E5500
Phase Noise Measurement System
Version A.02.00

User's Guide for E5500A/B

Agilent Technologies

DOCUMENT PART NO. E5500-90024
PRINTED IN USA
MARCH 2002
EDITION ED. 1.0

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WARNING: A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

CAUTION: A **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a **CAUTION** notice until the indicated conditions are fully understood and met.

Safety summary

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Agilent Technologies, Inc. assumes no liability for the customer's failure to comply with these requirements.

General

This product is a Safety Class 1 instrument (provided with a protective earth terminal). The protective features of this product may be impaired if it is used in a manner not specified in the operation instructions.

All light emitting diodes (LEDs) used in this product are Class 1 LEDs as per IEC 60825-1.

WARNING: DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE
Do not operate the instrument in the presence of flammable gases or flames.

WARNING: DO NOT REMOVE THE 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

Unless otherwise noted in the specifications, this instrument or system is intended for indoor use in an installation category II, pollution degree 2 environment. It is designed to operate at a maximum relative humidity of 95% and at altitudes of up to 2000 meters. Refer to the specifications tables for the ac mains voltage requirements and ambient operating temperature range.

Before applying power

Verify that the product is set to match the available line voltage, the correct fuse is installed, and all safety precautions are taken. Note the instrument's external markings described in Table 1.

Ground the instrument

To minimize shock hazard, the instrument chassis and cover must be connected to an electrical protective earth ground. The instrument 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.

Fuses

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.

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 1 defines the symbols and markings you may find in a manual or on an instrument.

Table 1 Safety symbols and instrument markings

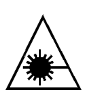
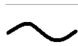
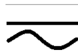
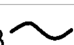
Safety symbols	
	Warning: risk of electric shock.
	Warning: hot surface
	Caution: refer to accompanying documents.
	Laser radiation symbol: marked on products that have a laser output.
	Alternating current.
	Both direct and alternating current.
3 	Three-phase alternating current.
	Earth (ground) terminal
	Protective earth (ground) terminal

Table 1 Safety symbols and instrument markings (continued)

Safety symbols	
	Frame or chassis terminal
	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 off. To completely disconnect the unit from ac mains, either disconnect the power cord, or have a qualified electrician install an external switch.

Instrument markings	
	The CE mark is a registered trademark of the European Community. If it is accompanied by a year, it indicates the year the design was proven.
	The CSA mark is a registered trademark of the Canadian Standards Association.
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).

Service and Support

Any adjustment, maintenance, or repair of this product must be performed by qualified personnel. Contact your customer engineer through your local Agilent Technologies Service Center.

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/contacts/English/noscript.html

Double-click the link to **Test & Measurement**. Select your country from the drop-down menus. The Web page that appears next has contact information specific for your country.

Agilent by Phone

If you do not have access to the Internet, call one of the numbers in Table 2.

Table 2 Agilent Call Centers and Regional Headquarters

United States and Canada:	Test and Measurement Call Center (800) 452 4844 (toll-free in US)
Europe:	(41 22) 780 8111
Japan:	Measurement Assistance Center (81) 0426 56 7832
Latin America:	305 269 7548
Asia-Pacific:	(85 22) 599 7777

7 Absolute Measurement Examples

8 Residual Measurement Fundamentals

9 Residual Measurement Examples

10 FM Discriminator Fundamentals

11 FM Discriminator Measurement Examples

20 Connector Care and Preventive Maintenance

1

Getting Started with the E5500 Phase Noise Measurement System

Introduction

Table 1-1 guide you to what chapters in this manual pertain to:

- Leaning about the E5500 Phase Noise Measurement System
- Learning about phase noise basics and measurement fundamentals.
- Using the phase noise measurement system to make specific phase noise measurements.

NOTE: Installation information for your system is provided in the E5500A Installation Guide (part number E5500-90001)or E5500B Installation Guide (part number E5500-90002).

NOTE: For application assistance, contact you local Agilent Technologies sales representative.

Training Guidelines

Table 1-1 Training Guidelines

Learning about the E5500 Phase Noise System	Learning about Phase Noise Basics and Measurement Fundamentals	Using the E5500 to Make Specific Phase Noise Measurements
Chapter 2, "E5500 Phase Noise Measurement System"		
Chapter 3, "Your First Measurement"		
	Chapter 4, "Phase Noise Basics"	
Chapter 5, "Expanding Your Measurement Experience"		
	Chapter 6, "Absolute Measurement Fundamentals"	Chapter 7, "Absolute Measurement Examples"
	Chapter 8, "Residual Measurement Fundamentals"	Chapter 9, "Residual Measurement Examples"
	Chapter 10, "FM Discriminator Fundamentals"	Chapter 11, "FM Discriminator Measurement Examples"
	Chapter 12, "AM Noise Measurement Fundamentals"	Chapter 13, "AM Noise Measurement Examples"
		Chapter 14, "Baseband Noise Measurement Examples"
		Chapter 15, "Evaluating Your Measurement Results"
		Chapter 16, "Advanced Software Features"
		Chapter 17, "Reference Graphs and Tables"

2

E5500 Phase Noise Measurement System

Introducing the Graphical User Interface

The graphical user interface 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 define process.

Three default segment tables are provided. To obtain a quick look at your data, select the “fast” quality level. If more frequency resolution to separate spurious signals is important, the ‘normal’ and “high resolution” quality levels are available. 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 2-1 shows an example of the graphical user interface.

NOTE: Although this document contains screen captures titled “HP E5500,” the E5500 is an Agilent Technologies product. In future revisions of this document, all screen captures will be updated to reflect Agilent Technologies E5500 rather than HP E5500.

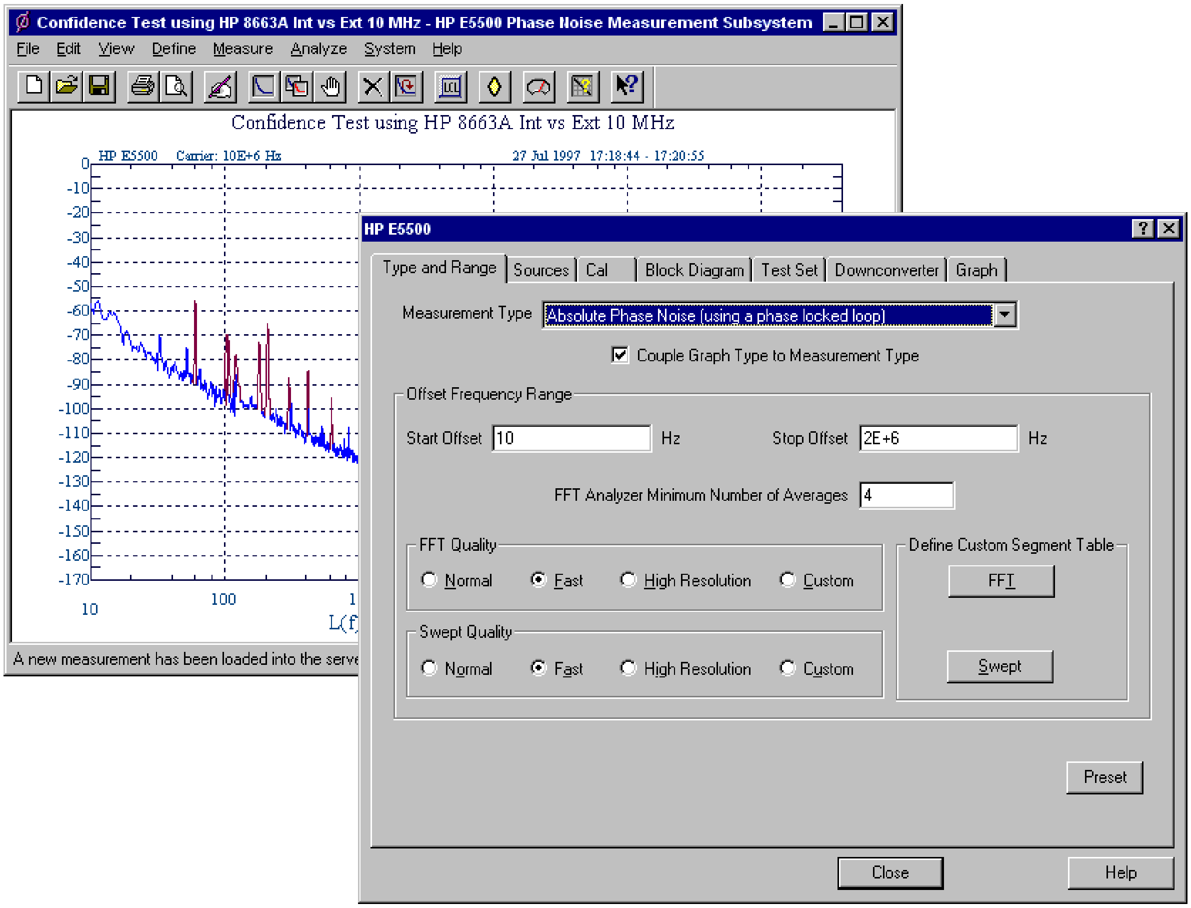


Figure 2-1 E5500 Graphical User Interface

System Requirements

The minimum system requirements for the phase noise measurement software are:

- Pentium® microprocessor (100 MHz or higher recommended)
- 32 megabytes (MB) of memory (RAM)
- 1 gigabyte (GB) hard disk
- Super Video Graphics Array (SVGA)
- 2 additional 16-bit slots available for the phase noise system hardware.

  1 for PC-Digitizer or VXI/MXI Interface

  1 for GPIB Interface Card
- Microsoft® Windows® 2000
- Agilent 82350 GPIB Interface Card

3

Your First Measurement

Designed to Meet Your Needs

The Agilent E5500 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 E5500 (A or B) installation guide now. Once you have completed the installation procedures, return to "E5500 Operation; A Guided Tour" on page 3-3 to begin learning how to make noise measurements with the system.

As You Begin

The "E5500 Operation; A Guided Tour" 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 5, "Expanding Your Measurement Experience". After you have completed that chapter, refer to Chapter 15, "Evaluating Your Measurement Results" for help in analyzing and verifying your test results.

E5500 Operation; A Guided Tour

This measurement demonstration will introduce 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 70420A test set's internal noise source. (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 E5500 Installation Guide if you need information about setting up the hardware or installing the software.)

How to Begin

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

Starting the Measurement Software

1 Place the E5500 phase noise measurement software disk in the disc holder and insert in the CD-ROM drive.

2 Using Figure 3-1 as a guide, navigate to the **E5500 User Interface.**

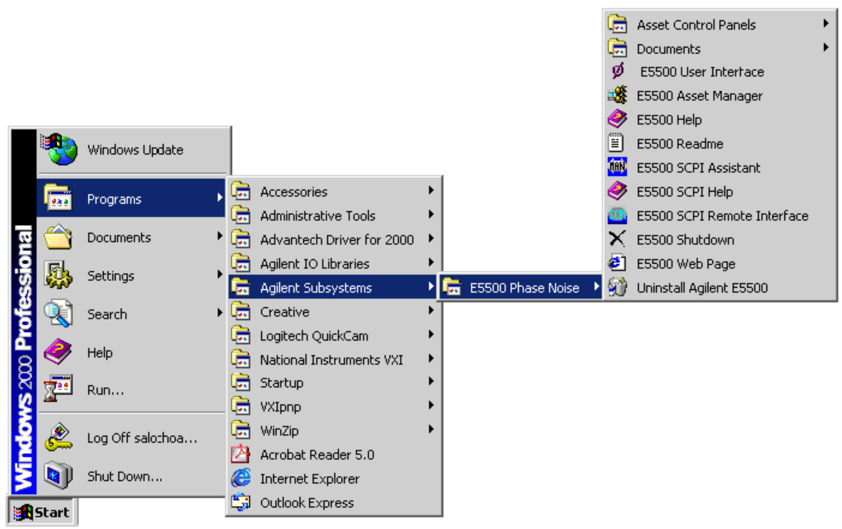


Figure 3-1 Navigation to the E5500 User Interface

3 The phase noise measurement subsystem dialog box (Figure 3-2) appears. Your dialog box may look slightly different.

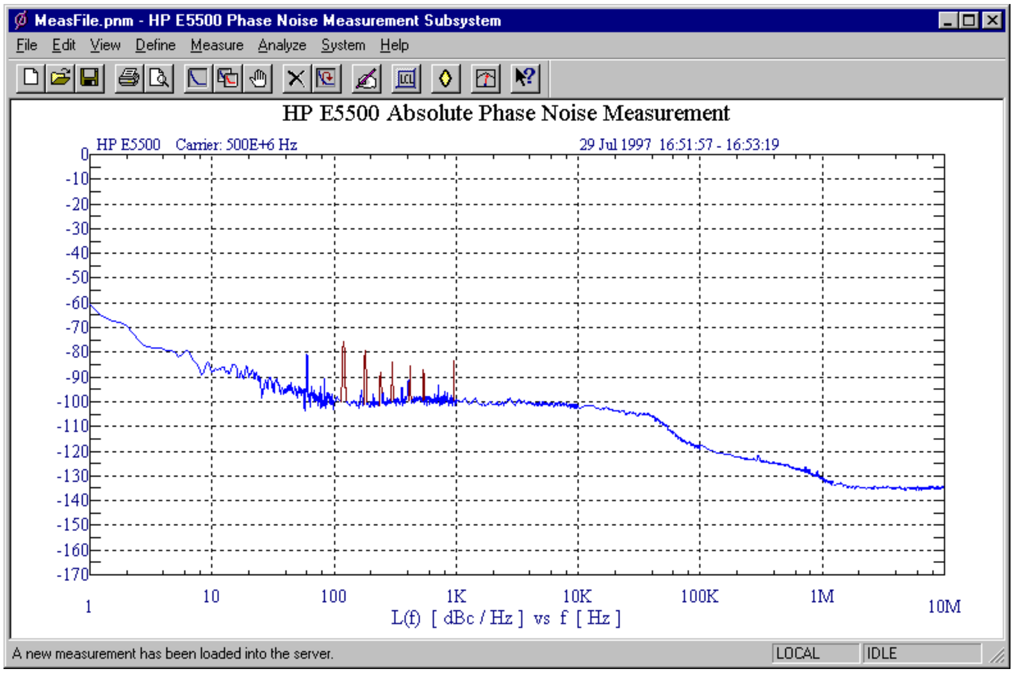


Figure 3-2 Phase Noise Measurement Subsystem Dialog Box

Making a Measurement

This first measurement is a confidence test that functionally checks the Agilent 70420A test set's filters and low-noise amplifiers using the test set's internal noise source. The phase detectors are not tested. This confidence test also confirms that the test set, PC, and analyzers are communicating with each other.

1. From the **File** menu in 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 **Confidence.pnm** (Figure 3-3).
4. Click the **Open** button.

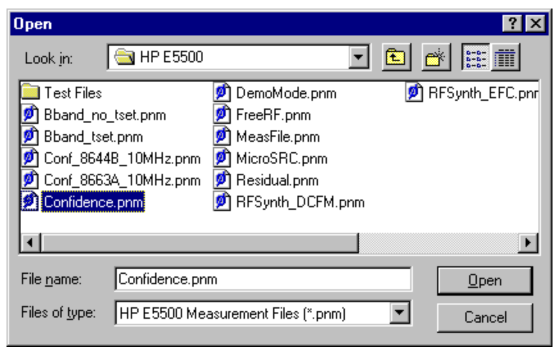


Figure 3-3 Opening the File Containing Pre-stored Parameters

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 3-1 lists the parameter data that has been entered for the Agilent 70420A confidence test example.

5. To view the parameter data in the software, navigate to the Define Measurement window use Figure 3-4 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.

