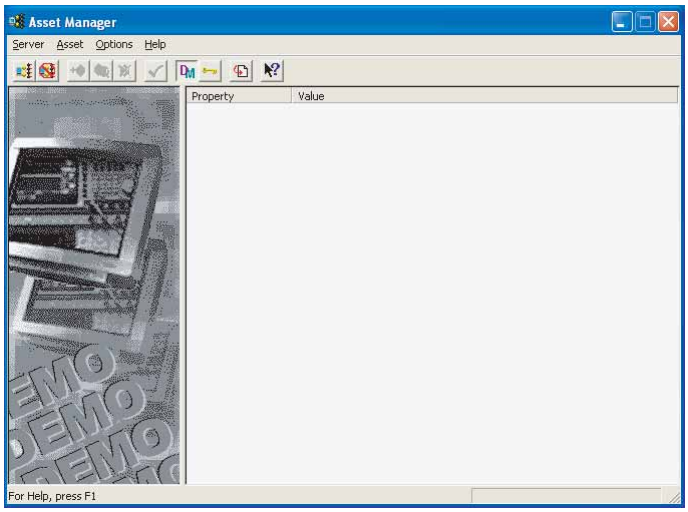
Before you use the Asset Manager to configure your system instruments, you may need to take it out of Demo Mode. (Asset Manager runs in Demo Mode on initial installation or if it is installed on a PC to which no system instruments are attached.) You must invoke the Asset Manager to determine if it is in Demo Mode.

To set up Asset Manager

Step	Note
1 Navigate to the Asset Manager by selecting Start/Programs/Agilent Subsystems/E5500 Phase Noise/E5500 Asset Manager.	• You can also invoke the Asset Manager from the E5500 software main menu. From the menu, select System/Asset Manager.



To set up Asset Manager (continued)

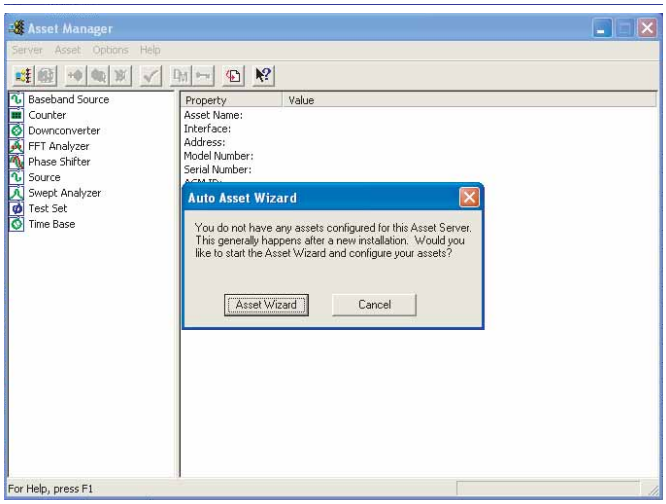
Step	Note
	
2 From the menu, select Options and deselect Demo Mode.	• If the Asset Manager is in Demo Mode, the left pane shows a graphic with the word DEMO. If it is not in Demo Mode, the left pane shows a list of assets.
	
3 Close the Asset Manager.	

NOTE When Asset Manager is invoked from the E5500 main menu, you must restart the E5500 software for any configurations changes to take effect.

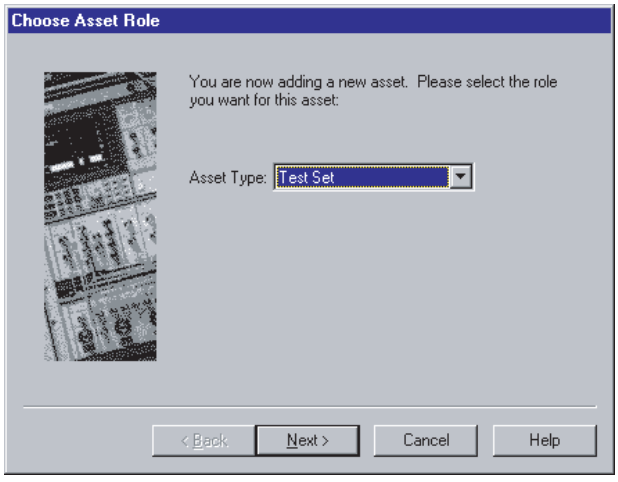
Configuring the Phase Noise Test Set

Now that you have taken the Asset Manager out of Demo Mode, use it to configure an instrument. This procedure shows you how to configure the phase noise test set.

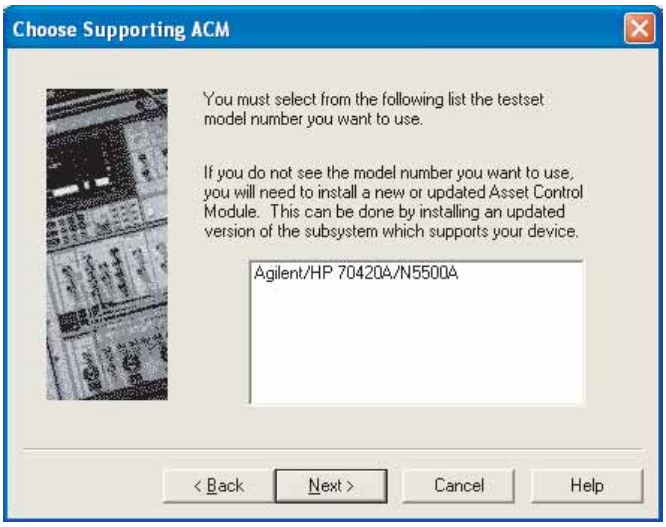
1 Double-click on the E5500 Phase Noise desktop shortcut.	• This invokes the E5500 software and the main phase-noise-graph screen appears.
2 From the menu, select System/Asset Manger.	• This invokes the Auto Asset Wizard.
3 Click on **Asset Wizard** on the Auto Asset Wizard dialog box.	



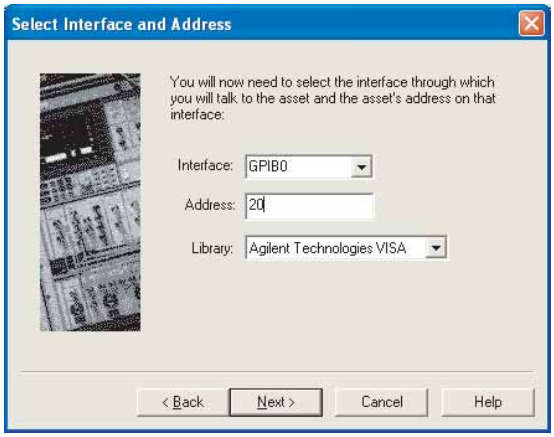
4 Select **Test Set** from the Asset Type drop down list and click **Next.**	• In the **Choose Asset Role** box



5 Confirm that Agilent/HP 70420A/N5500A appears in the pane, then click **Next**.	• In the **Choose Supporting ACM** box



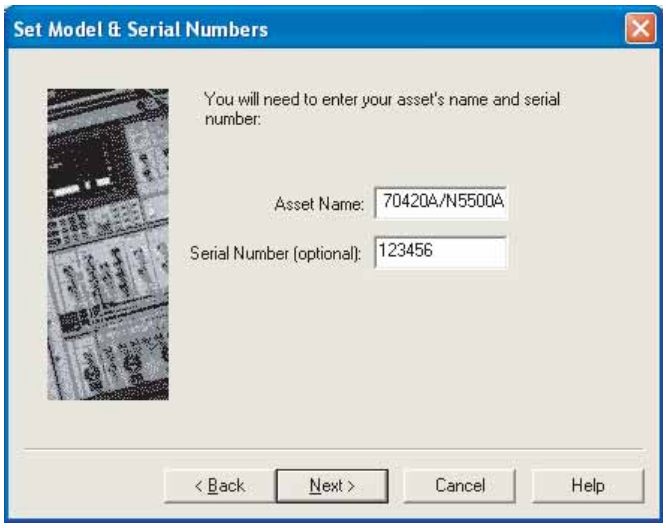
6 In the Interface field, select **GPIBO** from the pull-down list.	• In the **Select Interface and Address** box • Table 74 on page 438 shows the default device addresses.
7 In the Address field, type **20**, the default address for the test set.	
8 In the Library field, keep the default and click **Next**.	• The Library field does not apply to this example. It applies specifically to the GPIB interface card.



9 Type **Agilent N5500A** or **Agilent 70420A**, in the Asset Name field, depending on your model.	• In the **Set Model & Serial Numbers** box

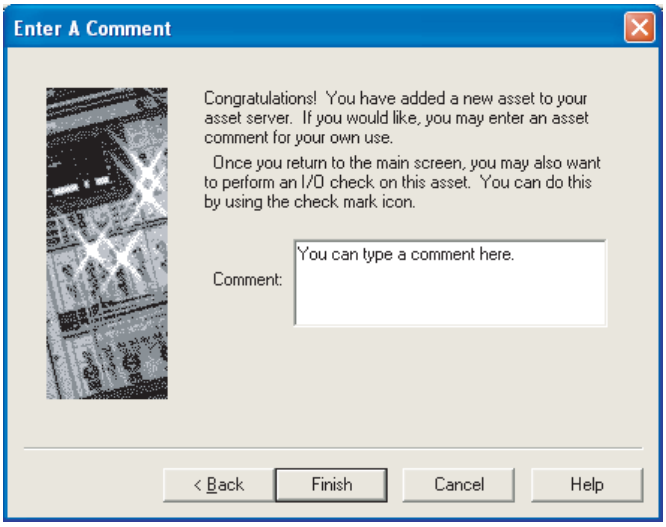
10 Type the serial number in the Serial Number field and click **Next.**

- The serial number of the N550A test set is found on the rear panel. On the 70420A it is found below the front panel.
- This entry is optional.



11 Type a comment in the Comment field, if desired.

- The comment associates itself with the asset you have just configured.

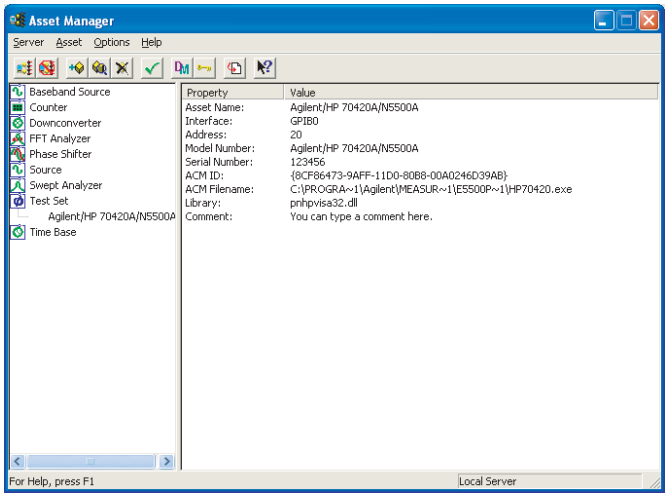


12 Click **Finish.**

- The Asset Manager window appears.