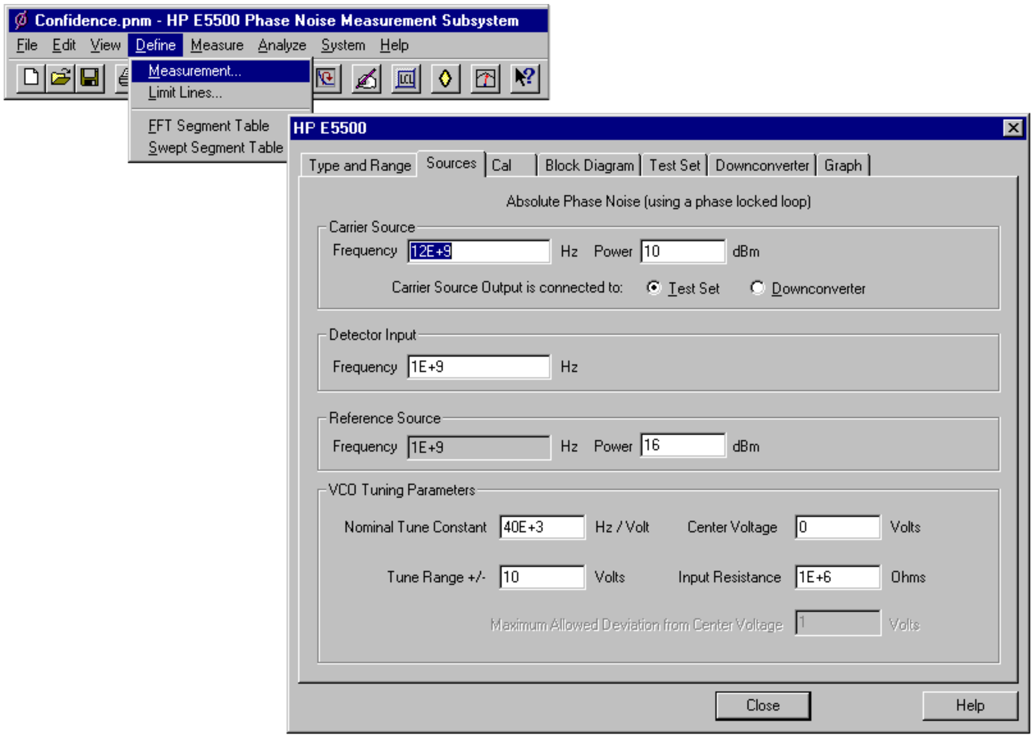


Figure 3-4 Navigating to the Define Measurement Window.

6 Click the **Close** button.

Beginning the Measurement

1 From the **Measure** menu, choose **New Measurement** (Figure 3-5).

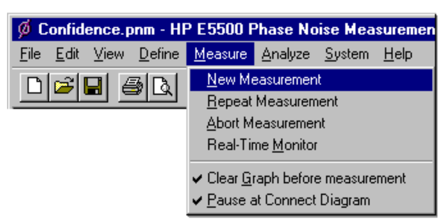


Figure 3-5 Navigating to the New Measurement Window

2 When the **Perform a New Calibration and Measurement?** dialog box appears, click **Yes.**

3 When the **Connect Diagram** dialog box appears, connect the 50 Ω termination, provided with your system, to the Agilent 70420A test set's noise input connector. Refer to Figure 3-6 for more information about the correct placement of the 50 Ω termination.

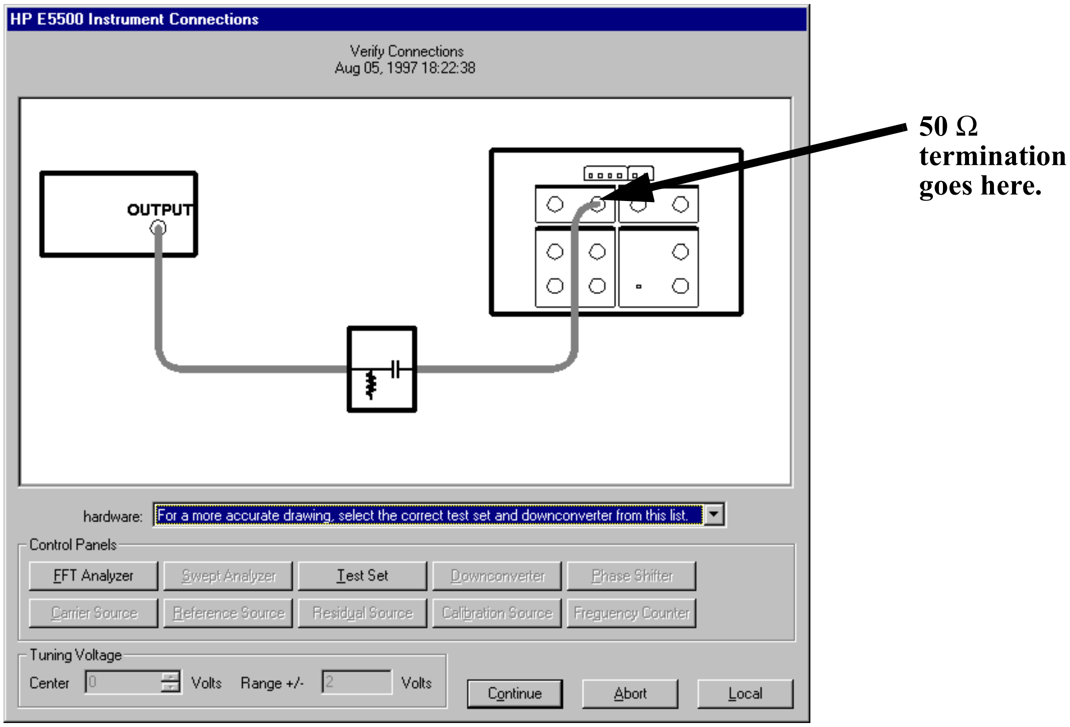


Figure 3-6 Setup Diagram Displayed During the Confidence Test.

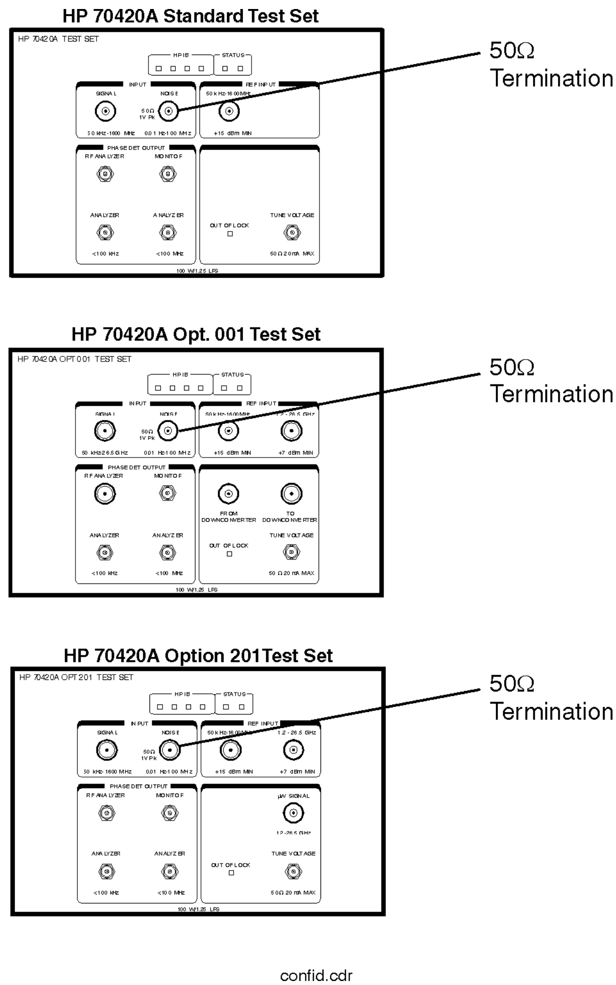


Figure 3-7 Connect Diagram Example

Making the Measurement

1 Press the **Continue** key. Because you selected New Measurement to begin this measurement, the system starts by running the routines required to calibrate the current measurement setup.

Figure 3-8 shows a typical baseband phase noise plot for an Agilent 70420A phase noise test set.

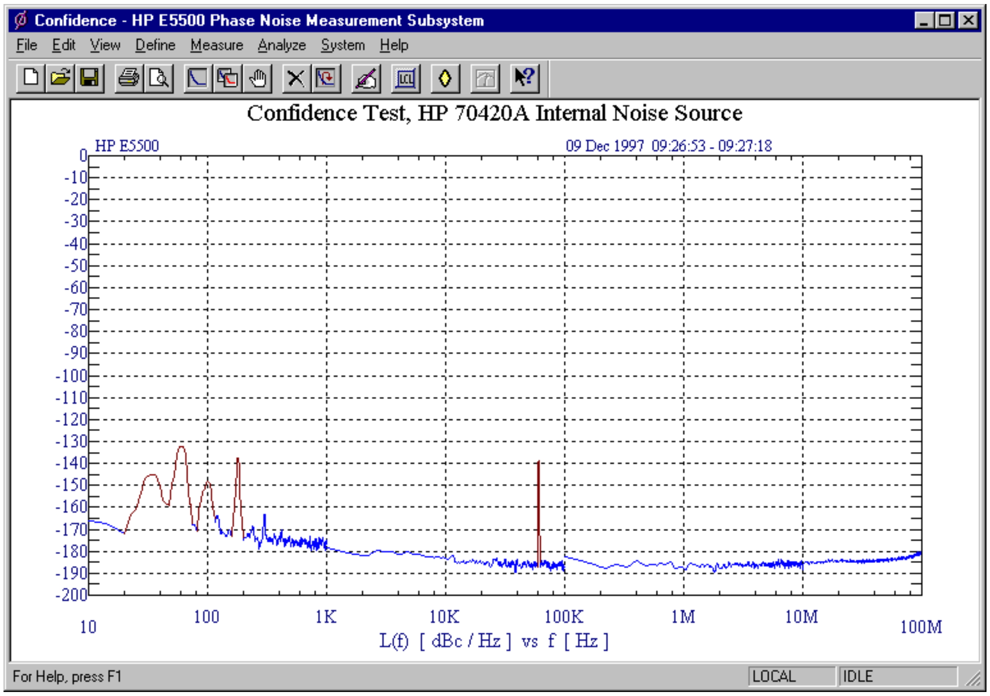


Figure 3-8 Typical Phase Noise Curve for an Agilent 70420A Confidence Test

Sweep-Segments

When the system begins measuring noise, it places the noise graph on its display. As you watch the graph, you will 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. You will find that this measurement of the Agilent 70420A test set’s internal noise source 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 3-8, you now have confidence that your system is operating normally.

To Learn More

Now continue with this demonstration by turning to Chapter 5, "Expanding Your Measurement Experience" to learn more about performing phase noise measurements.

Table 3-1 Parameter Data for the Agilent 70420A 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*
	• 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
5	**Graph Tab**	
	• Title	• Confidence Test, Agilent 70420A Internal Noise Source.
	• 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 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

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

4

Phase Noise Basics

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 4-1.

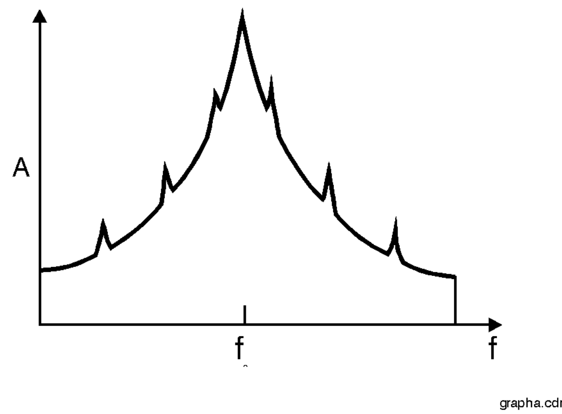


Figure 4-1 RF Sideband Spectrum

There are two types of fluctuating phase terms. The first, deterministic, 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.

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.

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 4-2) 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).

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).

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

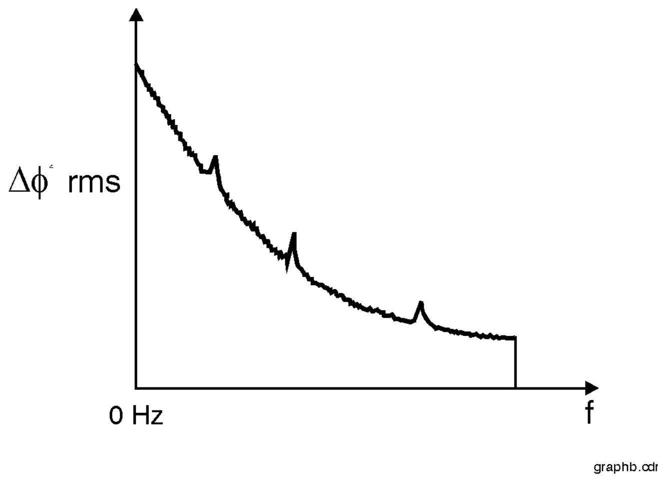


Figure 4-2 CW Signal Sidebands viewed in the frequency domain

L(f) is an indirect measurement of noise energy easily related to the RF power spectrum observed on an RF analyzer. Figure 4-3 shows that the National Institute Science 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.

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

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

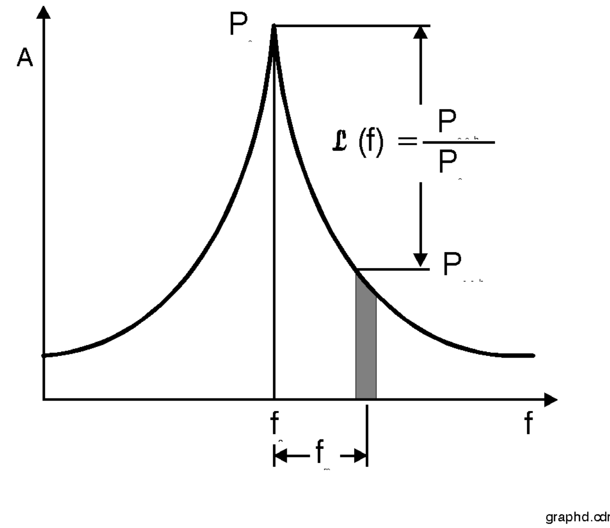


Figure 4-3 Deriving L(f) from a RF Analyzer Display

$L(f)$ 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 4-4. This chapter, except where noted otherwise, will use the logarithmic form of $L(f)$ as follows: $S_{\Delta f}(f) = 2f^2 L(f)$.

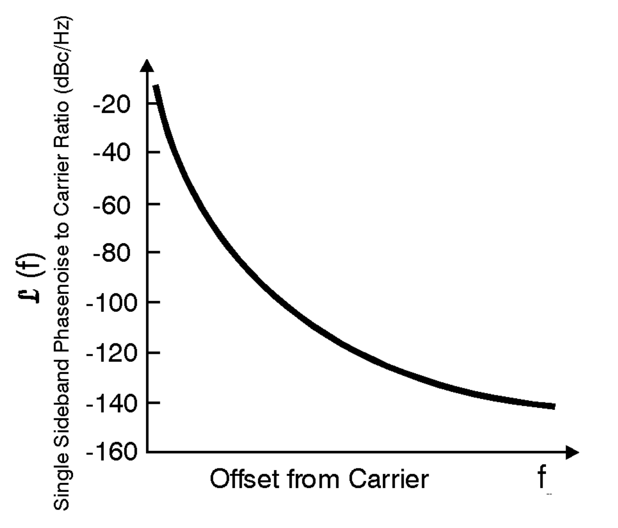


Figure 4-4 L(f) Described Logarithmically as a Function of Offset Frequency

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 4-5, 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 4-5 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.

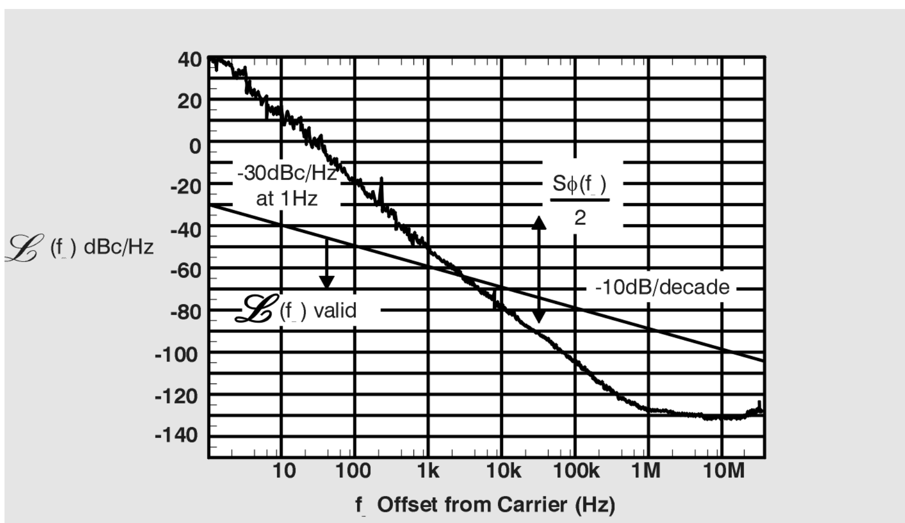


Figure 4-5 Region of Validity of L(f)

5

Expanding Your Measurement Experience

Starting the Measurement Software

1 Make sure your computer and monitor are turned on.

2 Place the Agilent E5500 phase noise measurement software disk in the disc holder and insert in the CD-ROM drive.

3 Using Figure 5-1 as a guide, navigate to the **E5500 User Interface**.

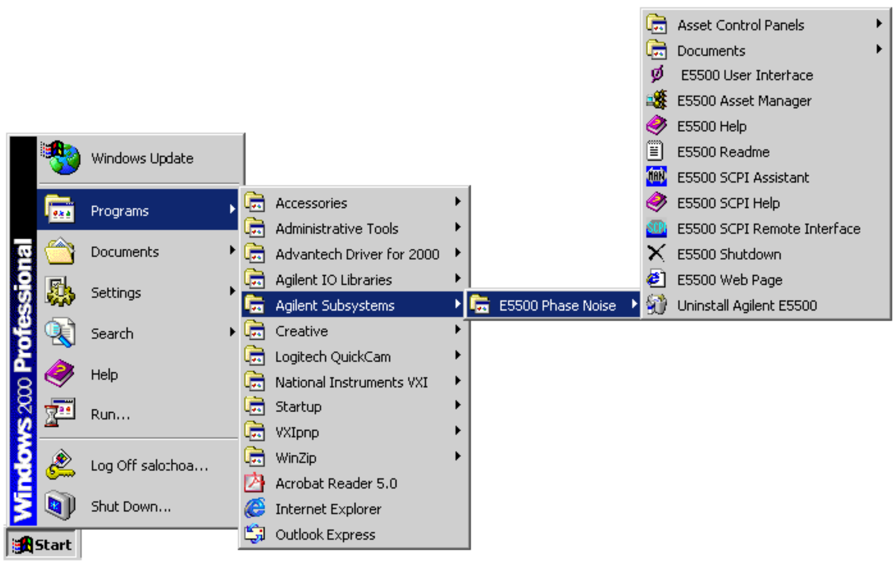


Figure 5-1 Navigate to E5500 User Interface

Using the Asset Manager to Add a Source

This procedure configures both the Agilent 70420A phase noise test set and PC-digitizer so they can be used with the E5500A phase noise measurement software to make measurements.

NOTE: If you have ordered a preconfigured phase noise system from Agilent Technologies, skip this step and proceed to “Testing the Agilent 8663A Internal/External 10 MHz” on page 5-11.

4 Using Figure 5-2 as a guide, navigate to **Asset Manager**.

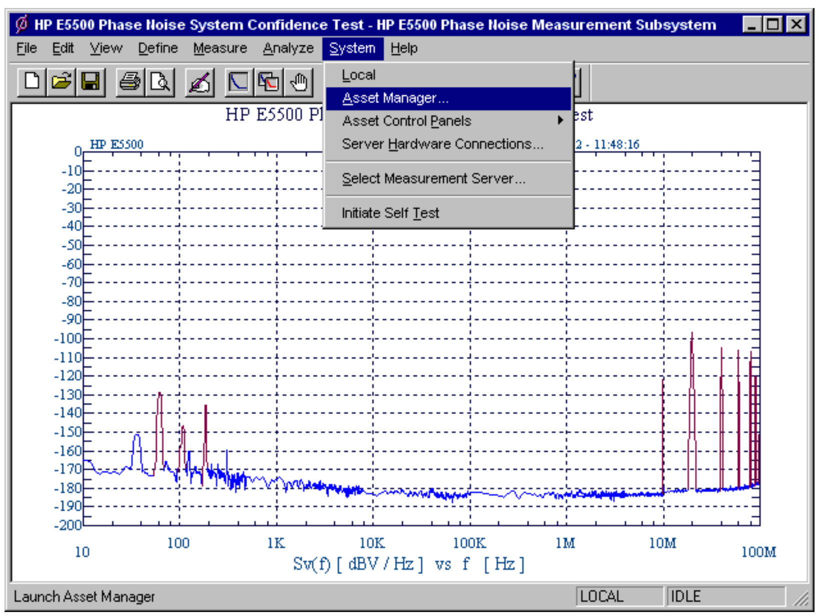


Figure 5-2 Navigate to Asset Manager

Configuring a Source

For this example we invoke the Asset Manager Wizard from within the Asset Manager. This is the most common way to add assets.

5 Using as a navigational guide, select **Add** in the Asset Manager window.

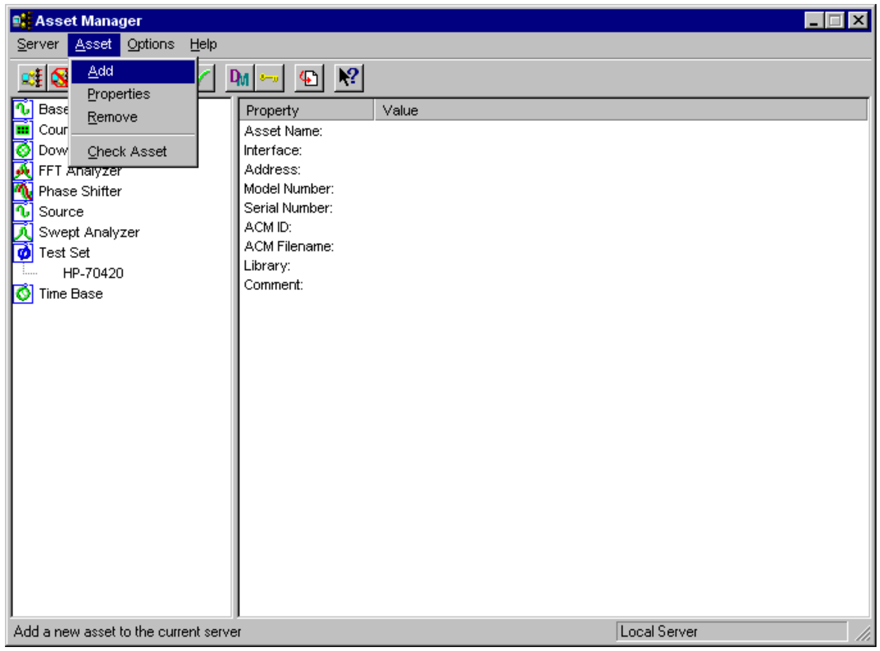


Figure 5-3 Navigate to **Add** in the Asset Manager

6 From the **Asset Type** pull-down list in **Choose Asset Role** dialog box (Figure 5-4), select **Source,** then click the **Next** button.

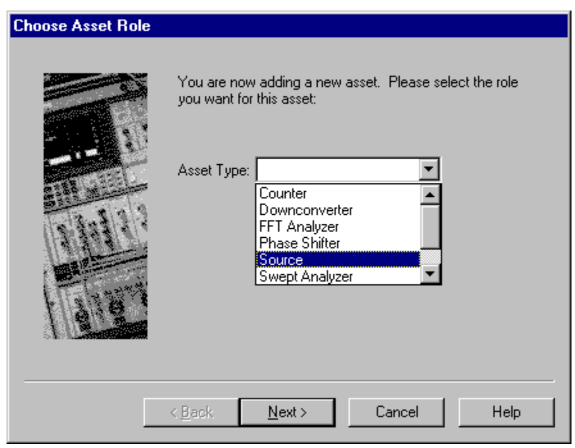


Figure 5-4 Select Source as Asset Type

7 Click on the source to be added, then click the **Next** button. See Figure 5-5.

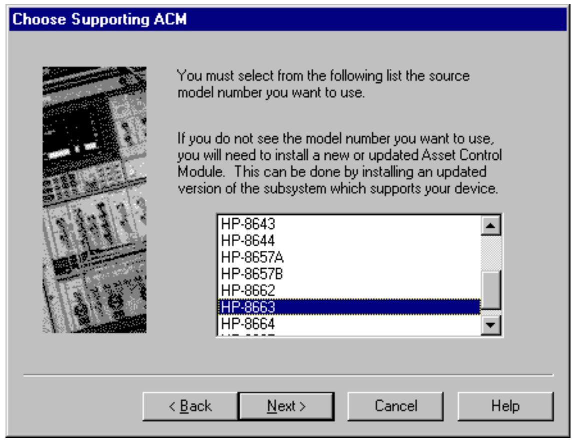


Figure 5-5 Chose Source to be Added

8 From the **Interface** pull-down list, select **GPIB0**.

9 In the **Address** box, type **19.** 19 is the default address for the Agilent 8663A sources, including the Agilent 8662A, 8663A, and 8644B.

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

11 In the **Set Model & Serial Numbers dialog** box, type in your source asset name and its corresponding serial number. **See Figure 5-6.**

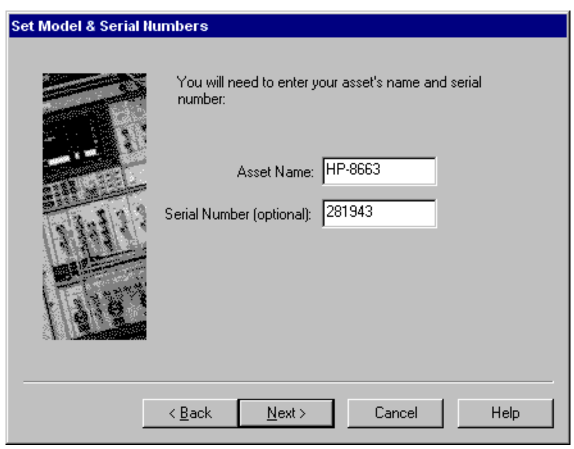


Figure 5-6 Choose Asset and Serial Number

12 In the **Enter A Comment** dialog box, you may type a comment that associates itself with the asset you have just configured. See Figure 5-7. Click the **Finish** button.

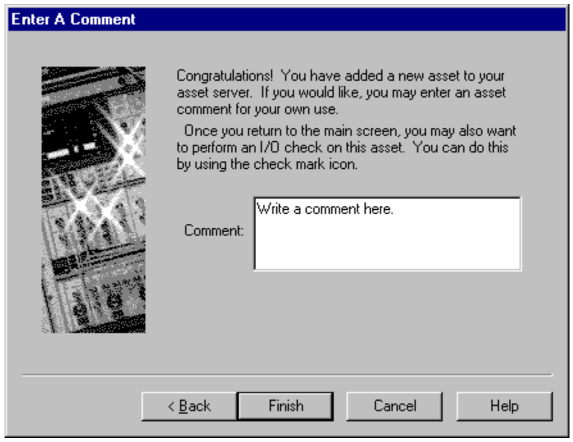


Figure 5-7 Enter Asset Comment

13 You have just used the Asset Manager to configure a source. See Figure 5-8. Use the same process to add other software controlled assets to the phase noise measurement software.

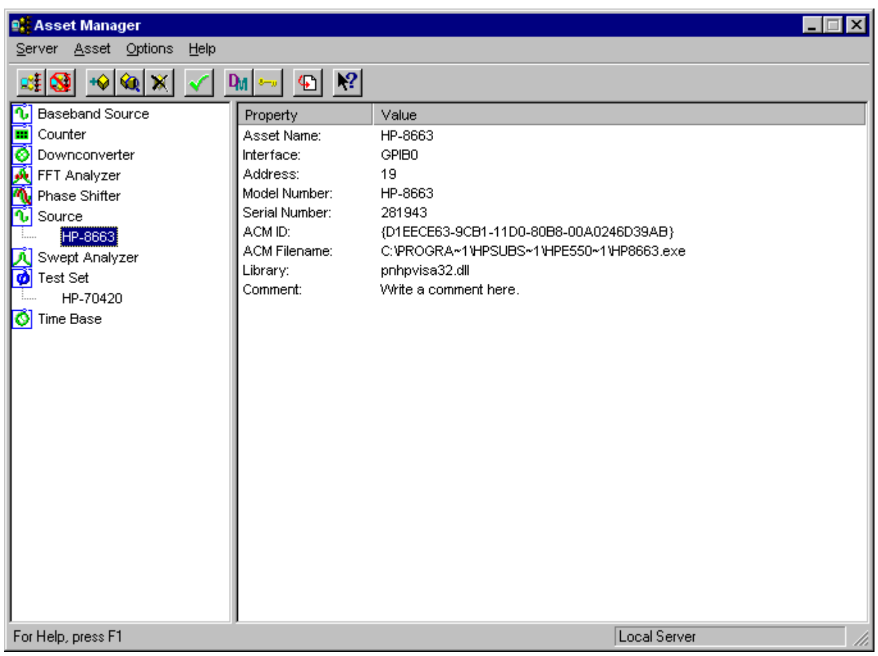


Figure 5-8 Asset Manager Showing Added Source

14 click **Server in the Asset Manager window,** and then click **Exit** to exit the Asset Manager.

15 Next continue to “Using the Server Hardware Connections to Specify an Asset” on the next page.

Using the Server Hardware Connections to Specify the Source

1 From the **System** menu, choose **Server Hardware Connections.** See Figure 5-9.

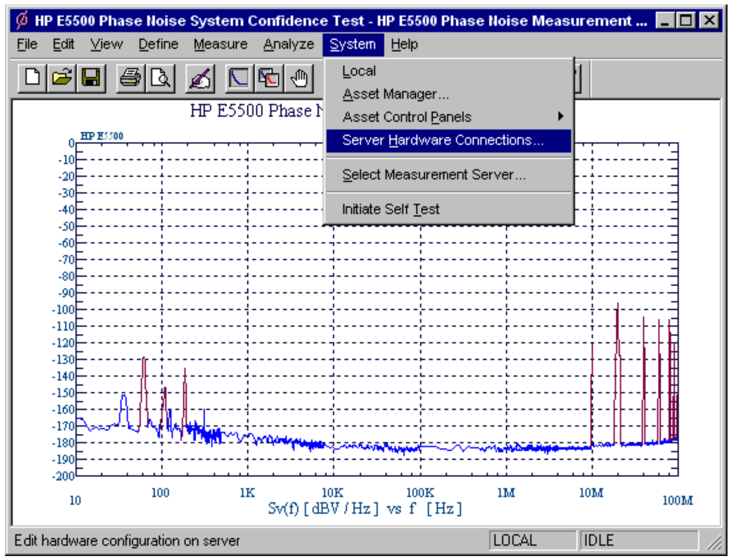


Figure 5-9 Navigate to Server Hardware Connections

2 From the **Test Set** pull-down list, select **Agilent 8663.** A green check-mark appears after the I/O check has been performed by the software. **See Figure 5-11.** If a green check-mark does not appear, click the **Check I/O** button. See Figure 5-10**.**

- **a** If a red circle with a slash appears, return to the Asset Manager (click the **Asset Manager** button) and verify that the Agilent 8663A is configured correctly.
- **b** Check your system hardware connections.
- **c** Click the green check-mark button on the asset manager's tool bar to verify connectivity.
- **d** Return to "Server Hardware Connections" and click the **Check I/O** button for a re-check.

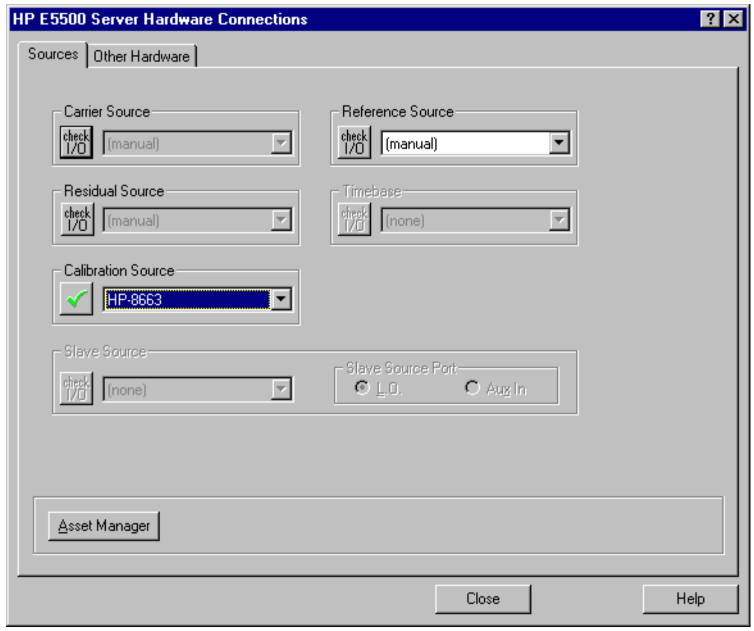


Figure 5-10 Green Check-mark Verifies I/O Check

.