13 View the test set information in the Asset Manager window and confirm that it is correct.

- The left pane shows the list of asset roles and assets. The right pane shows the asset information. The right pane is information only. The left pane is active.



14 To change information about an asset, double-click on the asset in the left pane and change the information in the box that appears.

You have just used the Asset Manager to configure the N5500A test set. The process for configuring any asset is essentially the same. Repeat this procedure for all of the assets that you wish to add to your N5505A system.

You must add the test set and the PC digitizer to perform the confidence test (see “Performing a Confidence Test" on page 39). The PC digitizer configuration procedure follows on page 435.

Table 74 on page 438 contains the default GPIB addresses for the instruments in the system.

Configuring the PC Digitizer

This procedure shows how to configure the PC Digitizer using Asset Manager Wizard from within the Asset Manager. This is the most common way to add assets.

1 From Asset Manager click **Asset,** then click **Add.** See Figure 324.

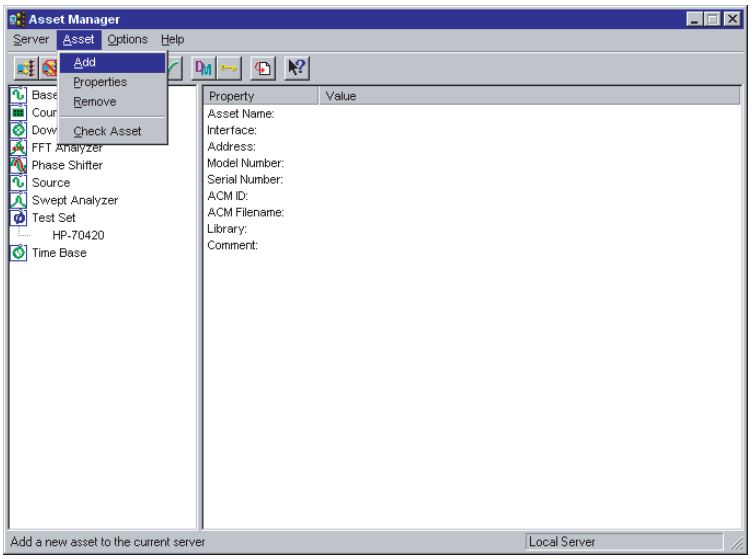


Figure 324 Add assets

2 From the **Asset Type** pull-down list (Figure 325 on page 435), select **FFT Analyzer,** then select **Next.**

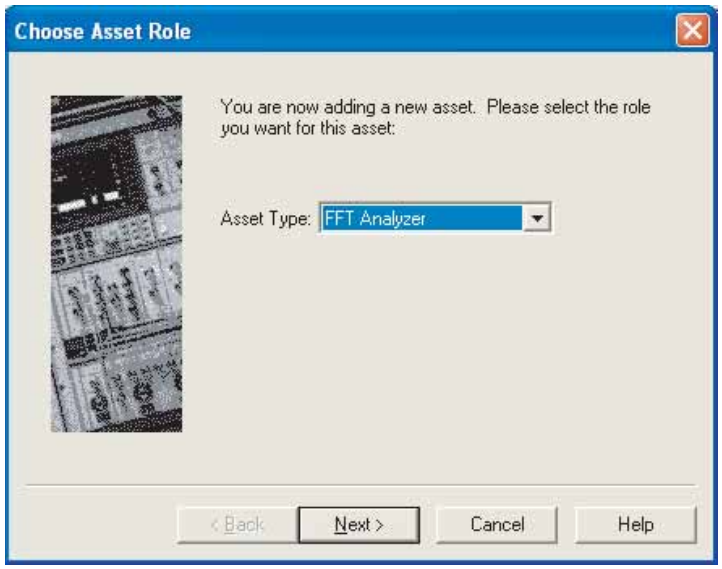


Figure 325 Choose asset type

3 In the **Choose Supporting ACM** dialog, click on **II PCI20428W-1,** then click the **Next** button. See Figure 326.

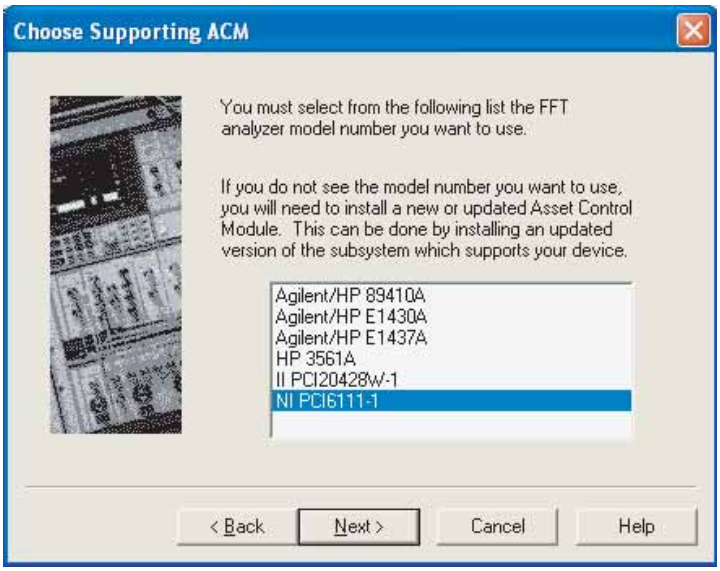


Figure 326 Select supporting ACM

4 In the **Select Interface and Address** dialog:

a Select **PCI** From the **Interface** pull-down list.

b Type 320, the default address for the II20428 PC Digitizer, in the **Address** box. Table 74 on page 438 shows the default device addresses.

c The **Library** pull-down list does not apply to this example. It applies specifically to either the Agilent GPIB or the National GPIB interface cards.

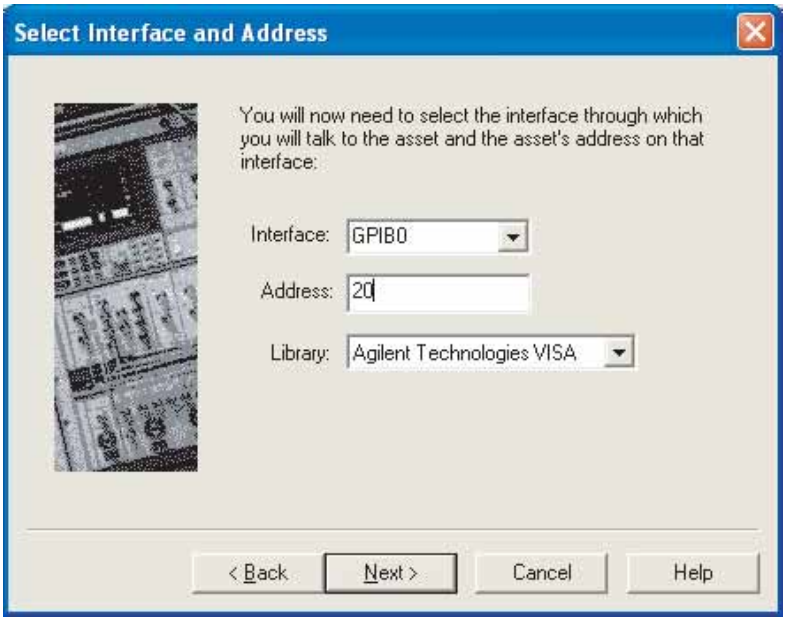


Figure 327 Choose the interface and address for the PC digitizer

Default GPIB addresses

Table 74 shows the default GPIB address for each instrument in the system.

Table 74 Default GPIB addresses

Instrument	GPIB Address
Test set	20
Downconverter	28
Microwave downconverter	28
RF analyzer	17
FFT analyzer (PC digitizer card)	1
FFT analyzer (89410A)	18
Source # 1	19
Source # 2	23
Counter	3
Agilent E1430 VXI digitizer[1]	129
Agilent E1437 VXI digitizer[1]	192
Agilent E1420B VXI counter[1]	48
Agilent E1441 VXI ARB[1]	80
Agilent GPIB slave Port	22

1 The E5500 software supports this instrument although it is not part of the standard E5505A system.

CAUTION If an address is a single digit address, for example (3), do not add a leading zero (03) to the address. The phase noise software treats these (3 and 03) as different addresses.

5 Select **Next**.

6 In the **Set Model & Serial Numbers** box (Figure 328):

   a Type **II PCI20428W-1** in the **Asset Name** box.

   b Type the serial number for your PC Digitizer in the **Serial Number (optional)** box.

7 Select **Next.**

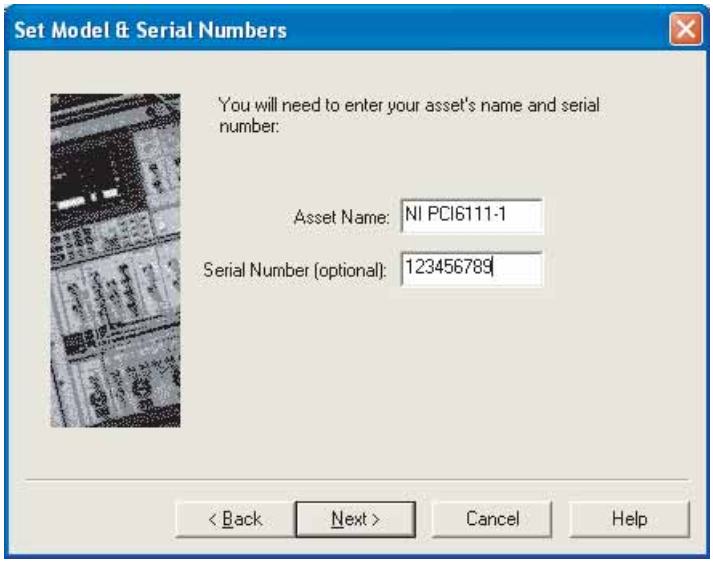


Figure 328 Choose model and serial number

8 From the **Baseband Source** pull-down list in the **Select FFT Analyzer Options** box, select (**internal)**. See Figure 329. This designates the noise source on the PC Digitizer board as the noise source to be used for loopsuppression verification suppression verification.

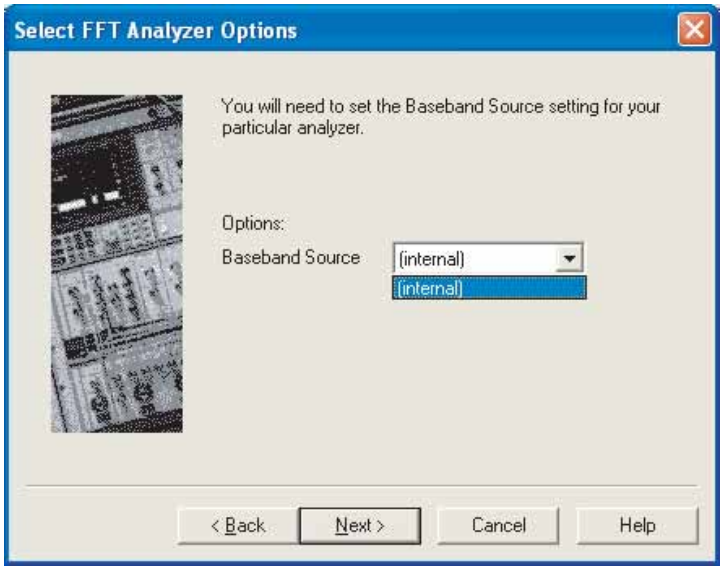


Figure 329 Select **(internal)** in baseband source

9 Click the **Next** button.

10 You can type a comment in the **Enter a Comment** box (Figure 330). The comment associates itself with the asset you have just configured.

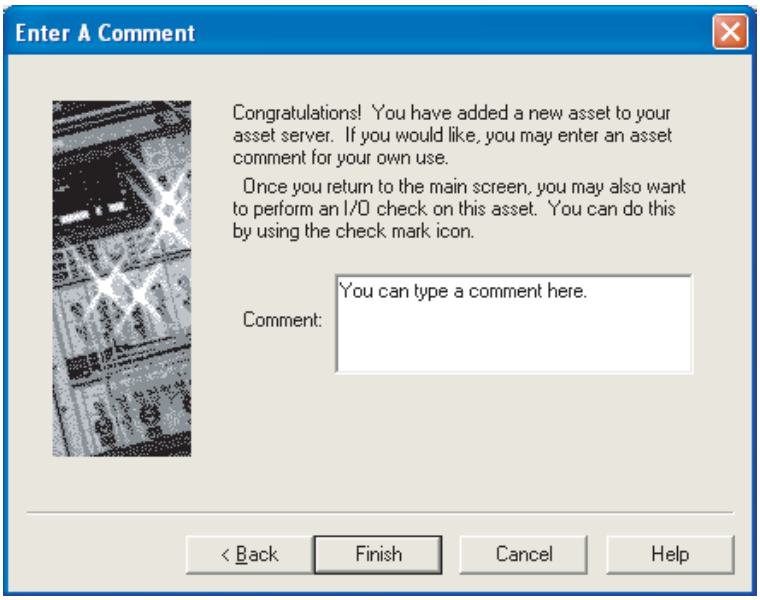


Figure 330 Enter a comment about the configured asset

11 Click the **Finish** button. The Asset manager window appears. See Figure 331.

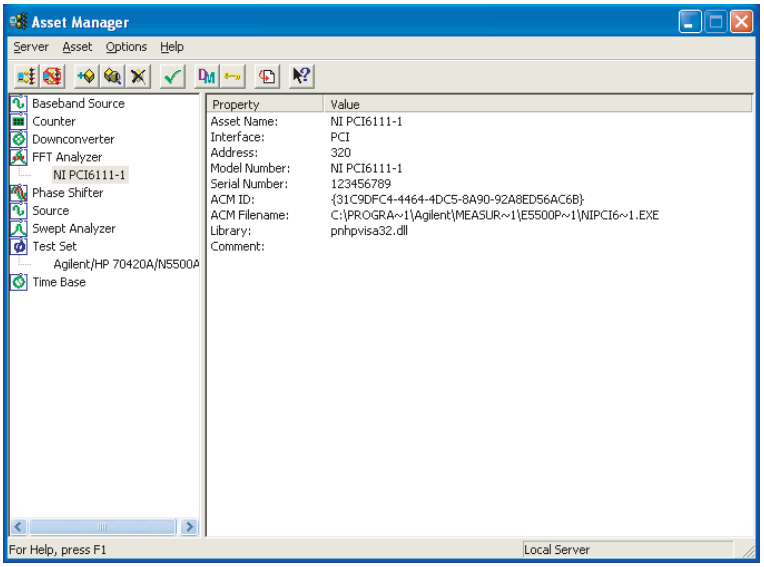


Figure 331 Asset manager screen showing configured PC Digitizer

You have just used the Asset Manager to configure the PC digitizer. The process for configuring the test set and PC digitizer is the same process you use to add software-controlled assets to the phase noise measurement system.

Configuring the Agilent E4411A/B (ESA-L1500A) Swept Analyzer

1 To configure the E4411A/B Swept Analyzer, follow the same steps you used to configure the test set. (Refer to "Configuring the Phase Noise Test Set" on page 431.)

2 In the Select Interface and Address box, use 8, the default GPIB address for the E4411A/B. (Table 74 on page 438 contains the default GPIB addresses for the system instruments.)

3 Click **Server,** then click **Exit** to exit the Asset Manager.

Step 13: License Key for the Phase Noise Test Set

Use this procedure to enter the keyword for your phase noise test set.

NOTE If you have ordered a preconfigured phase noise system from Agilent Technologies, skip this step and proceed to "Powering the System On" on page 36.

1 Make sure your computer and display are on.

2 Referring to Figure 332, navigate to the **E5500 Asset Manager.**

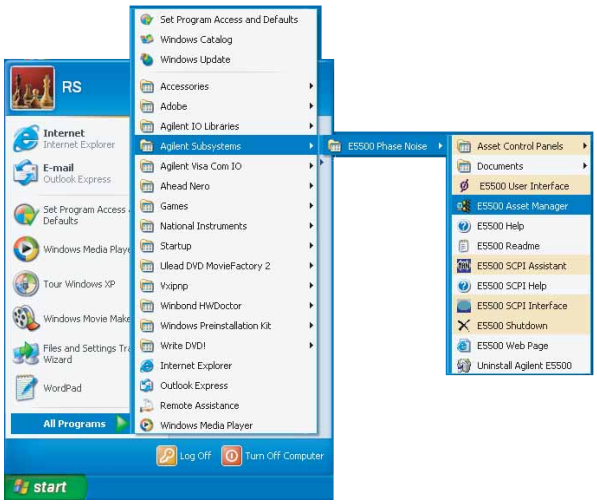


Figure 332 Navigate to E5500 asset manager

3 Click **Options,** and then click **License Keys**. See Figure 333 on page 442**.**

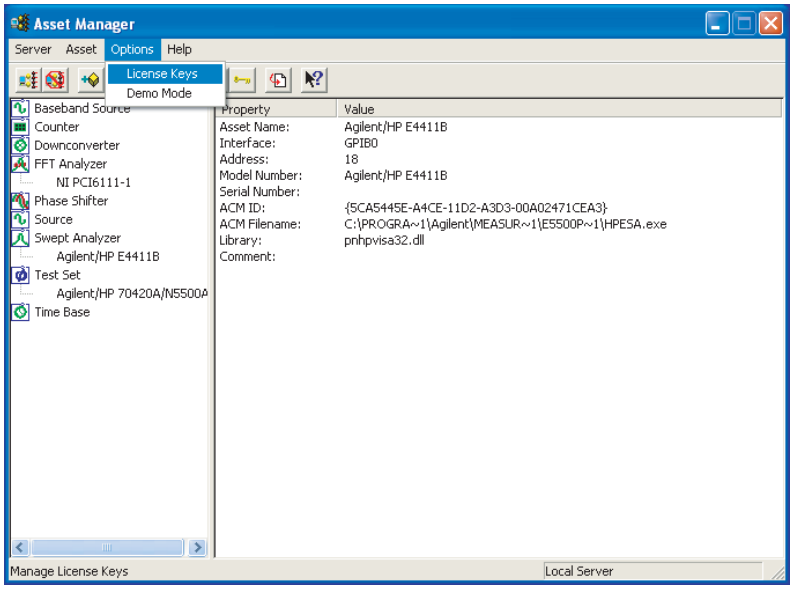


Figure 333 Navigate to license keys

NOTE

The license key for your system is unique and may only be used with a specific N5500A test set serial number. The license key may be found both on your license-key document and in the file “license_key.txt” on the License_key floppy disk provided with your system.

4 Enter the license key for your phase noise test set and click the **Set** button. Use **Licence_key.txt** described in the next steps to facilitate entering your license key into the licensing dialog box.

a Insert the E5500 License Key disk in the computer.

b Using Notepad, load **License_key.txt**. See Figure 334 on page 443.

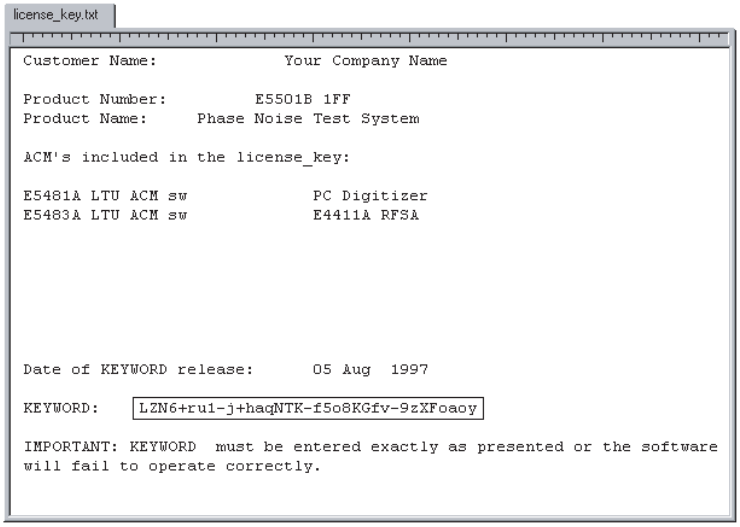


Figure 334 License_key.txt

c Highlight the keyword in the License_key.txt file and copy it to the dialog box as shown in Figure 335.