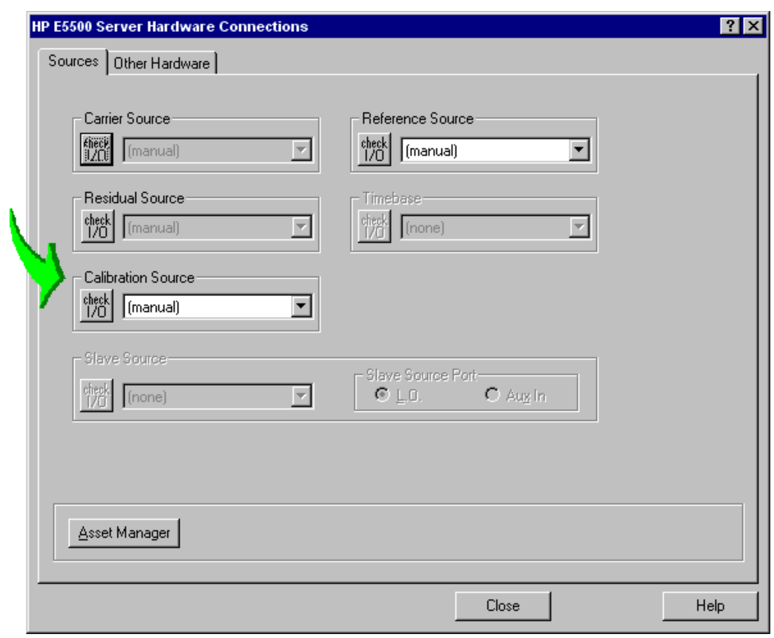


Figure 5-11 Check I/O Connections

3 Next proceed to one of the following absolute measurements using either an Agilent 8663A or an Agilent 8644B source:

- "Testing the Agilent 8663A Internal/External 10 MHz" on page 5-11.
- "Testing the Agilent 8644B Internal/External 10 MHz" on page 5-28.

Testing the Agilent 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 Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 5-3. Apply the input signal when the connection diagram appears.

Table 5-1 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 5-1 Required Equipment for the Agilent 8663A 10 MHz Measurement

Equipment	Quantity	Comments
Agilent 8663A	1	Refer to the "Selecting a Reference" on page 6-9 section of this chapter for more information about reference source requirements
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

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_8663A_10MHz.pnm**." See Figure 5-12.

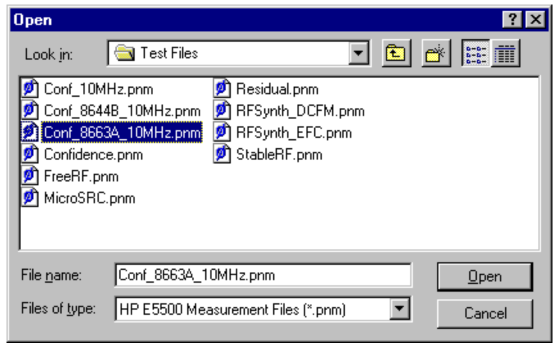


Figure 5-12 Select the Parameters Definition File

3 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 5-4 lists the parameter data that has been entered for this measurement example.)

NOTE: Note that the source parameters entered for step 2 in Table 5-4 may not be appropriate for the reference source you are using. To change these values, refer to Table 5-2, then continue with step 4 below. Otherwise, go to "Beginning the Measurement" on page 5-17:

---

4 Using Figure 5-13 as a guide, navigate to the **Sources** tab.

- **a** Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.
- **b** Enter the VCO (Nominal) Tuning Constant (see Table 5-2).
- **c** Enter the Tune Range of VCO (see Table 5-2).
- **d** Enter the Center Voltage of VCO (see Table 5-2).
- **e** Enter the Input Resistance of VCO (see Table 5-2).

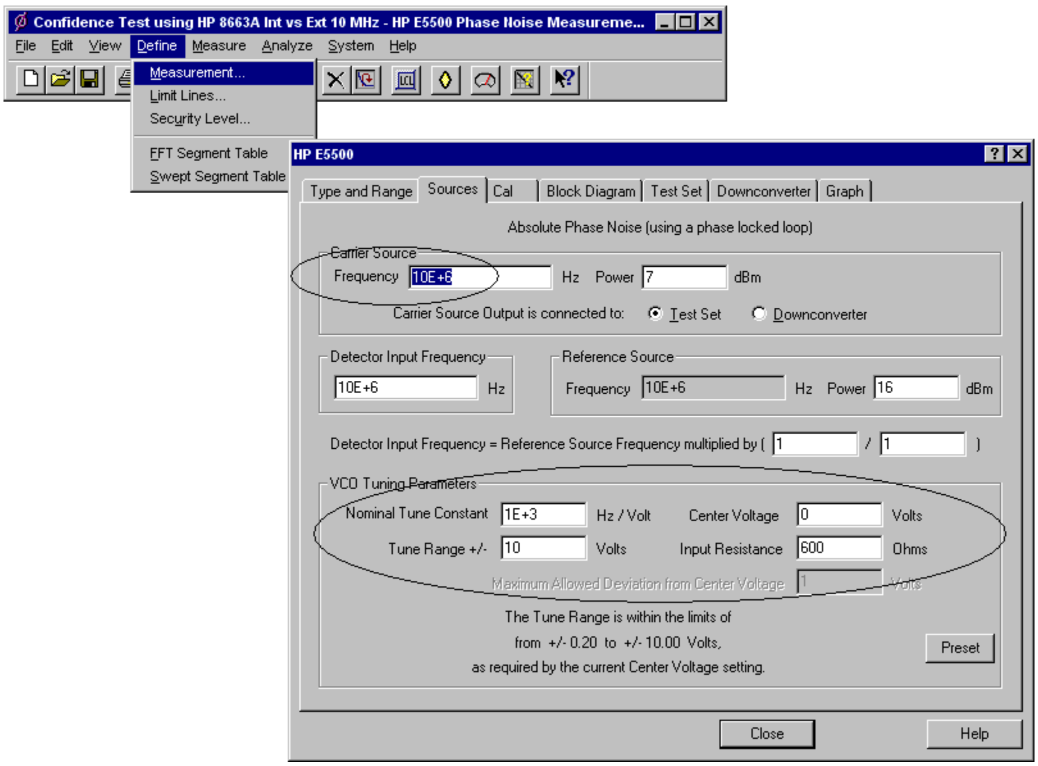


Figure 5-13 Enter Source Information

.

Table 5-2 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	$5\ E - 9\ x\ \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662)	Compute
					600 (8663)	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 5-14 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.

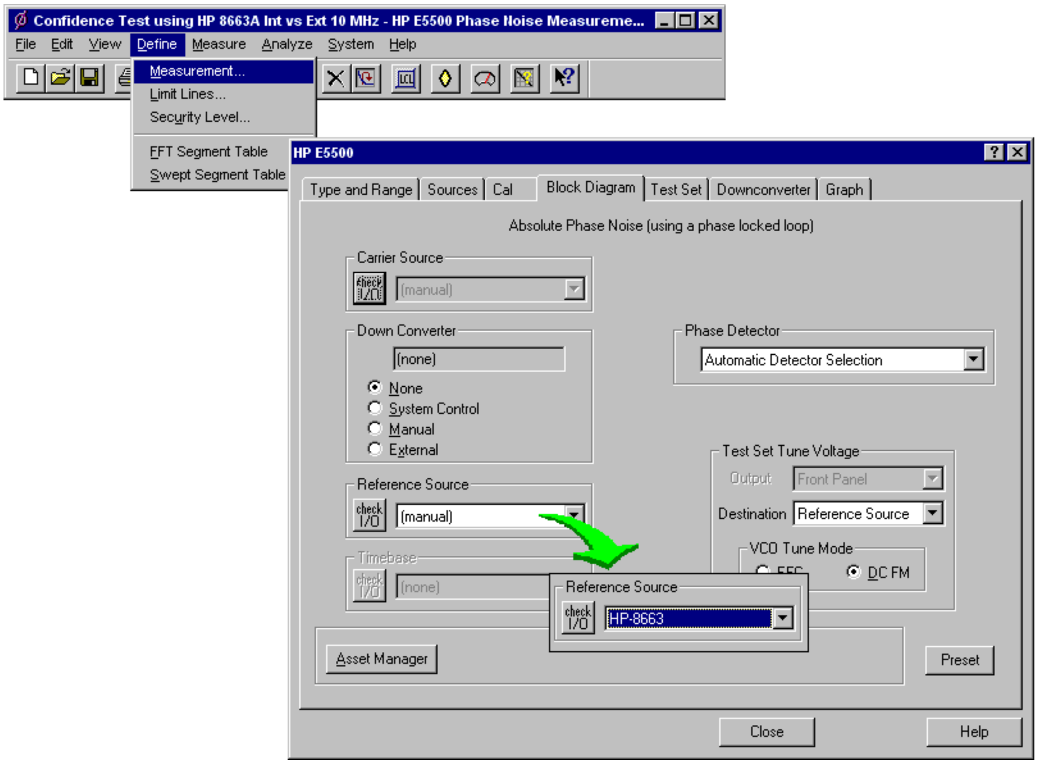


Figure 5-14 Selecting a Reference Source

Selecting Loop Suppression Verification

1 Using Figure 5-15 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.

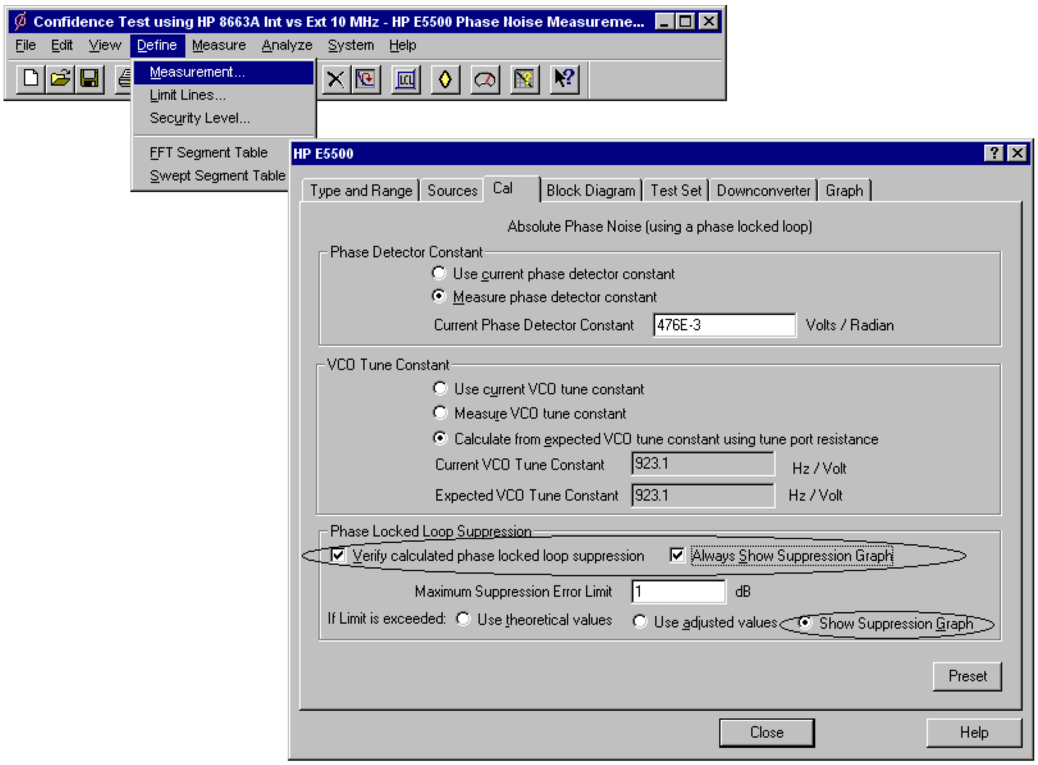


Figure 5-15 Selecting Loop Suppression Verification

Setup Considerations for the Agilent 8663A 10 MHz Measurement

The signal amplitude at the R input (Signal Input) port on the Agilent 70420A sets the measurement noise floor level. Use Figure 5-16 and Figure 5-17 to help determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. For more information about this graph, refer to Chapter 17, “Reference Graphs and Tables”.

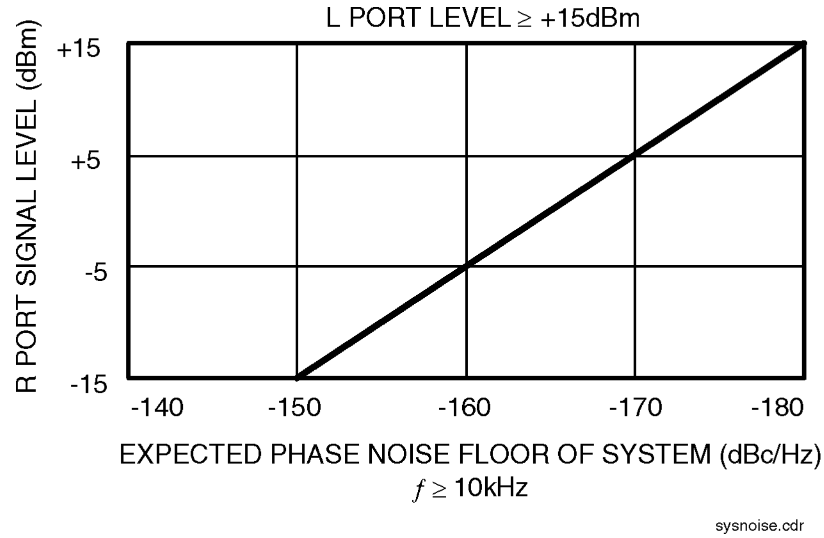


Figure 5-16 Noise Floor for the Agilent 8663 10 MHz Measurement

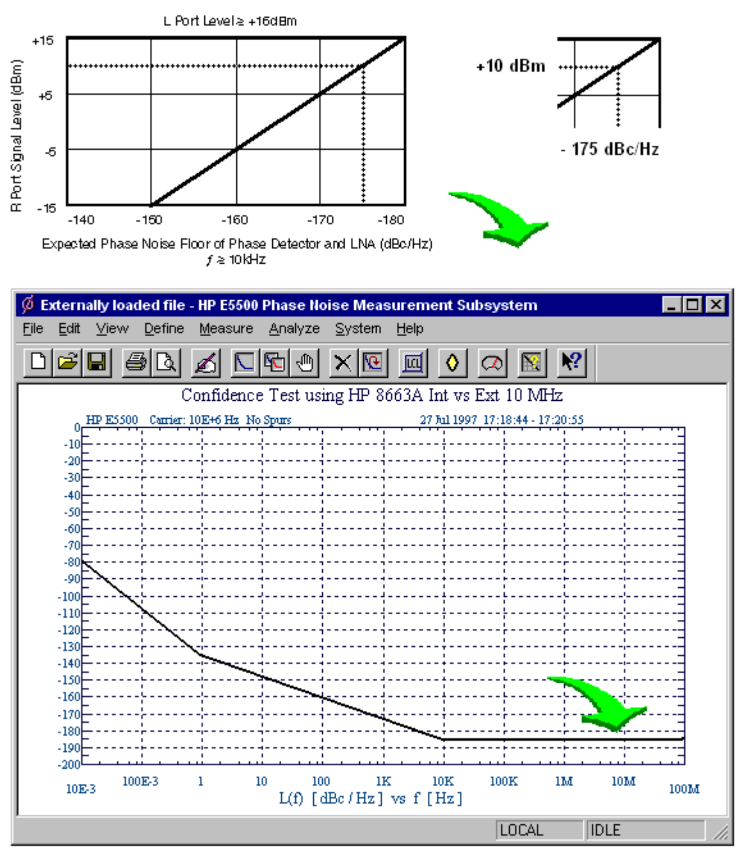


Figure 5-17 Noise Floor Example

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low-noise amplifier between the UUT and the test set. Refer to "Inserting an Device" in Chapter 6, "Absolute Measurement Fundamentals" for details on determining the effect the amplifiers noise will have on the measured noise floor.

Beginning the Measurement

CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 5-3. Apply the input signals when the connection diagram appears, as shown below in step 3.

1 From the **Measurement** menu, choose **New Measurement. See Figure 5-18.**

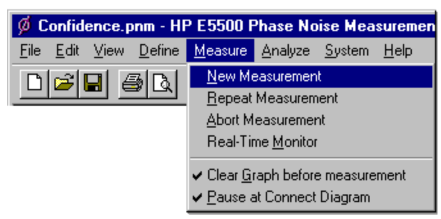


Figure 5-18 Selecting New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK.**

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

   Confirm your connections as shown in the Connect Diagram (Figure 5-19). At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 5-3 Agilent 70420A Test Set Signal Input Limits and Characteristics

Limits	
Frequency	50 kHz to 26.5 GHz
Maximum Signal Input Power	+30 dBm
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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A Test Set's hardware components, the input signal must not be applied 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 at the connection diagram.	
Characteristics:	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

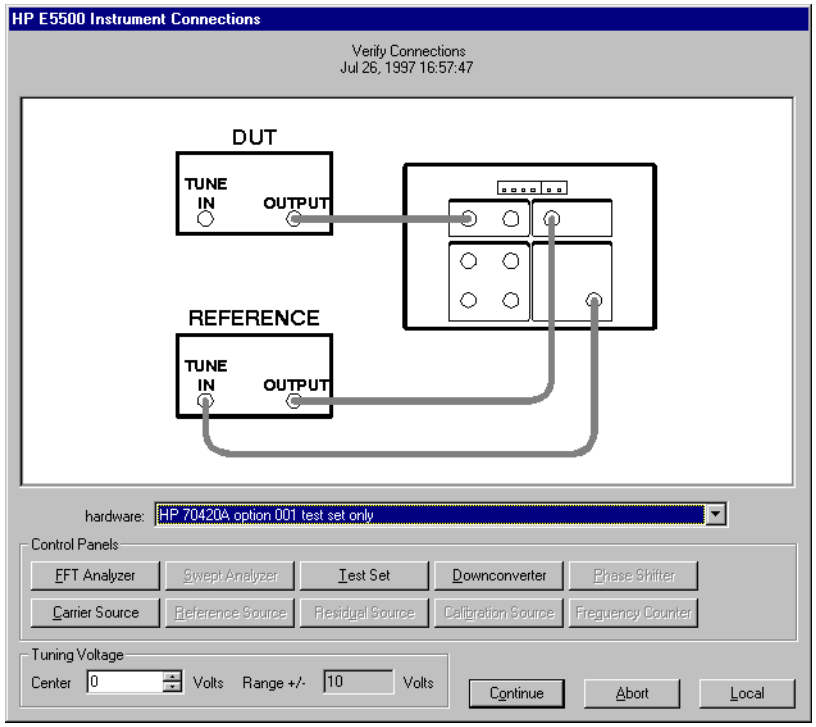


Figure 5-19 Connect Diagram for the Agilent 8663A 10 MHz Measurement

4 Refer to the following system connect diagram examples in Chapter 18, “Connect Diagrams”of this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-1, “E5501A Standard Connect Diagram,” on page 18-3
- Figure 18-14, “E5501B Standard Connect Diagram,” on page 18-16
- Figure 18-6, “E5502A Opt. 001 Connect Diagram,” on page 18-8
- Figure 18-15, “E5501B Opt. 001 Connect Diagram,” on page 18-17
- Figure 18-9, “E5503A Opt. 001 Connect Diagram,” on page 18-11
- Figure 18-21, “E5503B Opt. 001 Connect Diagram,” on page 18-23
- Figure 18-13, “E5504A Opt. 201 Connect Diagram,” on page 18-15

- Figure 18-25, “E5504B Opt. 201 Connect Diagram,” on page 18-27

5 The following messages appear on the display as the system performs the calibration routines. (You will have time to read through these message descriptions while the system completes the 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 will be 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.

6 The computer displays the PLL suppression curve and associated measurement values. Press **Continue using Adjusted Loop Suppression** to continue making the noise measurement. The measurement can be stopped by pressing the **Abort** key.

Sweep-Segments

When the system begins measuring noise, it places the noise graph on its display. As you watch the graph, you will 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 15, “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.

Checking the Beatnote

While the Connect Diagram is still displayed, recommend that you use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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. See Figure 5-20.

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.

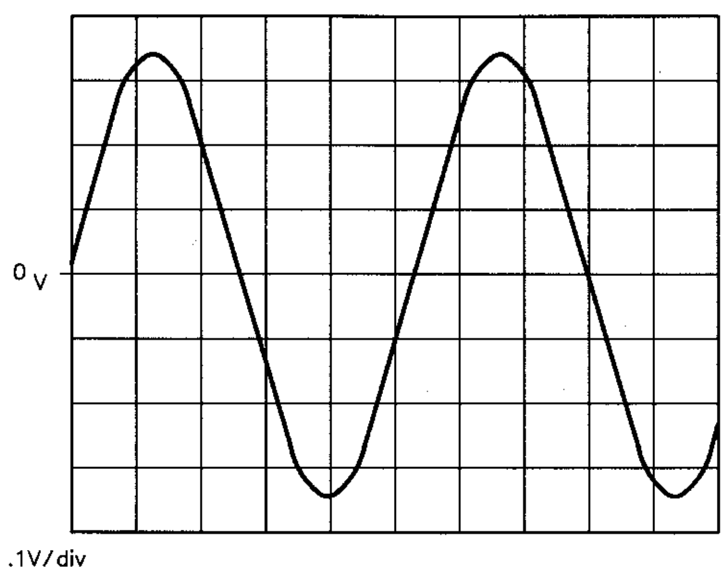


Figure 5-20 Oscilloscope Display of a Beatnote out of the Agilent 70420A Monitor Port

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 in the lower right of the dialog box. See** **Figure 5-21**.

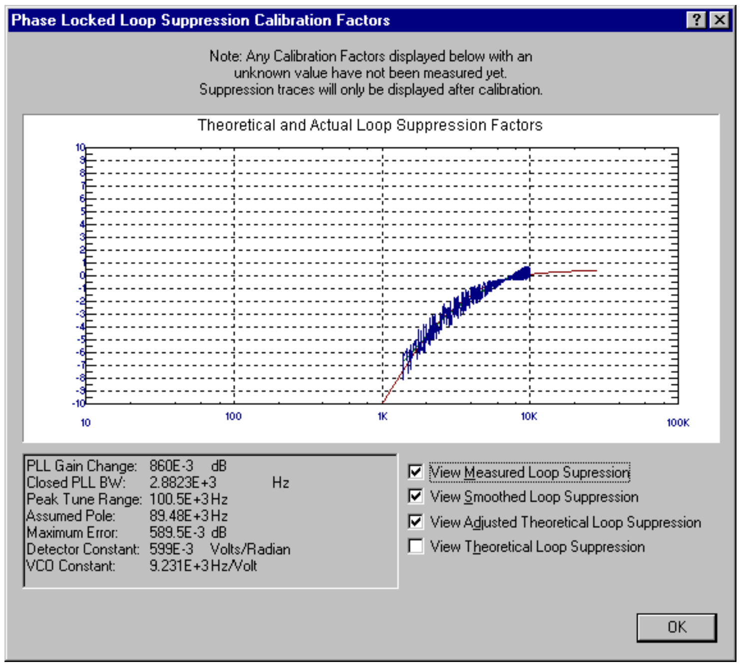


Figure 5-21 Selecting Suppression

There are four different curves available for the this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

a “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 5-22 shows a typical phase noise curve for a RF Synthesizer.

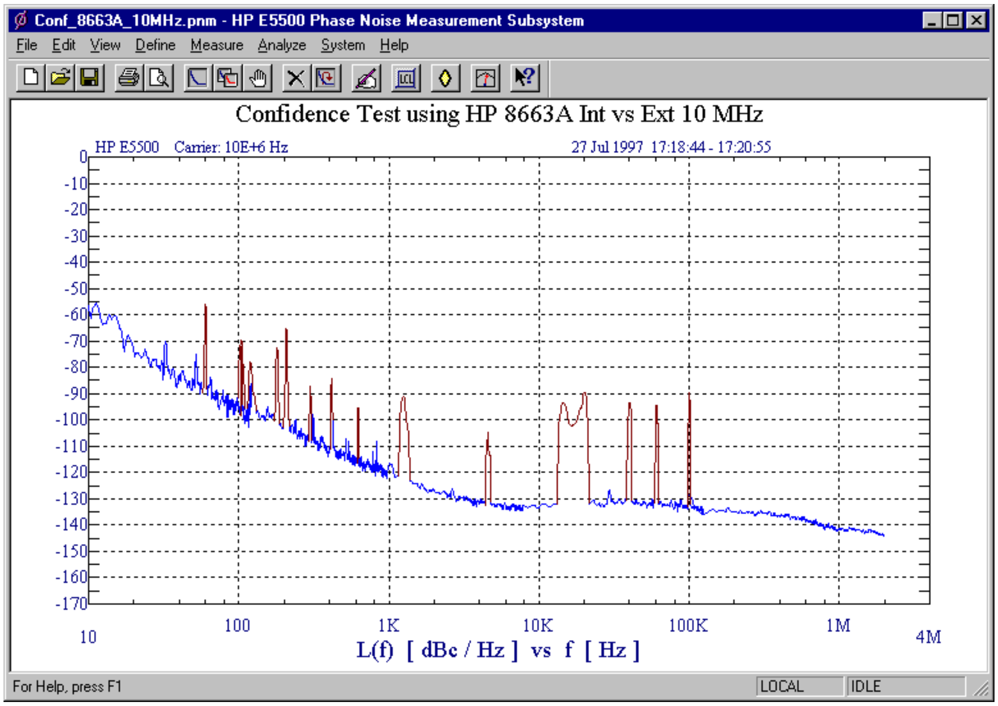


Figure 5-22 Typical Phase Noise Curve for an Agilent 8663A 10 MHz Measurement

Table 5-4 Parameter Data for the Agilent 8663A 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*
	• 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 8663A
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination	• Reference Source
	• VCO Tune Mode	• DCFM

Table 5-4 Parameter Data for the Agilent 8663A 10 MHz Measurement

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	**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

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

Testing the Agilent 8644B Internal/External 10 MHz

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

CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 5-7. Apply the input signal when the connection diagram appears.

Table 5-5 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 5-5 Required Equipment for the Agilent 8644B 10 MHz Measurement

Equipment	Quantity	Comments
Agilent 8644B	1	Refer to the "Selecting a Reference" on page 6-9 section of this chapter for more information about reference source requirements
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

Defining the Measurement

1. From the File menu of 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_8644B_10MHz.pnm.**" See Figure 5-23.

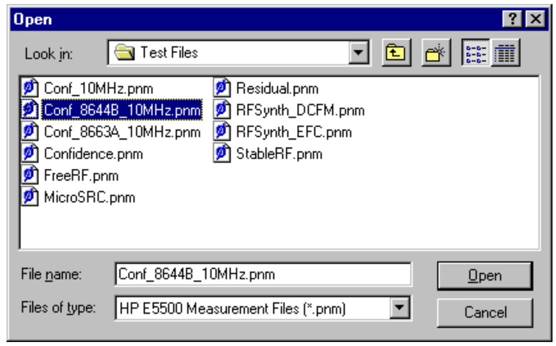


Figure 5-23 Select the Parameters Definition File

3 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 5-8 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 5-8 may not be appropriate for the reference source you are using. To change these values, refer to Table 5-6, then continue withstep 4 below. Otherwise, go to "Beginning the Measurement" on page 5-34:

---

4 Using Figure 5-24 as a guide, navigate to the **Sources** tab

- **a** Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.
- **b** Enter the VCO (Nominal) Tuning Constant (see Table 5-6).
- **c** Enter the Tune Range of VCO (see Table 5-6).
- **d** Enter the Center Voltage of VCO (see Table 5-6).
- **e** Enter the Input Resistance of VCO (see Table 5-6)

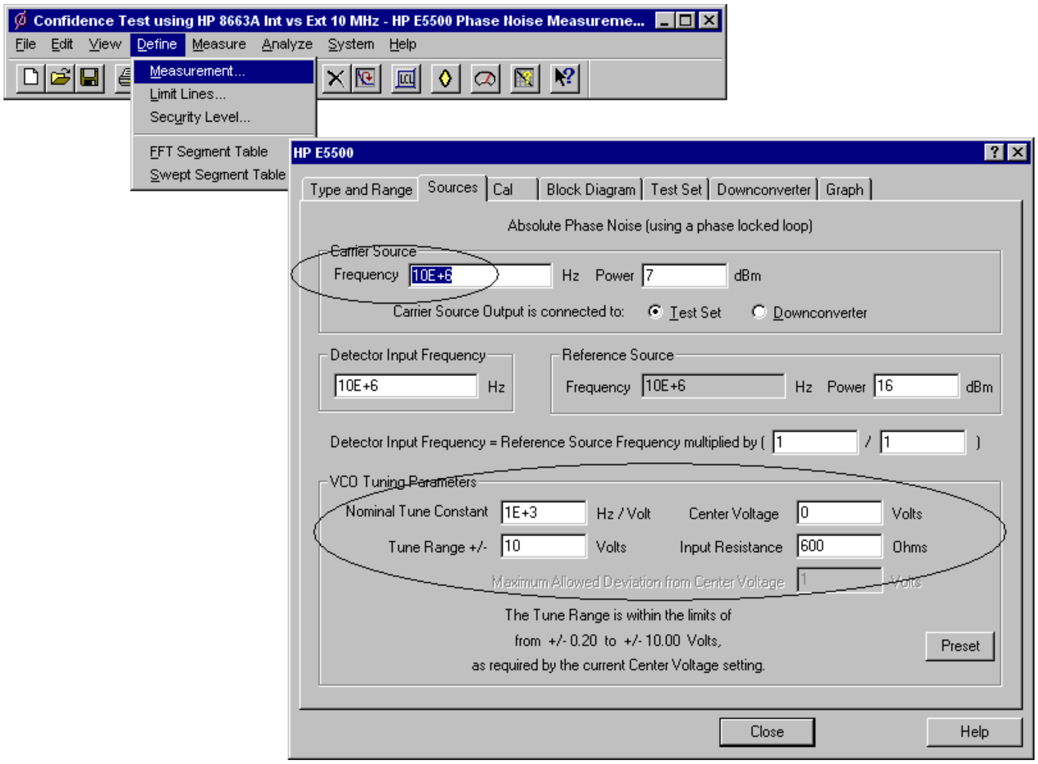


Figure 5-24 Sources Tab in Define Measurement Window

Table 5-6 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	$5\,E-9\times\upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662)	Compute
					600 (8663)	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 5-25.