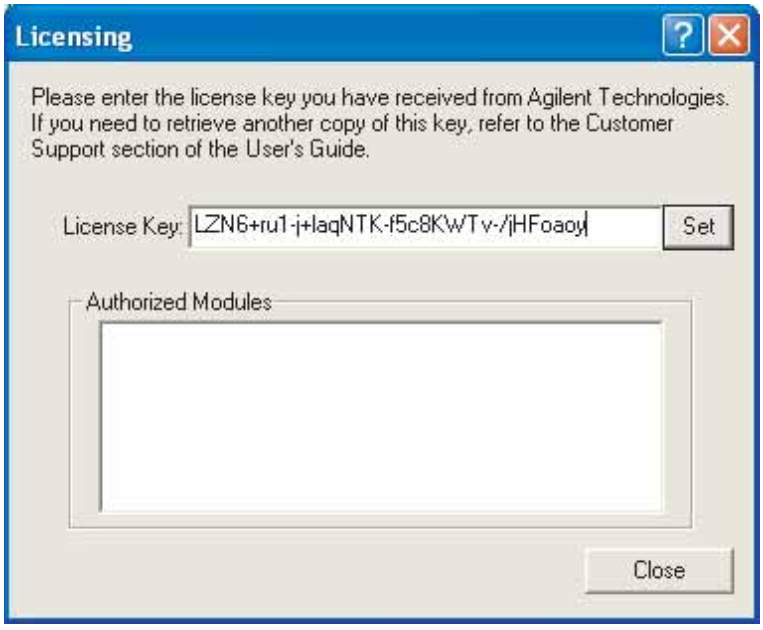


Figure 335 Copy keyword into license key field

d Click the **Set** button.

- The dialog box displays a message confirming licensing or indicating that there is a problem. See Figure 336 and Figure 337 on page 444.

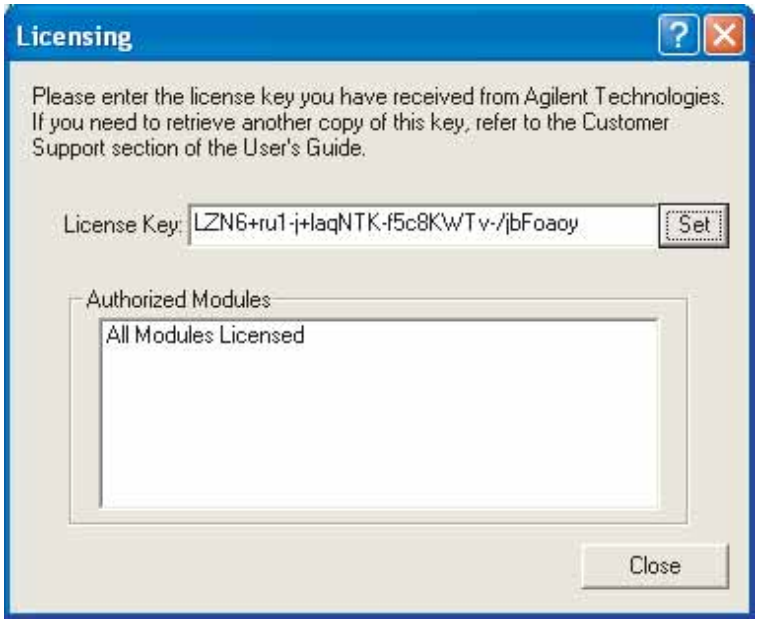


Figure 336 Licensing confirmation

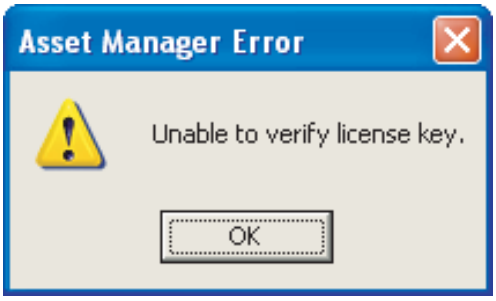


Figure 337 Licensing error

5 Perform the PC Digitizer Performance Verification procedure in Chapter 20 to ensure that the digitizer and adapter are functioning properly.

20 PC Digitizer Performance Verification

Verifying PC Digitizer Card Output Performance 446
PC Digitizer Card Input Performance Verification 451

This chapter contains information and procedures for verifying the performance of the NI-DAQ PC digitizer card (PCI-6111) and PC digitizer card adapter.

Verifying PC Digitizer Card Output Performance

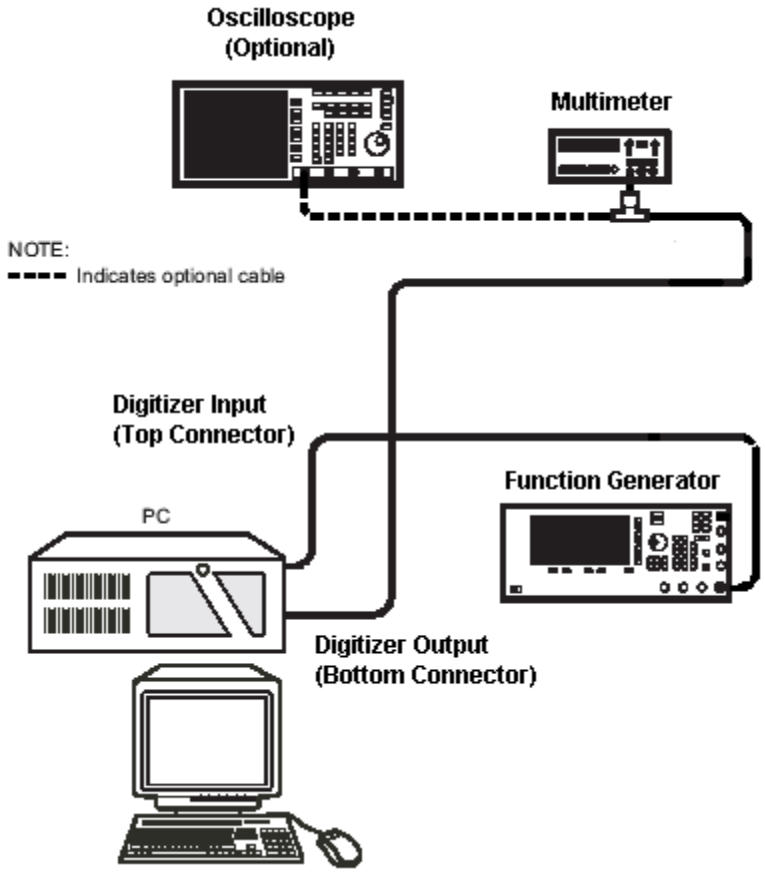
This procedure verifies the output performance of the PC digitizer card and adapter. Perform this procedure periodically to ensure the proper functioning of these two components, which affect measurement accuracy.

Required equipment

- Multimeter or oscilloscope (for reading output voltage)

To verify the PC digitizer card input's performance

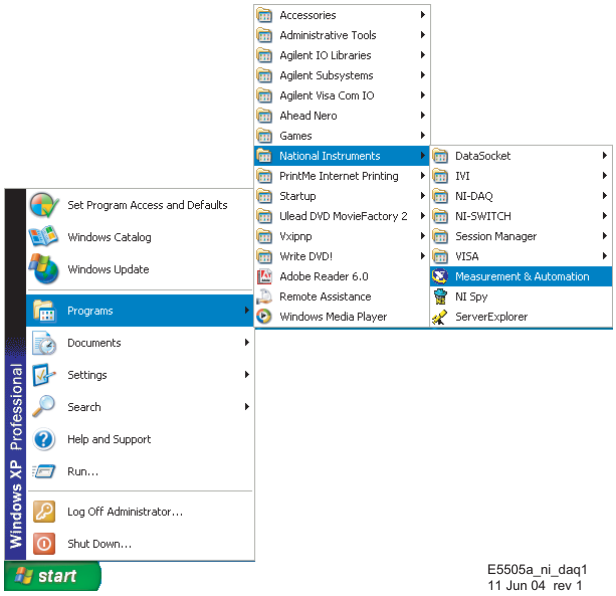
Step	Notes
1 Turn off the phase noise software.	
2 Connect the PC digitizer card adapter's output to the input of either a multimeter or oscilloscope.	• See connection diagram below.



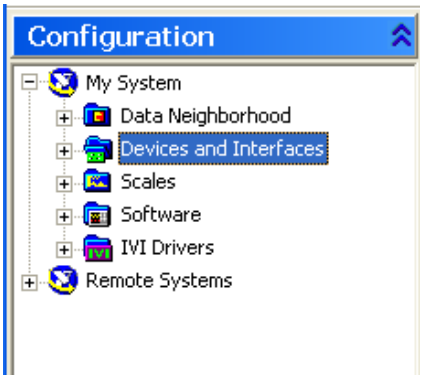
3 Open the **NI-DAQ Measurement and Automation Explorer** application.	• Path: Start\Programs\National Instruments\ Measurement & Automation

To verify the PC digitizer card input's performance (continued)

Step	Notes

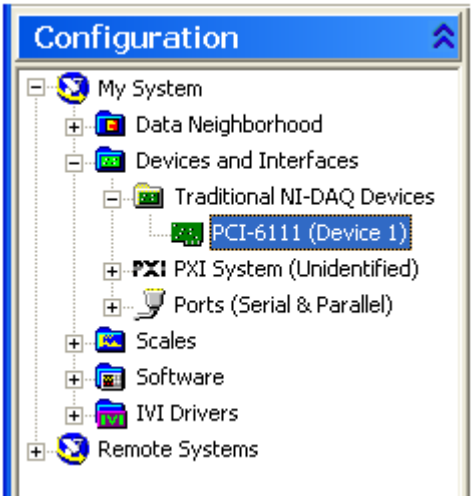


4 Double-click **Devices and Interfaces** in the Configuration content frame.

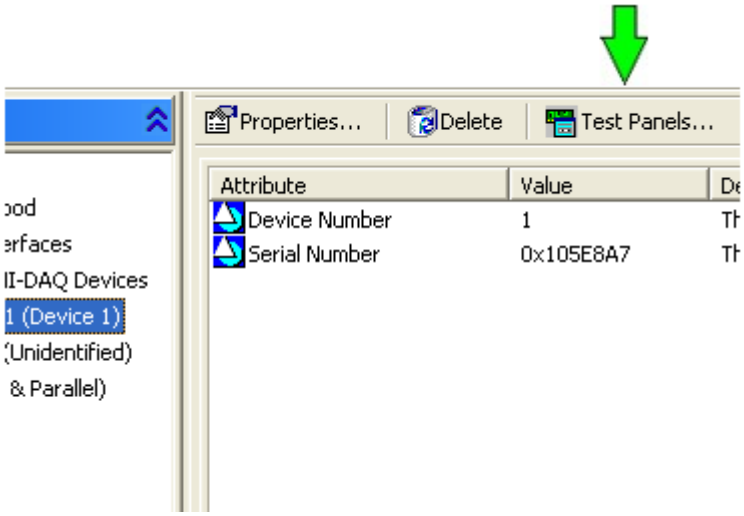


To verify the PC digitizer card input's performance (continued)

Step	Notes
5 Double-click on **Traditional NI-DAQ Devices**, then select **PCI-6111**.	