2 From the **Reference Source** pull-down list, select **Agilent-8644**.

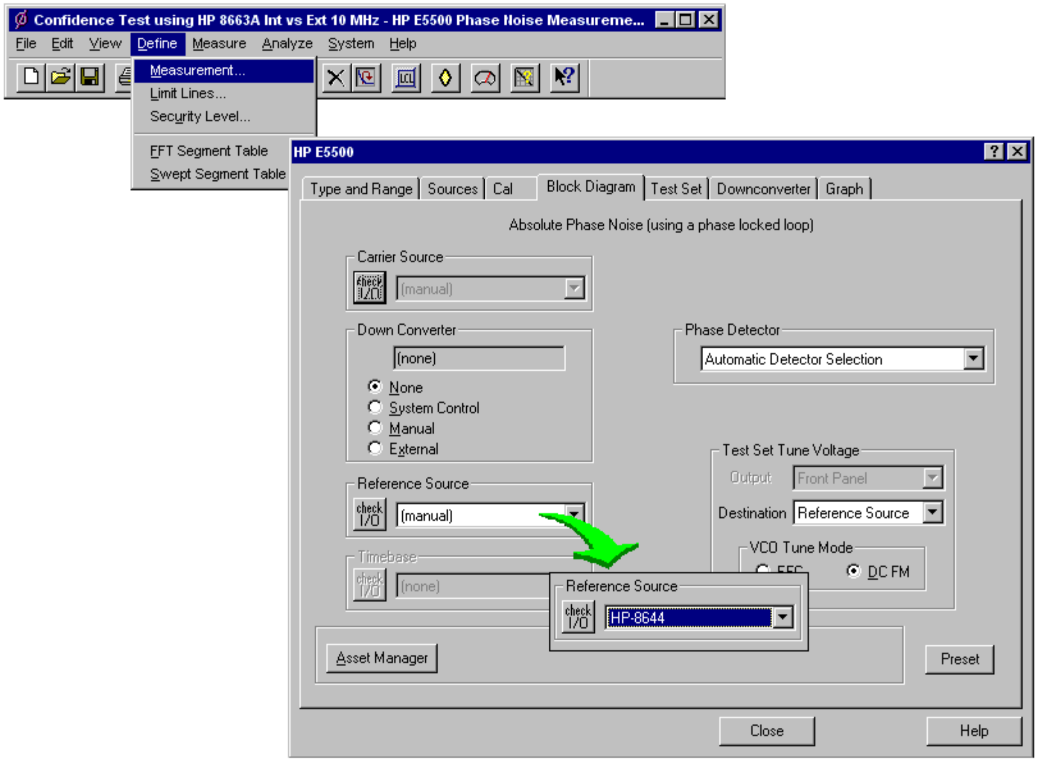


Figure 5-25 Selecting a Reference Source

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 5-26.

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

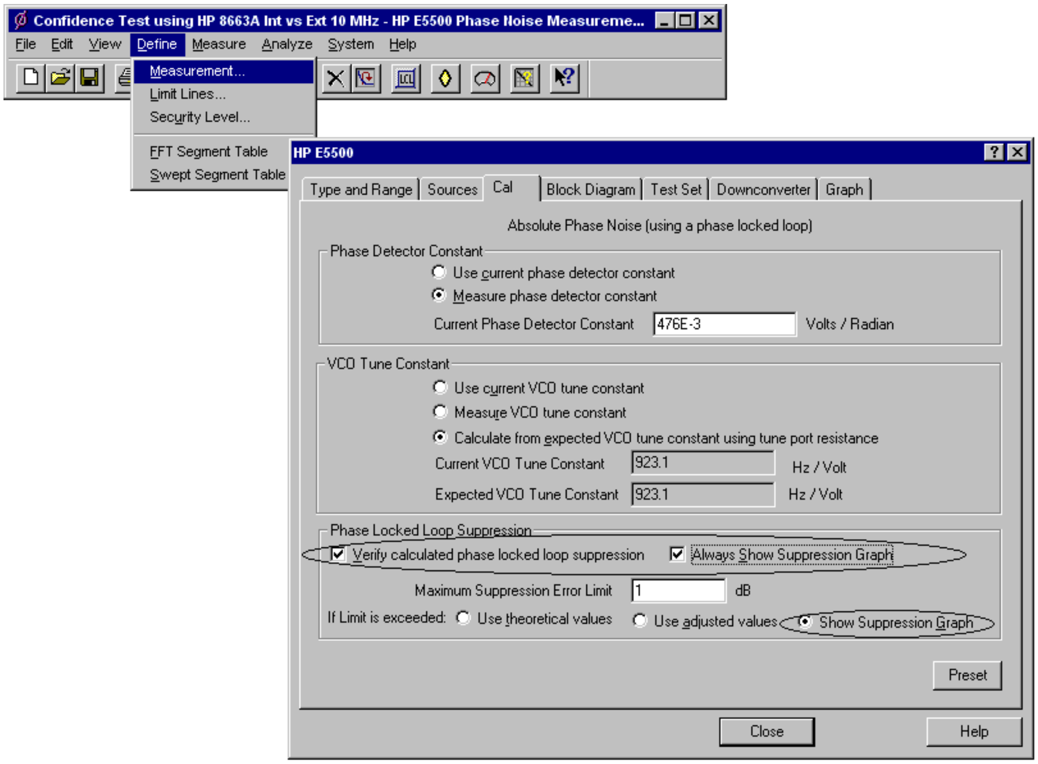


Figure 5-26 Selecting Loop Suppression Verification

Setup Considerations for the Agilent 8663A 10 MHz Measurement

The signal amplitude at the R input (Signal Input) port on the Agilent 70420A sets the measurement noise floor level. Use the following graph and example (Figure 5-27 and Figure 5-28) to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. For more information about this graph, refer to Chapter 17, “Reference Graphs and Tables”.

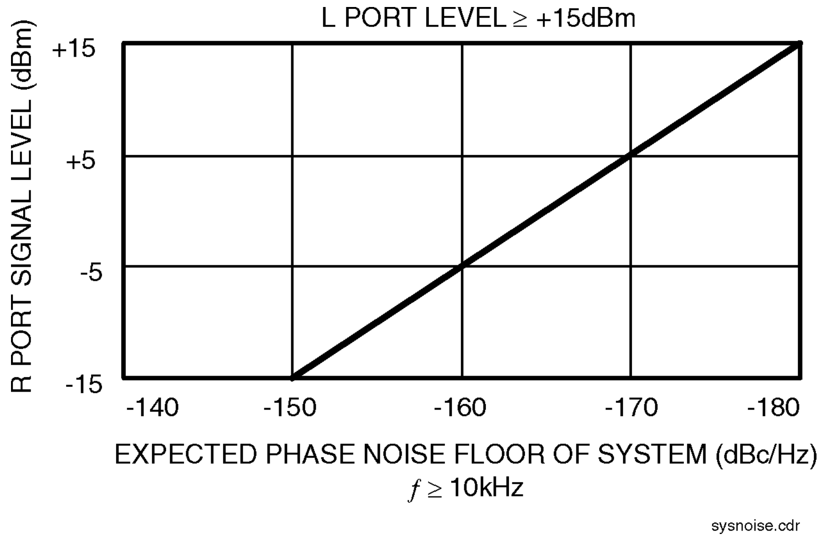


Figure 5-27 Noise Floor for the Agilent 8644B 10 MHz Measurement

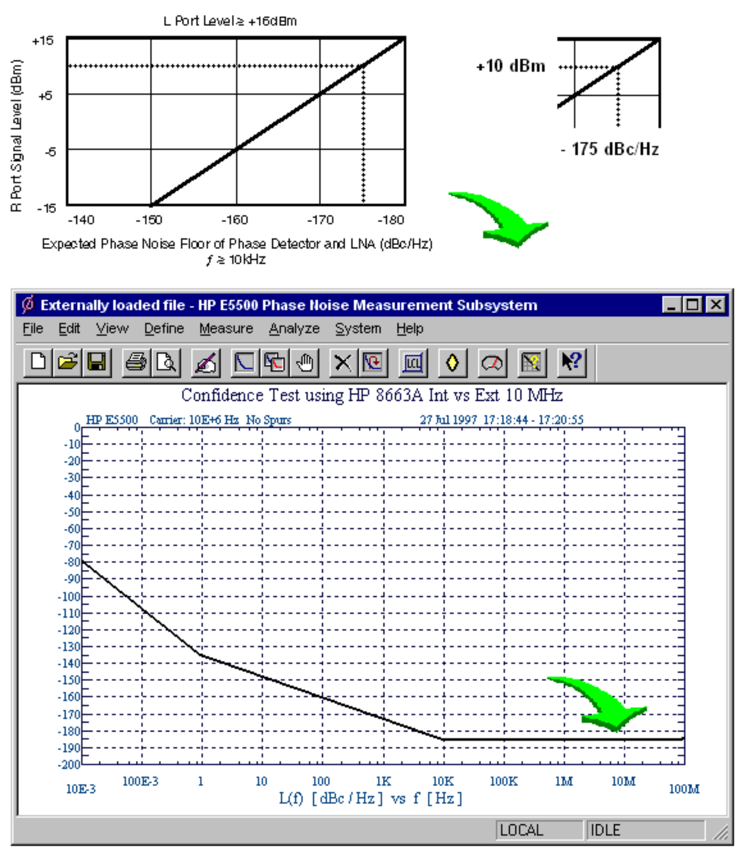


Figure 5-28 Noise Floor Example

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low-noise amplifier between the UUT and the test set. Refer to "Inserting an Device" in

for details on determining the effect the amplifiers noise will have on the measured noise floor.

Beginning the Measurement

CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 5-7 on page 5-35. Apply the input signals when the connection diagram appears, as shown below in step 3.

1 From the **Measurement** menu, choose **New Measurement. See Figure 5-29**.

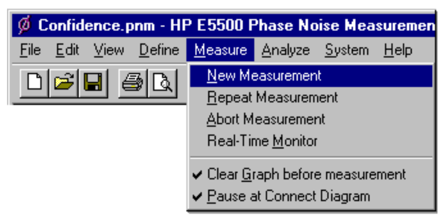


Figure 5-29 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

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

Confirm your connections as shown in the Connect Diagram (Figure 5-30). At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 5-7 Agilent 70420A Test Set Signal Input Limits and Characteristics

Limits	
Frequency	50 kHz to 26.5 GHz
Maximum Signal Input Power	+30 dBm
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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A Test Set's hardware components, the input signal must not be applied 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 at the connection diagram.	
Characteristics:	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

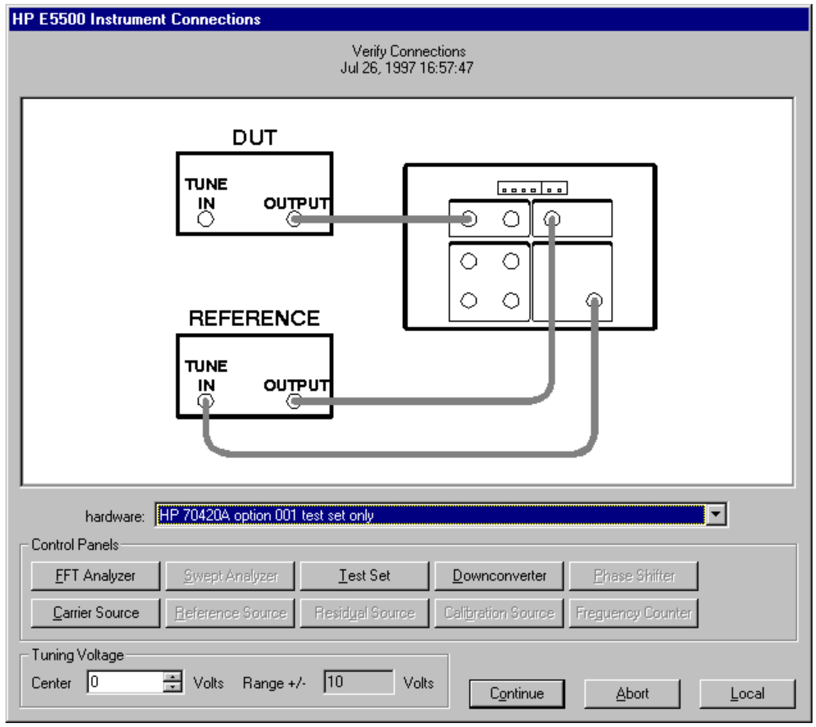


Figure 5-30 Connect Diagram for the Agilent 8644B 10 MHz Measurement

4 Refer to the following system connect diagram examples in Chapter 18, “Connect Diagrams”in this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-1, “E5501A Standard Connect Diagram,” on page 18-3
- Figure 18-14, “E5501B Standard Connect Diagram,” on page 18-16
- Figure 18-9, “E5503A Opt. 001 Connect Diagram,” on page 18-11
- Figure 18-21, “E5503B Opt. 001 Connect Diagram,” on page 18-23
- Figure 18-22, “E5503B Opt. 201 Connect Diagram,” on page 18-24
- Figure 18-25, “E5504B Opt. 201 Connect Diagram,” on page 18-27

5 The following messages will appear on the display as the system performs the calibration routines. (You will have time to read through these message descriptions while the system completes the 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 will be 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.

6 The computer displays the PLL suppression curve and associated measurement values. Press **Continue using Adjusted Loop Suppression** to continue making the noise measurement. The measurement can be stopped by pressing the **Abort** key.

Sweep-Segments

When the system begins measuring noise, it places the noise graph on its display. As you watch the graph, you will 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 15, “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.

Checking the Beatnote

While the Connect Diagram is still displayed, recommend that you use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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. See Figure 5-31.

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.

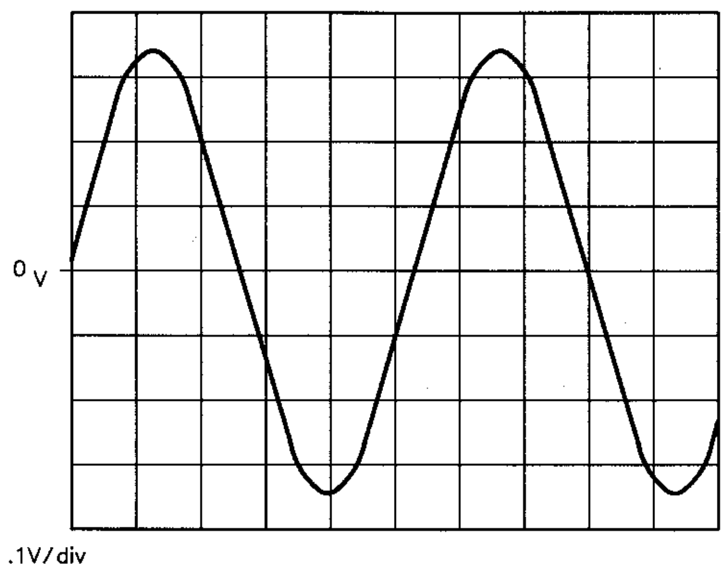


Figure 5-31 Oscilloscope Display of a Beatnote out of the Agilent 70420A Monitor Port

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 5-32.**

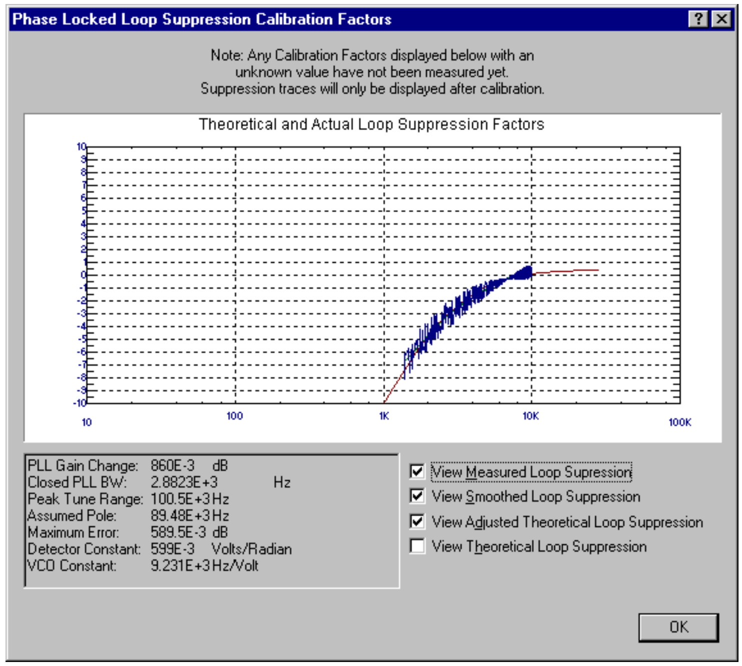


Figure 5-32 Suppression Selections

There are four different curves available for the this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

a “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 5-33 shows a typical phase noise curve for a RF Synthesizer.