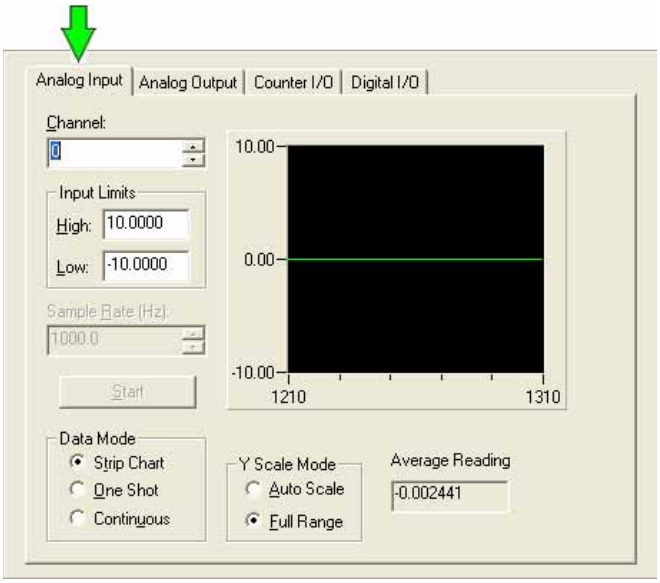


6 Click the **Test Panels...** button.

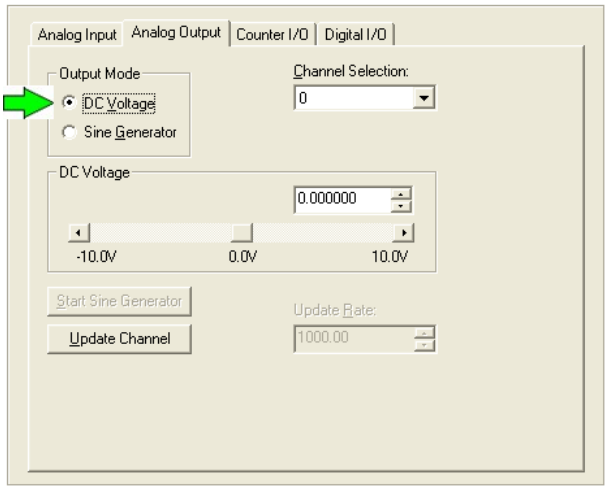


To verify the PC digitizer card input's performance (continued)

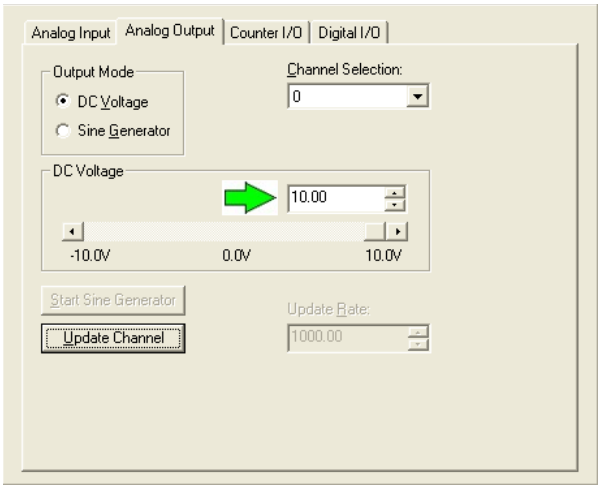
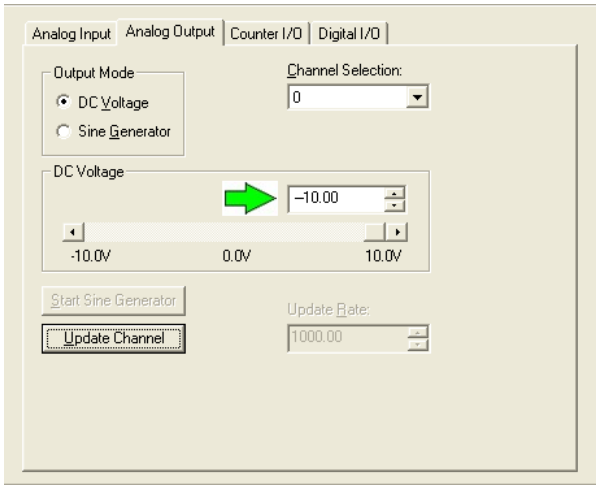
Step	Notes
7 Select the **Analog Output** Tab.	



8 Select **DC Voltage** output mode.	



To verify the PC digitizer card input's performance (continued)

Step	Notes
9 Enter +10 V in the DC Voltage window.	
	
10 Click the **Update Channel** button.	
11 Confirm that the multimeter or oscilloscope reads +5 V (±10%).	• PC digitizer adapter output specification is +5 V, ±10%.
12 Enter –10 V in the DC Voltage window.	
	
13 Click the **Update Channel** button.	
14 Confirm that the multimeter or oscilloscope reads –5 V (±10%).	• PC digitizer adapter output specification is –5 V, ±10%.

PC Digitizer Card Input Performance Verification

This procedure verifies the Input performance of the PC digitizer card and adapter. Perform this procedure periodically to ensure the proper functioning of these two components, which affect measurement accuracy.

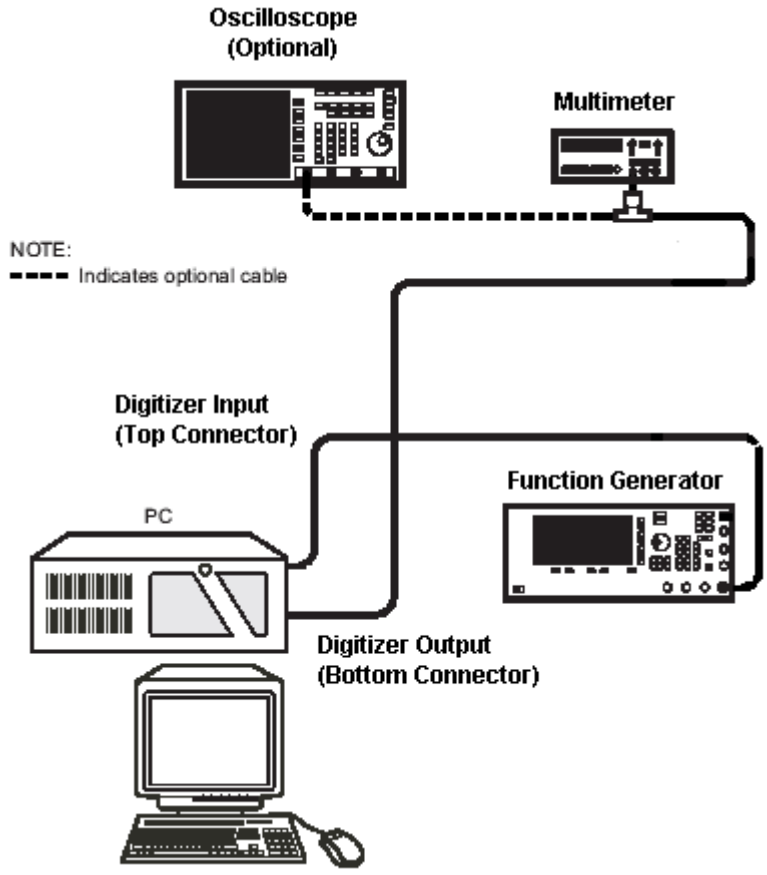
Required equipment

Function generator

- Frequency: 2 MHz
- Calibrated peak to peak

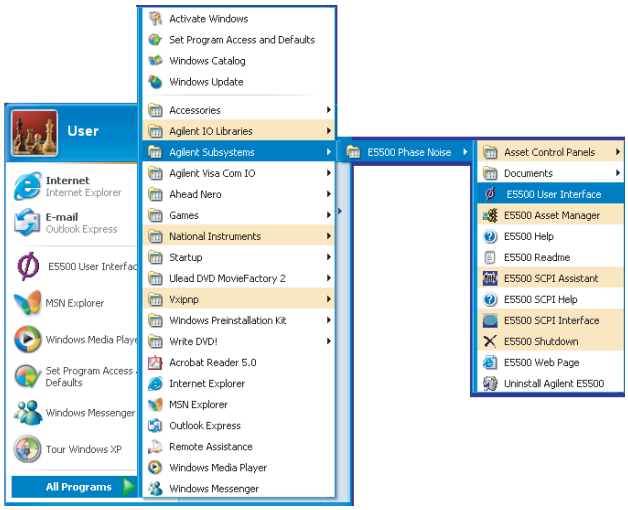
To verify the PC digitizer card input's performance

Step	Action
1 Connect the PC digitizer adapter's input connector to the output of the function generator.	

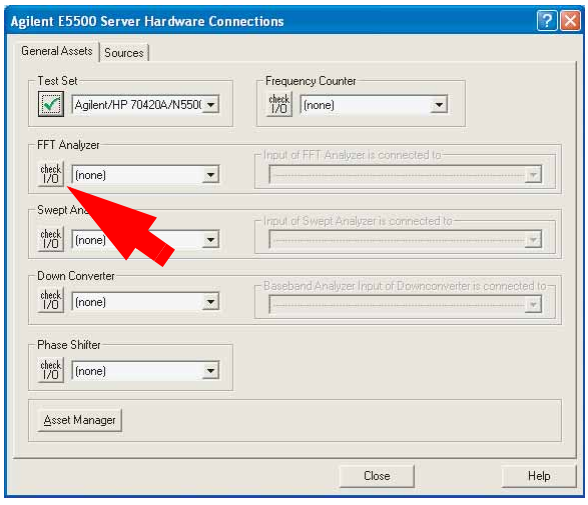


To verify the PC digitizer card input's performance (continued) (continued)

Step	Action
2 Open the E5505A phase noise software.	• Path: Start\Programs\Agilent Subsystems\E5500 Phase Noise System\E5500 User Interface