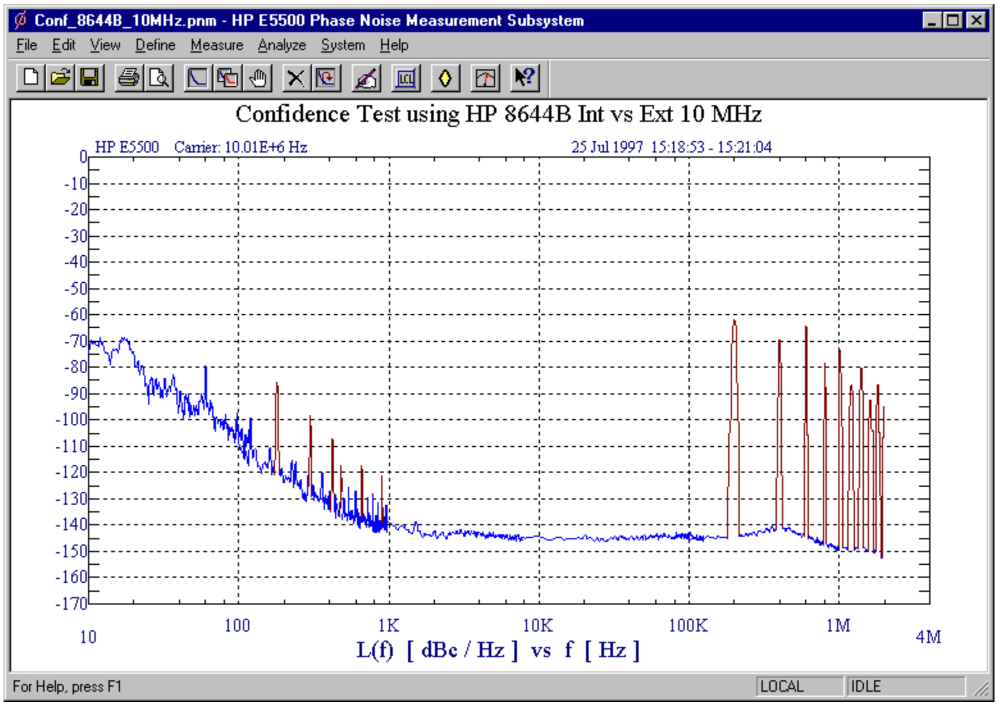


Figure 5-33 Typical Phase Noise Curve for an Agilent 8644B 10 MHz Measurement.

Table 5-8 Parameter Data for the Agilent 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*
	• 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

Table 5-8 Parameter Data for the Agilent 8644B 10 MHz Measurement

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	**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

* 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 5-34.

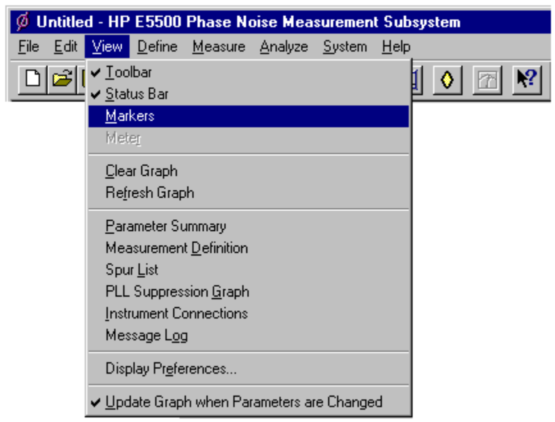


Figure 5-34 Navigate to Markers

In the dialog box containing Marker buttons, up to nine markers may be added. To remove the highlighted marker, click the **Delete** button. See Figure 5-35.

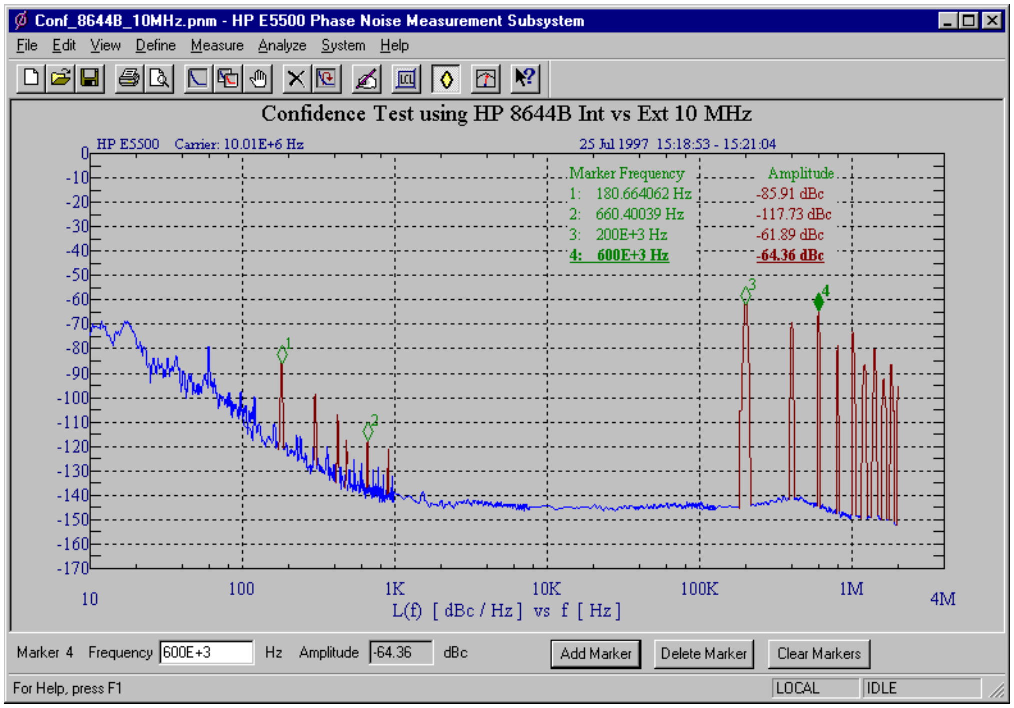


Figure 5-35 Adding and Deleting Markers

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 5-36.

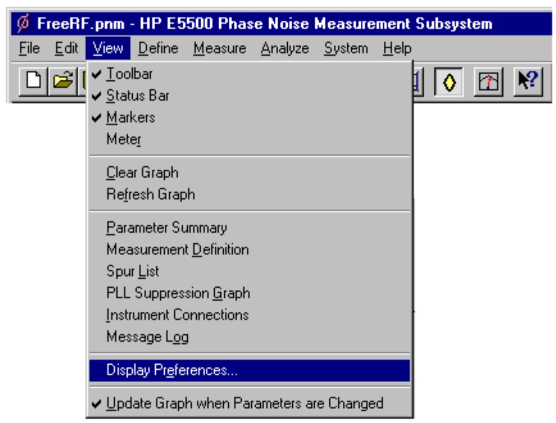


Figure 5-36 Navigate to Display Preferences

2 In the **Display Preferences** dialog box, uncheck **Spurs**. See Figure 5-37. Click OK.

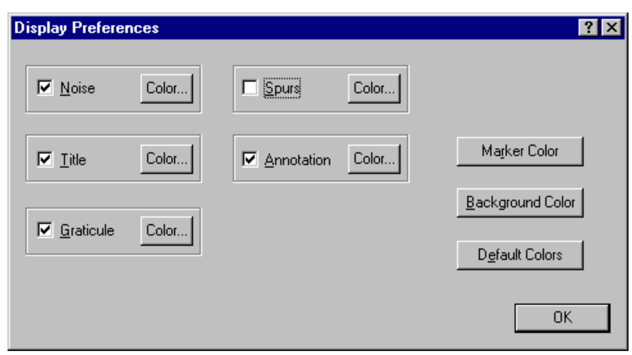


Figure 5-37 Uncheck Spurs

3 The Graph will be displayed without spurs. See Figure 5-38. To re-display the spurs, check **Spurs** in the **Display Preferences** dialog box.

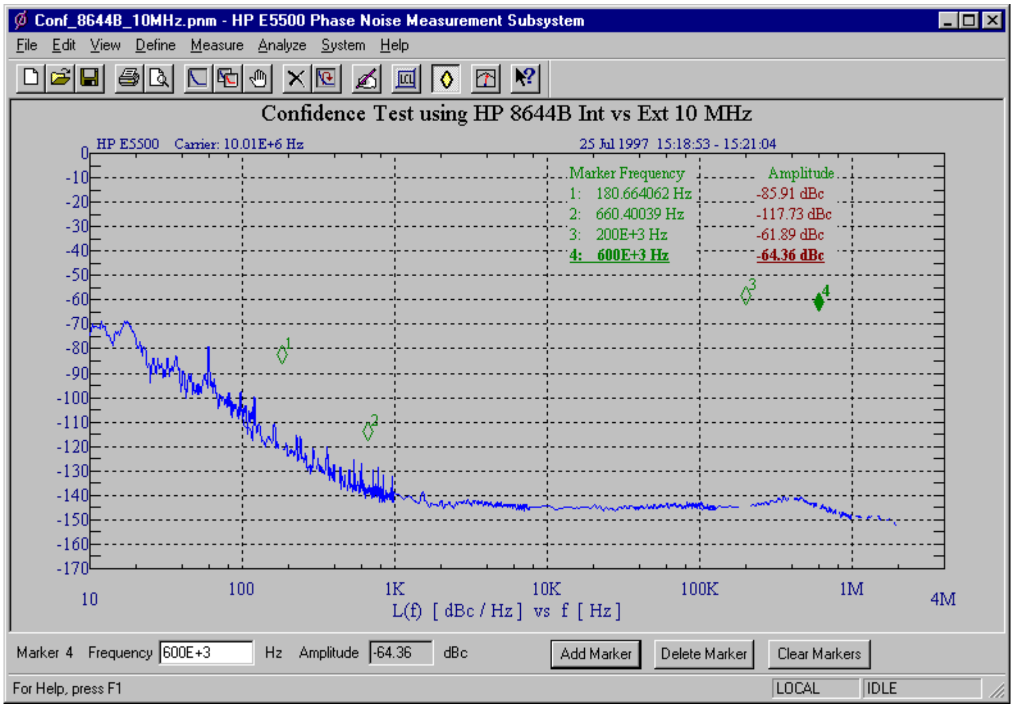


Figure 5-38 Graph Displayed without Spurs

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 5-39.

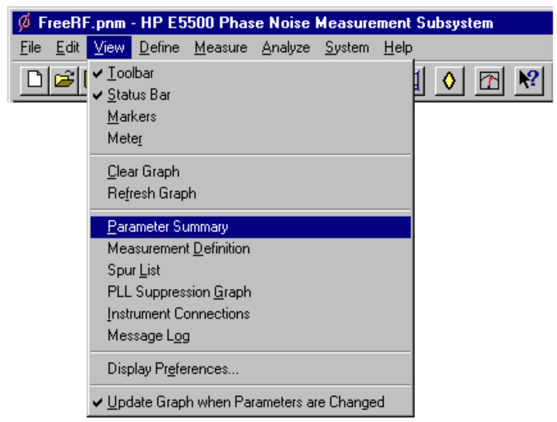
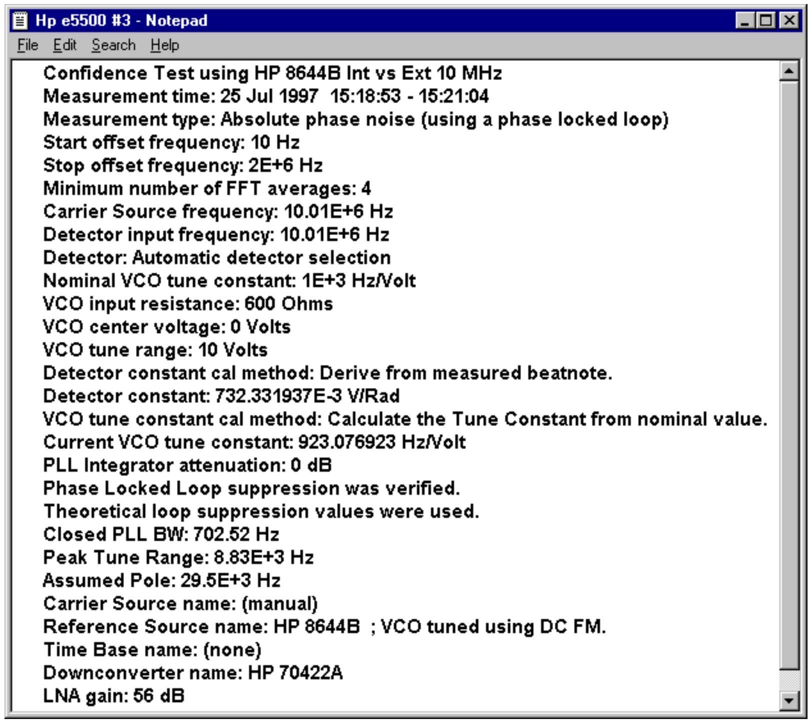


Figure 5-39 Navigate to Parameter Summary

2 The **Parameter Summary Notepad** dialog box appears. The data can be printed or changed using standard Notepad functionality. See Figure 5-40.



Hp e5500 #3 - Notepad

File Edit Search Help

Confidence Test using HP 8644B Int vs Ext 10 MHz
Measurement time: 25 Jul 1997 15:18:53 - 15:21:04
Measurement type: Absolute phase noise (using a phase locked loop)
Start offset frequency: 10 Hz
Stop offset frequency: 2E+6 Hz
Minimum number of FFT averages: 4
Carrier Source frequency: 10.01E+6 Hz
Detector input frequency: 10.01E+6 Hz
Detector: Automatic detector selection
Nominal VCO tune constant: 1E+3 Hz/Volt
VCO input resistance: 600 Ohms
VCO center voltage: 0 Volts
VCO tune range: 10 Volts
Detector constant cal method: Derive from measured beatnote.
Detector constant: 732.331937E-3 V/Rad
VCO tune constant cal method: Calculate the Tune Constant from nominal value.
Current VCO tune constant: 923.076923 Hz/Volt
PLL Integrator attenuation: 0 dB
Phase Locked Loop suppression was verified.
Theoretical loop suppression values were used.
Closed PLL BW: 702.52 Hz
Peak Tune Range: 8.83E+3 Hz
Assumed Pole: 29.5E+3 Hz
Carrier Source name: (manual)
Reference Source name: HP 8644B ; VCO tuned using DC FM.
Time Base name: (none)
Downconverter name: HP 70422A
LNA gain: 56 dB

Figure 5-40 Parameter Summary

Exporting Measurement Results

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

- "Exporting Trace Data" on page 5-51
- "Exporting Spur Data" on page 5-53
- "Exporting X-Y Data" on page 5-54

1 On the **File** menu, point to **Export Results,** then click on either **Trace Data**, **Spur Data**, or **X-Y Data.** See Figure 5-41.