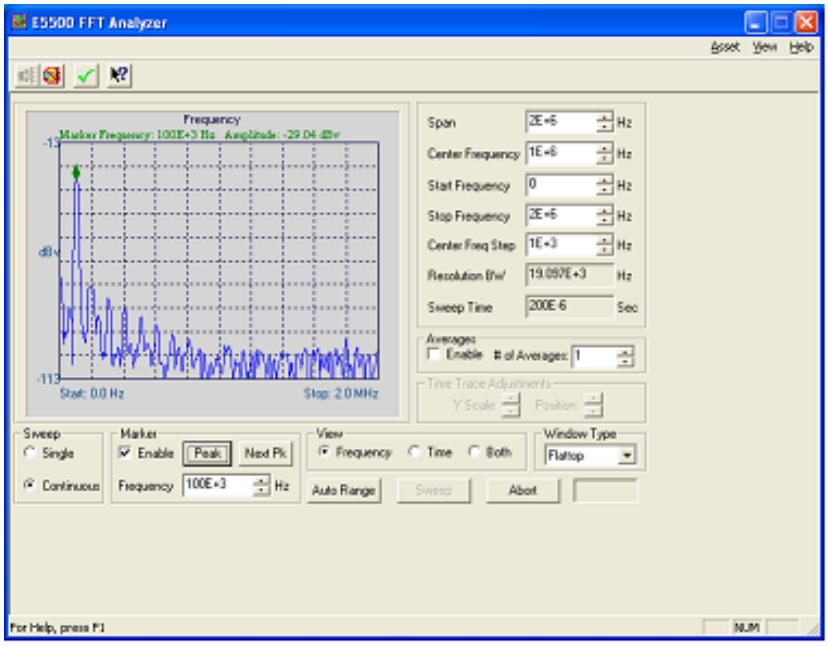


3 Click **FFT Analyzer Check I/O** button in **Server Hardware Connections** to verify the PC digitizer's connectivity.	• Path: System\Server Hardware Connections • A green check-mark appears on the button to confirm connectivity. If a red circle with a slash appears, check hardware connections and try again.



4 Configure the function generator using the appropriate keys on the instrument.	• Frequency: 100 kHz • Amplitude: 100 mV peak to peak • For instructions, refer to the function generator's user's guide.

To verify the PC digitizer card input's performance (continued) (continued)

Step	Action
5 Select the **FFT Analyzer Asset Control Panel**.	• Path: System\Asset Control Panels\FFT Analyzer
	
6 Configure the FFT Analyzer's Asset Control Panel.	• Span: 0 to 2 MHz • Window Type: Flattop • Sweep: Continuous • Marker: Enable
7 Connect the PC digitizer adapter's input connector to the output of the function generator.	• See diagram in step 1 on page 451.
8 Click the **Peak** button.	• The Frequency screen should reflect the 100 kHz power specification: –29.00 dBv, ± 0.25 dBv
9 Reconfigure the Function Generator.	• Frequency: 1.99 MHz • Amplitude: 100 mV peak to peak
10 Click the **Peak** button.	• The Frequency screen should reflect the 1.99 MHz power specification: –29.00 dBv, ± 0.5 dBv
11 Close the FFT Analyzer's Asset Control Panel.	• This concludes the procedure.

21
Preventive Maintenance

Using, Inspecting, and Cleaning RF Connectors 456
General Procedures and Techniques 460

Using, Inspecting, and Cleaning RF Connectors

Taking proper care of cables and connectors will protect your system's ability to make accurate measurements. One of the main sources of measurement inaccuracy can be caused by improperly made connections or by dirty or damaged connectors.

The condition of system connectors affects measurement accuracy and repeatability. Worn, out-of-tolerance, or dirty connectors degrade these measurement performance characteristics.

Repeatability

If you make two identical measurements with your system, the differences should be so small that they will not affect the value of the measurement. Repeatability (the amount of similarity from one measurement to another of the same type) can be affected by:

- Dirty or damaged connectors
- Connections that have been made without using proper torque techniques (this applies primarily when connectors in the system have been disconnected, then reconnected).

CAUTION

Static-Sensitive Devices

This system contains instruments and devices that are static-sensitive. Always take proper electrostatic precautions before touching the center conductor of any connector, or the center conductor of any cable that is connected to any system instrument. Handle instruments and devices only when wearing a grounded wrist or foot strap. When handling devices on a work bench, make sure you are working on an anti-static worksurface.

RF Cable and Connector Care

Connectors are the most critical link in a precision measurement system. These devices are manufactured to extremely precise tolerances and must be used and maintained with care to protect the measurement accuracy and repeatability of your system.

To extend the life of your cables or connectors:

- Avoid repeated bending of cables–a single sharp bend can ruin a cable instantly.
- Avoid repeated connection and disconnection of cable connectors.

- Inspect the connectors before connection; look for dirt, nicks, and other signs of damage or wear. A bad connector can ruin the good connector instantly.
- Clean dirty connectors. Dirt and foreign matter can cause poor electrical connections and may damage the connector.
- Minimize the number of times you bend cables.
- Never bend a cable at a sharp angle.
- Do not bend cables near the connectors.
- If any of the cables will be flexed repeatedly, buy a back-up cable. This will allow immediate replacement and will minimize system down time.

Before connecting the cables to any device:

- Check all connectors for wear or dirt.
- When making the connection, torque the connector to the proper value.

Proper Connector Torque

- Provides more accurate measurements
- Keeps moisture out of the connectors
- Eliminates radio frequency interference (RFI) from affecting your measurements

The torque required depends on the type of connector. Refer to Table 75. Do not overtighten the connector.

Never exceed the recommended torque when attaching cables.

Table 75 Proper Connector Torque

Connector	Torque cm-kg	Torque N-cm	Torque in-lbs	Wrench P/N
Type-N	52	508	45	hand tighten
3.5 mm	9.2	90	8	8720-1765
SMA	5.7	56	5	8710-1582

Connector Wear and Damage

Look for metal particles from the connector threads and other signs of wear (such as discoloration or roughness). Visible wear can affect measurement accuracy and repeatability. Discard or repair any device with a damaged connector. A bad connector can ruin a good connector on the first mating. A magnifying glass or jeweler's loupe is useful during inspection.

SMA Connector Precautions

Use caution when mating SMA connectors to any precision 3.5 mm RF connector. SMA connectors are not precision devices and are often out of mechanical tolerances, even when new. *An out-of-tolerance SMA connector can ruin a 3.5 mm connector on the first mating.* If in doubt, gauge the SMA connector before connecting it. The SMA center conductor must *never* extend beyond the mating plane.

Cleaning Procedure

1. Blow particulate matter from connectors using an environmentally-safe aerosol such as Aero-Duster. (This product is recommended by the United States Environmental Protection Agency and contains tetrafluoroethane. You can order this aerosol from Agilent (see Table 76).)
2. Use alcohol and a lint-free cloth to wipe connector surfaces. Wet a small swab with a small quantity of alcohol and clean the connector with the swab.
3. Allow the alcohol to evaporate off of the connector before making connections.

CAUTION *Do not allow excessive alcohol to run into the connector.* Excessive alcohol entering the connector collects in pockets in the connector's internal parts. The liquid will cause random changes in the connector's electrical performance. If excessive alcohol gets into a connector, lay it aside to allow the alcohol to evaporate. This may take up to three days. If you attach that connector to another device it can take much longer for trapped alcohol to evaporate.

Table 76 Cleaning Supplies Available from Agilent

Product	Part Number
Aero-Duster	8500-6460
Isopropyl alcohol	8500-5344
Lint-Free cloths	9310-0039
Small polyurethane swabs	9301-1243

WARNING **Cleaning connectors with alcohol should only be performed with the instruments' mains power cord disconnected, in a well ventilated area. Connector cleaning should be accomplished with the minimum amount of alcohol. Prior to connector reuse, be sure that all alcohol used has dried, and that the area is free of fumes.**

WARNING **If flammable cleaning materials are used, the material should not be stored, or left open in the area of the equipment. Adequate ventilation should be assured to prevent the combustion of fumes, or vapors.**

General Procedures and Techniques

This section introduces you to the various cable and connector types used in the system. Read this section before attempting to remove or install an instrument! Each connector type may have unique considerations.

Always use care when working with system cables and instruments.

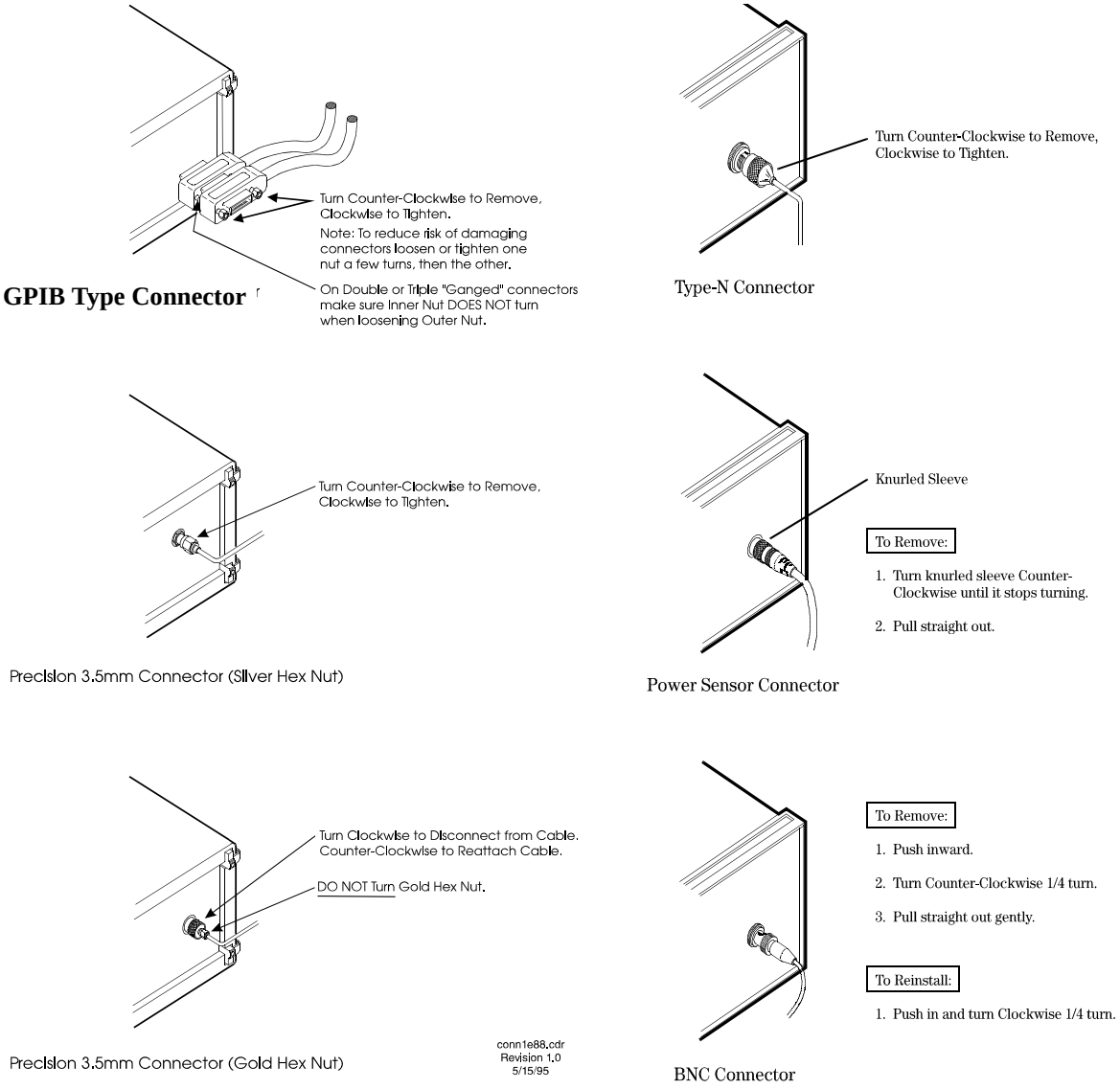


Figure 338GPIB, 3.5 mm, Type-N, power sensor, and BNC connectors

Connector Removal

GPIB Connectors

These are removed by two captured screw, one on each end of the connector; these usually can be turned by hand. Use a flathead screwdriver if necessary.

GPIB connectors often are stacked two or three deep. When you are removing multiple GPIB connectors, disconnect each connector one at a time. It is a good practice to connect them back together even if you have not yet replaced the instrument; this avoids confusion, especially if more than one instrument has been removed.

When putting GPIB connectors back on, you must again detach them from one another and put them on one at a time.

Precision 3.5 mm Connectors

These are precision connectors. Always use care when connecting or disconnecting this type of connector. When reconnecting, make sure you align the male connector properly. Carefully join the connectors, being careful not to cross-thread them.

Loosen precision 3.5 mm connectors on flexible cables by turning the connector nut counter-clockwise with a 5/16 inch wrench. Always reconnect using an 8 inch-lb torque wrench (Agilent part number 8720-1765). Semirigid cables are metal tubes, custom-formed for this system from semirigid coax cable stock.

3.5 mm Connectors with a gold hex nut

The semirigid cables that go to the RF outputs of some devices have a gold connector nut. These do not turn. Instead, the RF connector on the instrument has a cylindrical connector body that turns. To disconnect this type of connector, turn the connector body on the instrument clockwise. This action pushes the cable's connector out of the instrument connector.

To reconnect, align the cable with the connector on the instrument. Turn the connector body counterclockwise. You may have to move the cable slightly until alignment is correct for the connectors to mate. When the two connectors are properly aligned, turning the instrument's connector body will pull in the semirigid cable's connector. Tighten firmly by hand.

3.5 mm connectors with a silver hex nut

All other semirigid cable connectors use a silver-colored nut that *can* be turned. To remove this type of connector, turn the silver nut counter-clockwise with a 5/16 inch wrench.

When reconnecting this type of cable:

- Carefully insert the male connector center pin into the female connector. (Make sure the cable is aligned with the instrument connector properly before joining them.)
- Turn the silver nut clockwise by hand until it is snug, then tighten with an 8 inch-lb torque wrench (part number 8720-1765).

Bent Semirigid Cables

Semirigid cables are not intended to be bent outside of the factory. An accidental bend that is slight or gradual may be straightened carefully by hand. Semirigid cables that are crimped will affect system performance and must be replaced. Do not attempt to straighten a crimped semirigid cable.

Instrument Removal

To remove an instrument from the system, use one of the following procedures.

Required tools

- #2 Phillips screwdriver
- #2 POZIDRIV screwdriver

Standard instrument

To remove an instrument from a rack

	Step	Notes
1	Turn off system power, but leave the system computer turned on.	• If you do plan to turn computer power off for any reason, have the computer system administrator: • Shut down all running software. • Shut down the computer.
2	Read “General Procedures and Techniques”, then disconnect all cables on the front and on the rear panel.	• Most cables are fairly easy to remove and reconnect, and have no special considerations (besides making sure you put the cables back in the right place). • Semirigid cables require more care, especially when reconnecting them. *Make sure all semirigid cables, on the front and back of an instrument are fully disconnected before removing the unit.*
3	When *all* cables are disconnected (including the power cord), remove the screws in the instrument’s rack “ears” that hold it in the rack.	
4	Slide the instrument out.	• If you feel any resistance when attempting to pull the instrument out, STOP! Look inside the cabinet and carefully examine all surrounding cables. Make sure all cables are fully disconnected.

Half-Rack-Width Instrument

To remove a half-width instrument from a system rack

1	Power off the system.	• For details see the system installation guide.
2	Remove the selected instrument's power cord from the power strip in the rack.	
3	The instrument is attached to the half-rack width instrument beside it; remove that instrument's power cord from the power strip also.	• The instruments are secured together by lock links at the front and rear. The lock links at the rear attach with screws. The lock links at the front hook together.
4	Remove the power cord and other cables from the front and rear of both instruments.	• Note the location of cables for re-installation.
5	Remove the four corner screws on the front of the rack panel that secures the instruments in place.	• The screws are located near the corners of the face of the instrument. • Use a #2 Phillips screwdriver.
6	Slide both instruments, as a single unit, out from the front of the rack and set them on a secure, flat surface.	
7	Detach the lock links that secure the rear of the instruments together by removing their screws.	• Use a #2 POZIDRIV screwdriver. • See Figure 339 on page 465.
8	Carefully and at the same time, push one instrument forward and pull the other back to unhook the lock links that secure the front of the instruments to each other.	
9	Store the "partner" instrument and lock links while the selected instrument is out of the rack.	• Only install the instruments as a pair; individual installation is not secure.

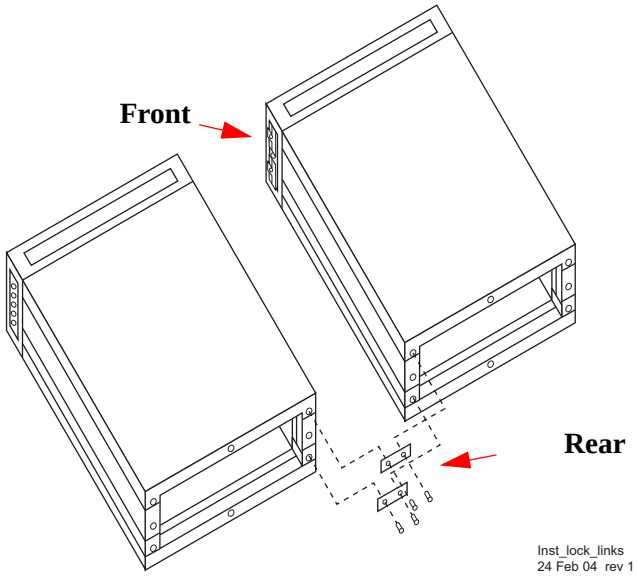


Figure 339 Instrument lock links, front and rear

Benchtop Instrument

To remove an instrument from a benchtop system

1 Power off each instrument in the system.	• For details, see “Powering the System Off" on page 45.
2 Unplug the selected instrument’s power cord from the AC power supply.	
3 Remove the power cord and other cables from the front and rear of the instrument.	• Note the location of cables for re-installation.

Instrument Installation

To install or re-install an instrument in a system, use one of the following procedures.

Required tools

- #2 Phillips screwdriver
- #2 POZIDRIV screwdriver
- system installation guide

Standard rack instrument

To install an instrument

	Step	Notes
1	Slide the instrument gently into the rack.	
2	Insert the screws in the rack ears.	• Most cables are fairly easy to remove and reconnect and have no special considerations (besides making sure you put the cables back in the right place). • Semirigid cables require more care, especially when reconnecting them. *Make sure all semirigid cables, on the front and back of an instrument are fully disconnected before removing the unit.*
3	To reconnect the semirigid cables, carefully align them before you insert the male connector.	• Do not insert the male pin in at an angle or you will damage the female connector. RF connector center pins are very delicate, and if damaged must be replaced. System performance may be greatly impaired if there is a bad RF connector.
4	Turn on system power and restart the system computer if necessary.	

Half-Rack-Width instrument

To install the instrument in a rack

Step	Note
1 Make sure the system is powered off.	• For details, see “Powering the System Off" on page 45.
2 Re-attach the lock link that secures the front of the returned instrument to it’s partner half-rack-width instrument.	• Use a #2 POZIDRIV screwdriver. • See Figure 339 on page 465.
3 Re-attach the lock link that secures the rear of the instruments together.	• Use a #2 POZIDRIV screwdriver.
4 Insert the attached instruments in the same slot from which you removed them, sliding them along the support rails until they meet the rack-mount ears.	• The rack-mount ears stop the instruments at the correct depth.
5 Replace the rack panel in front of the instruments and secure the four corner screws.	• The screws are located near the corners of the face of the instrument. • Use a #2 Phillips screwdriver.
6 Confirm that the instrument is turned off.	
7 Connect the appropriate cables to the instruments (front and rear), including the power cords.	
8 Power on the system.	• For details, see “Powering the System On" on page 36.

Benchtop instrument

To install an instrument in a benchtop system

1 Make sure the system is powered off.	• For details, see “Powering the System Off" on page 45.
2 Connect all cables to the instrument (front and rear), including the power cord.	
3 Connect the power cord to the AC power source.	
4 Power on the system.	• For details, see “Powering the System On" on page 36.
5 Set the instrument GPIB address, if necessary.	

A
Service, Support, and Safety Information

Safety and Regulatory Information 470
Service and Support 476
Return Procedure 477

This appendix provides safety and regulatory information, which you should review prior to working with your Agilent system. The information contained in it applies to all Agilent-supplied instruments in the system, and the system as a whole.

It also contains information on servicing and obtaining support for an Agilent system or instrument, including procedures for removing an instrument from a system, returning it to Agilent, and re-installing it.

Safety and Regulatory Information

Safety summary

The following general safety precautions must be observed during all phases of operation of this instrument or system. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of this instrument or system. Agilent Technologies, Inc. assumes no liability for the customer's failure to comply with these requirements.

General

This product has been designed and tested in accordance with the standards listed on the Manufacturer's Declaration of Conformity, and has been supplied in a safe condition. The documentation contains information and warnings that must be followed by the user to ensure safe operation and to maintain the product in a safe condition.

All light-emitting diodes (LEDs) used in this product are Class 1 LEDs per IEC 60825-1.

Equipment Installation

Install the instrument or system so that the detachable power cord is readily identifiable and is easily reached by the operator. The detachable power cord is the disconnecting device. It disconnects the mains circuits from the mains supply before other parts of the instrument or system. The instrument front panel switch is only a standby switch and is not a LINE switch. Alternatively, an externally installed switch or circuit breaker (which is readily identifiable and is easily reached by the operator) may be used as a disconnecting device.

WARNING **This is a Safety Class 1 Product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall be inserted only in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor inside or outside of the products is likely to make the product dangerous. Intentional interruption is prohibited (IEC 348 clauses 17.3.3 c and 17.3.4).**

WARNING **DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE.**
Do not operate the instrument or system in the presence of flammable gases or flames.

WARNING **DO NOT REMOVE AN INSTRUMENT COVER.**

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made only by qualified service personnel.

Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

Environmental conditions

WARNING **If this product is not used as specified, the protection provided by the equipment could be impaired. This product must be used only in a normal condition (in which all means for protection are intact).**

CAUTION Unless otherwise noted in the specifications, this instrument or system is intended for indoor use in an installation category II, pollution degree 2 environment.

CAUTION **Ventilation Requirements:** When installing the product in a cabinet, the convection into and out of the product must not be restricted. The ambient temperature (outside the cabinet) must be less than the maximum operating temperature of the product by 4 °C for every 100 watts, then forced convection must be used.

Before applying power

CAUTION Verify that the product is set to match the available line voltage, the correct-rating service breaker is installed, the correct fuse is installed, and all safety precautions are taken. Note the instrument external markings described in Table 77, “Safety symbols and instrument markings,” on page 473.

WARNING **The mains wiring and connectors shall be compatible with the connector used in the premise electrical system. Failure to ensure adequate earth grounding by not using the correct components may cause product damage and serious injury.**

Ground the instrument or system

WARNING **To minimize shock hazard, the instrument chassis and cover must be connected to an electrical protective earth ground. The instrument and/or system must be connected to the AC power mains through a grounded power cable, with the ground wire firmly connected to an electrical ground (safety ground) at the power outlet. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury.**

WARNING **This is a Safety Class 1 Product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall be inserted only in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor inside or outside of the products is likely to make the product dangerous. Intentional interruption is prohibited (IEC 348 clauses 17.3.3 c and 17.3.4).**

CAUTION Always use the three-prong AC power cord supplied with this product. Failure to ensure adequate earth grounding by not using this cord may cause product damage.

CAUTION The detachable power cord is the disconnecting device. It disconnects the mains circuit from the mains supply before other parts of the instrument or system. The instrument front panel switch is only a standby switch and is *not* a line switch.

Fuses and Circuit Breakers

Refer to individual instrument manuals for detailed information on operator accessible fuses.

WARNING **Use only fuses with the required rated current, voltage, and specified type (normal blow, time delay). Do not use repaired fuses or short-circuited fuse holders. To do so could cause a shock or fire hazard.**

WARNING **For continued protection against fire hazard, replace fuses and circuit breakers only with the same type and ratings. The use of other fuses or circuit breakers or materials is prohibited (IEC 348 clause 17.3.5.d).**

WARNING **The premise wiring should have a system-dedicated circuit breaker in the mains wiring for installation of the system.**

Agilent system cabinet power strips are equipped with a thermal circuit breaker for each power phase. If one phase shorts or overloads, one or both of the circuit breakers in the power strip trip. Unplug the power strip before trying to locate and correct the electrical problem, then reset both circuit breakers on the power strip to restore power to the cabinet.

Maintenance

WARNING **To prevent electrical shock, disconnect the instrument and/or system from mains before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally.**

Safety symbols and instrument markings

Symbols and markings in manuals and on instruments alert you to potential risks, provide information about conditions, and comply with international regulations. Table 77 defines the symbols and markings you may find in a manual or on an instrument.

Table 77 Safety symbols and instrument markings

Safety symbols	Definition
	Warning: risk of electric shock.
	Warning: hot surface.
	Caution: refer to instrument documentation.
	Laser radiation symbol: marked on products that have a laser output.
	Alternating current.
	Both direct and alternating current.
	Three-phase alternating current.
	Earth (ground) terminal.
	Protective earth (ground) terminal.
	Frame or chassis terminal.

Table 77 Safety symbols and instrument markings (continued)

Safety symbols	Definition
⊥	Terminal is at earth potential. Used for measurement and control circuits designed to be operated with one terminal at earth potential.
N	Terminal for neutral conductor on permanently installed equipment.
L	Terminal for line conductor on permanently installed equipment.
⏻	Standby (supply); units with this symbol are not completely disconnected from AC mains when this switch is in the standby position. To completely disconnect the unit from AC mains, either disconnect the power cord, or have a qualified/licensed electrician install an external switch.
○	OFF (supply); a switch with this symbol opens the instrument's power supply circuit, disconnecting it with the mains supply.
|	ON (supply); a switch with this symbol closes the instrument's power supply circuit, connecting it with the mains supply.
Instrument markings	**Definition**
CE	The CE mark is a registered trademark of the European Community.
SA	The CSA mark is a registered trademark of the CSA-International.
✓N10149	The C-tick mark is a registered trademark of the Spectrum Management Agency of Australia. This signifies compliance with the Australian EMC Framework regulations under the terms of the Radio Communications Act of 1992.
1SM1-A	This text indicates that the instrument is an Industrial Scientific and Medical Group 1 Class A product (CISPER 11, Clause 4).
ICES/NMB-001	This text indicates product compliance with the Canadian Interference-Causing Equipment Standard (ICES-001).

Regulatory Compliance

EMC: Complies with the essential requirements of the European EMC Directive as well as current editions of the following standards (dates and editions are cited in the Declaration of Conformity):

- IEC/EN 61326-1
- CISPR Pub 11 Group 1, class A
- AS/NZS CISPR 11
- ICES/NMB-001
  This ISM device complies with Canadian ICES-001.
  Cet appareil ISM est conforme a la norme NMB-001 du Canada.

SAFETY: Complies with the essential requirements of the European Low Voltage Directive as well as current editions of the following standards (dates and editions are cited in the Declaration of Conformity):

- IEC/EN 61010-1
- Canada: CSA C22.2 No. 61010-1
- USA: UL std no. 61010-1

Acoustic statement: (European Machinery Directive)

Acoustic noise emission
LpA <70 dB
Operator position
Normal operation mode per ISO 7779

To find a current Declaration of Conformity for a specific Keysight product, go to: http://www.keysight.com/go/conformity

Service and Support

Any adjustment, maintenance, or repair of this product must be performed by qualified personnel. Contact your Agilent Technologies Service Center for assistance.

WARNING **There are no user serviceable parts inside the system. Any servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing unless you are qualified to do so.**

WARNING **The opening of covers or removal of parts is likely to expose dangerous voltages. Disconnect the product from all voltage sources while it is being opened.**

Agilent on the Web

You can find information about technical and professional services, product support, and equipment repair and service on the Web:

http://www.agilent.com

Click on the **Test & Measurement** link then click on **Select a Country**. Click on the **Contact Us** link for contact information.

Return Procedure

In any correspondence or telephone conversations with Agilent Technologies, please refer to the instrument by its model number (N5501A, for example) and serial number. With this information, the customer engineer can determine whether your instrument is still within its warranty period and provide accurate shipping information.

Determining your instrument's serial number

When Agilent Technologies manufactures an instrument, it is given a unique serial number. This serial number appears on a label on the rear panel of the instrument (see Figure 340). The serial number has two parts. The first part makes up the prefix and consists of four digits and a letter. The second part makes up the suffix and consists of the last five digits on the label. The serial number prefix is the same for all identical instruments; it changes only if the electrical or physical functionality differs between instruments. However, the serial number suffix changes sequentially from instrument to instrument to uniquely identify every one.

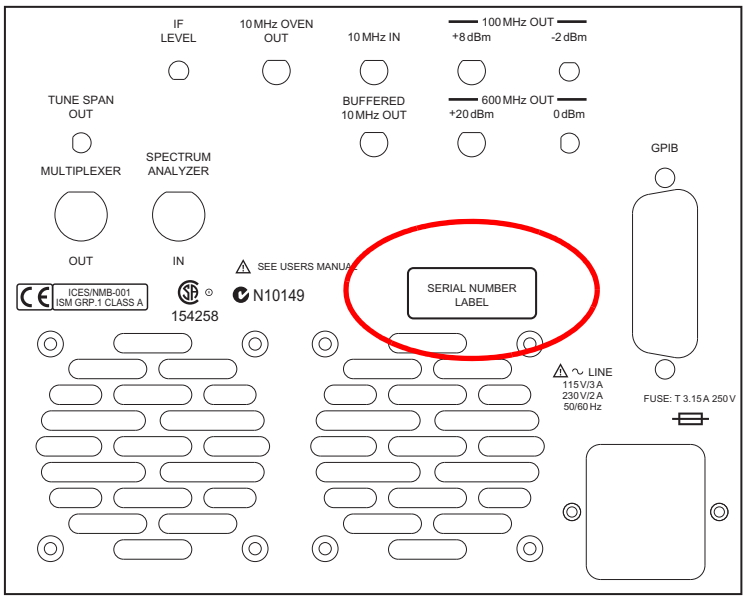


Figure 340 Serial number location

Shipping the instrument

Use the following procedure to package and ship your instrument for service. For instructions on removing an instrument from the system and re-installing it, refer to the system user's guide.

To package the instrument for shipping

Step	Notes
1 Place the instrument in its original packaging materials.	• If the original packaging materials are not available, use a professional packaging service. Contact your Agilent Service Center for more information.
2 Surround the instrument with at least 3 to 4 inches of its original packing material or bubble-pack to prevent the instrument from moving in its shipping container.	
3 After wrapping it with packing material, place the instrument in its original shipping container or a strong shipping container that is made of double-walled corrugated cardboard with 159 kg (350 lb) bursting strength.	• The shipping container must be large and strong enough to accommodate your instrument and allow at least 3 to 4 inches on all sides for packing material.
4 Seal the shipping container securely with strong nylon adhesive tape.	
5 Mark the shipping container "FRAGILE, HANDLE WITH CARE" to help ensure careful handling.	
6 Use the address obtained from your Agilent customer engineer.	
7 Retain copies of all shipping papers.	

CAUTION Damage can result if the original packaging materials are not used. Packaging materials should be anti-static and cushion the downconverter on all sides. NEVER USE STYRENE PELLETS IN ANY SHAPE AS PACKAGING MATERIALS. They do not adequately cushion the instrument or prevent it from moving in the shipping container. Styrene pellets can also cause equipment damage by generating static electricity or by lodging in fan motors.