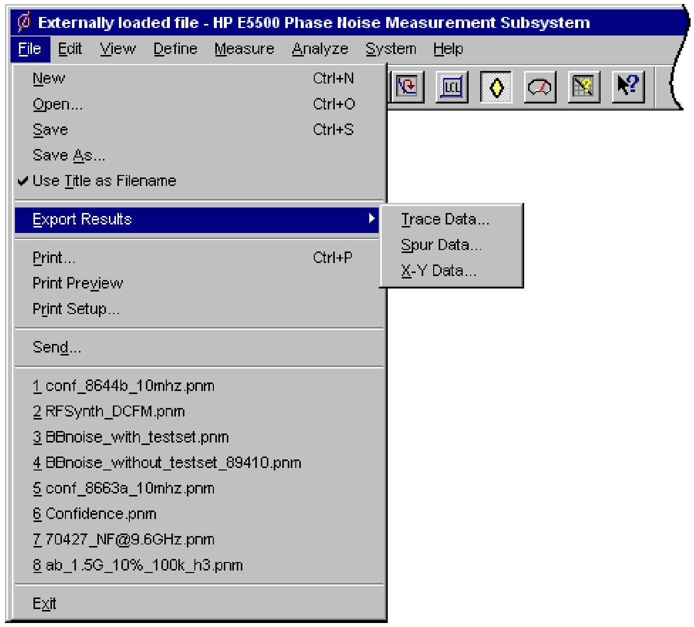


Figure 5-41 Export Results Choices

Exporting Trace Data

1 On the **File** menu, point to **Export Results,** then click on **Trace Data.** See Figure 5-42.

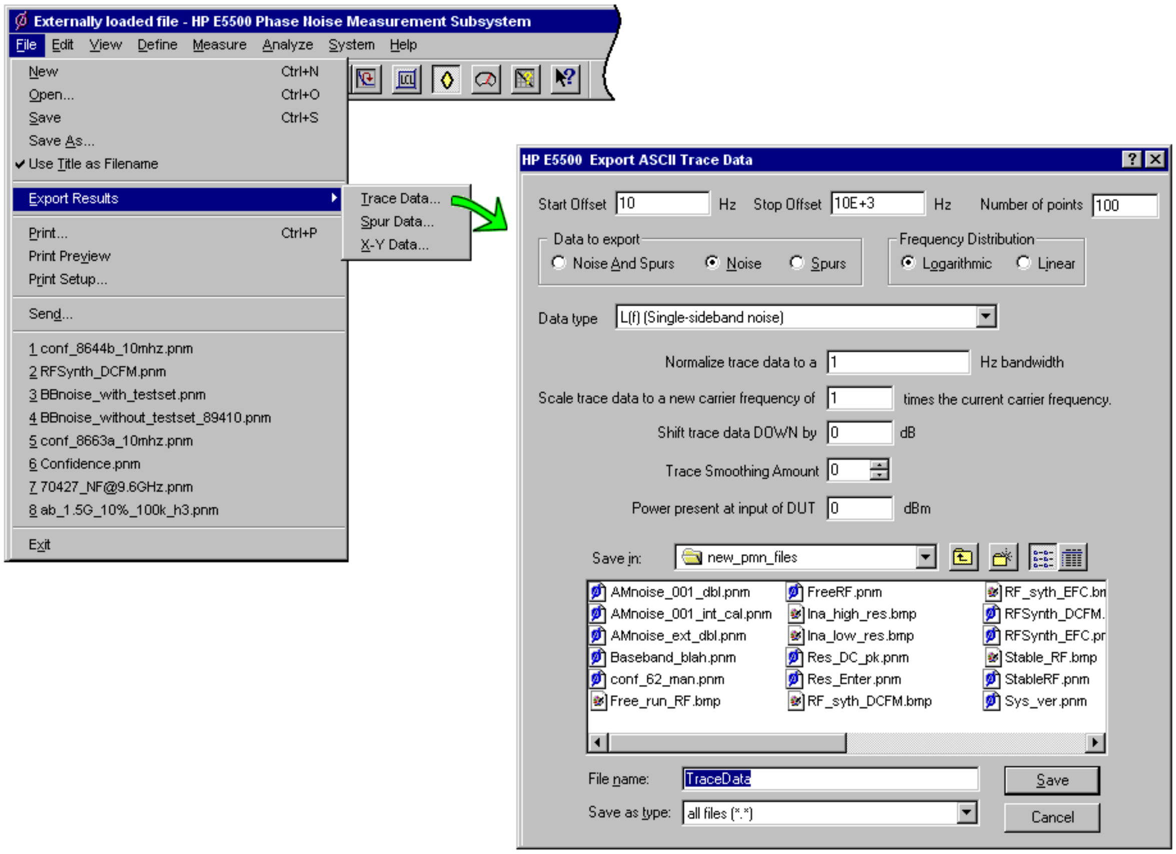


Figure 5-42 Trace Data Results

Exporting Spur Data

1 On the **File** menu, point to **Export Results,** then click on **Spur Data.** See Figure 5-43.

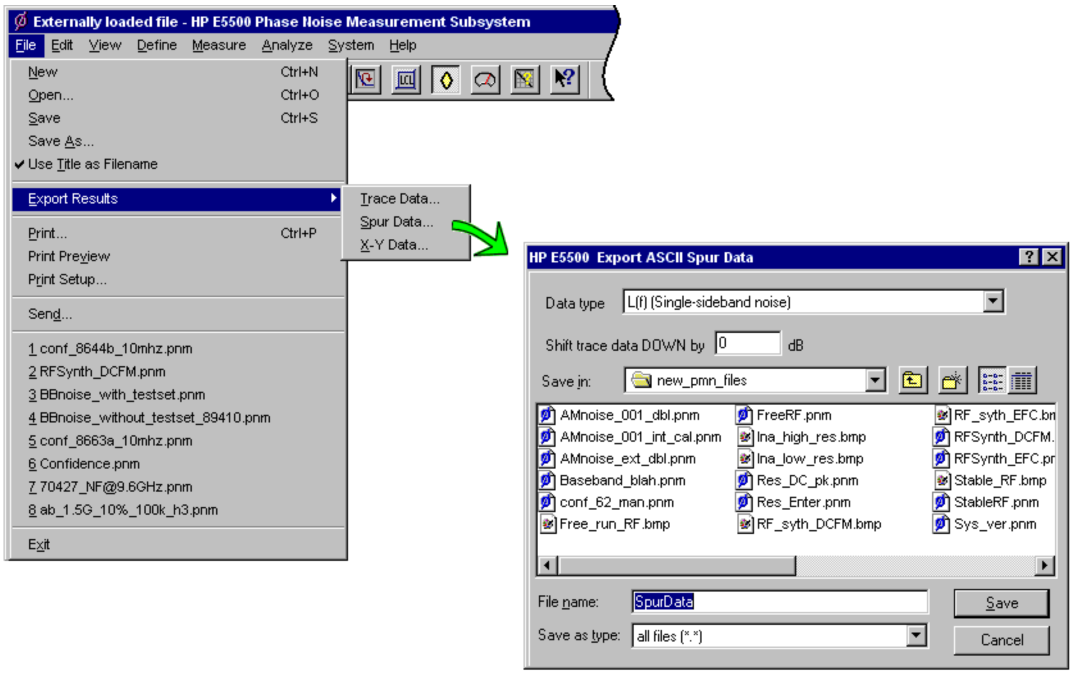


Figure 5-43 Spur Data Results

Exporting X-Y Data

1 On the **File** menu, point to **Export Results,** then click on **X-Y Data.** See Figure 5-44.

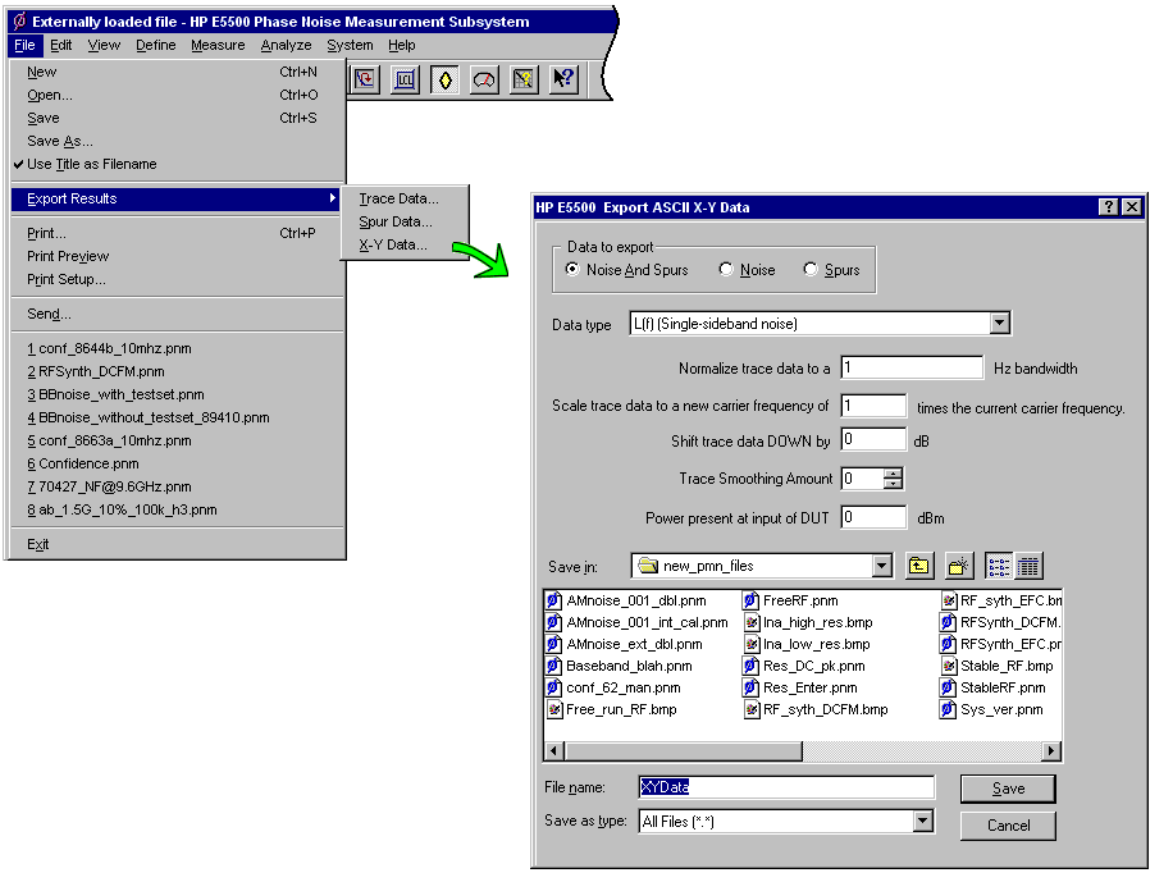


Figure 5-44 X-Y Data Results

6

Absolute Measurement Fundamentals

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 unit-under-test (UUT). The second source serves as the reference against which the UUT is measured. (One of the two sources must be a VCO source capable of being frequency tuned by the System.) Figure 6-1 shows a simplified diagram of the PLL configuration used for the measurement.

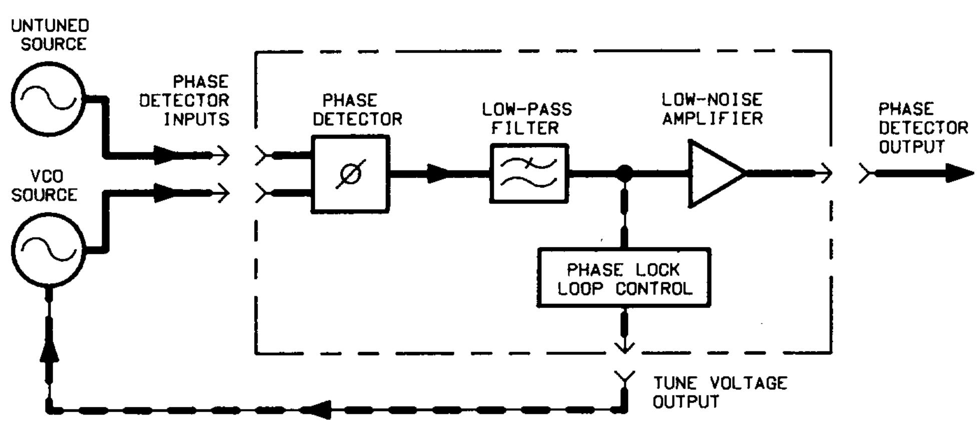


Figure 6-1 Simplified Block Diagram of the Phase Lock Loop Configuration

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 6-2 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

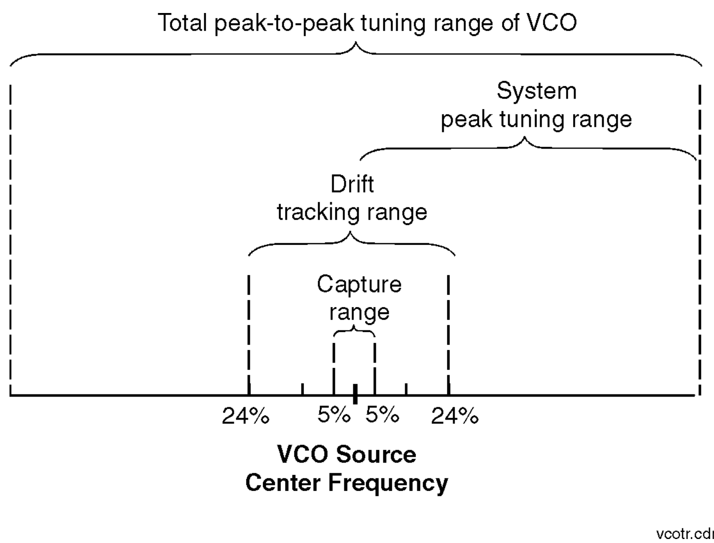


Figure 6-2 Typical Relationship of Capture Range and Drift Tracking Range to Tuning Range of VCO

As an Example:

A Peak Tuning Range of 1000 Hz will provide 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 will depend 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 6-3, the ranges calculated in the previous example are marked to show their relationship to the beatnote frequency.

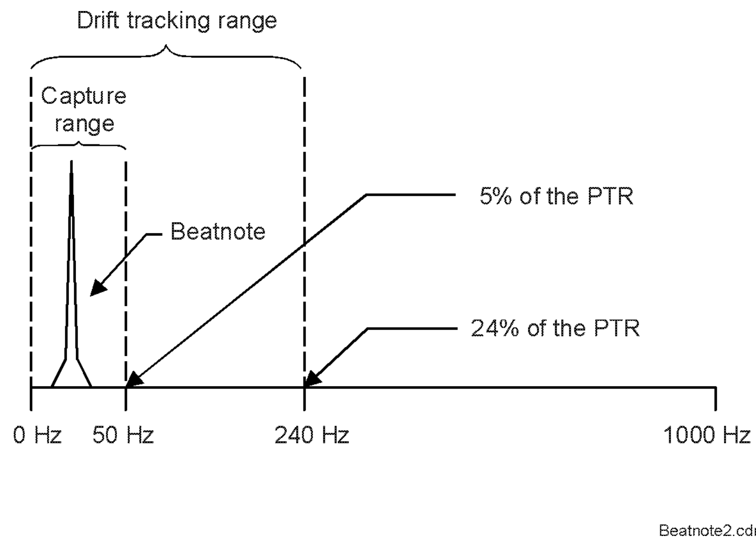


Figure 6-3 Relationship of Capture and Drift Tracking Ranges to Beatnote Frequency

If the beatnote does not remain within the drift tracking range during the measurement, the out of lock detector will be set and the System will stop the measurement. If this happens, you will 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 will provide 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 will need to know four things about the tuning characteristics of the VCO source you are using. The System will determine 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 will provide you with the tuning parameters for the specified source.

What Sets the Measurement Noise Floor?

The noise floor for your measurement will be 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 6-1 shows the amplitude ranges for the L and R ports.

Table 6-1 Amplitude Ranges for L and R Ports

Phase Detector				
50 kHz to 1.6 GHz		**1.2 to 26.5 GHz***		**50 kHz to 26.5 GHz†**
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

* Agilent 70420A phase noise test set Options 001 and 201with no attenuation

† Agilent 70420A phase noise test set Option 001 with no attenuation

If the L port (reference input) signal is within the amplitude range shown in the preceding table, the signal level at the R (signal) input port sets the noise floor for the system.

Figure 6-4 shows the relationship between the R (signal) input level and the system noise floor.

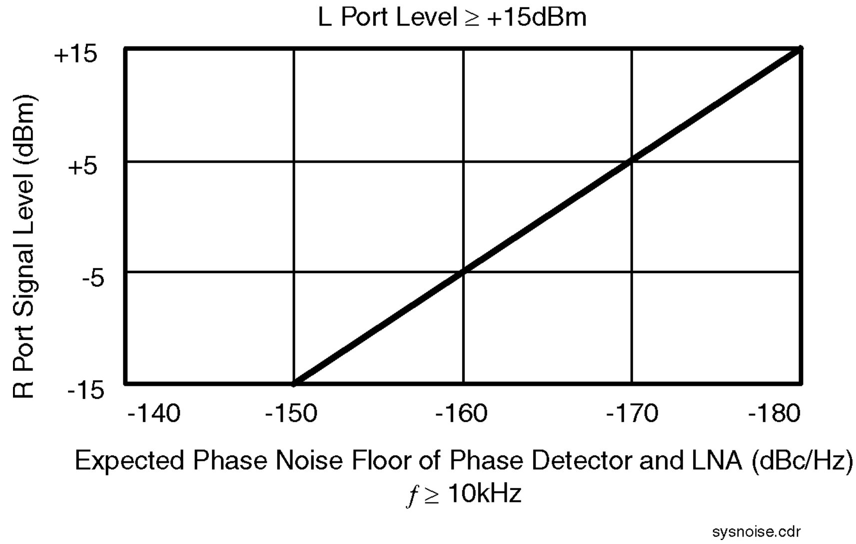


Figure 6-4 Relationship Between the R Input Level and System Noise Floor

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 will set the noise floor for the measurement. When you set up your measurement, you will 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 6-5 demonstrates that as the noise level of the reference source approaches the noise level of the UUT, 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 UUT.

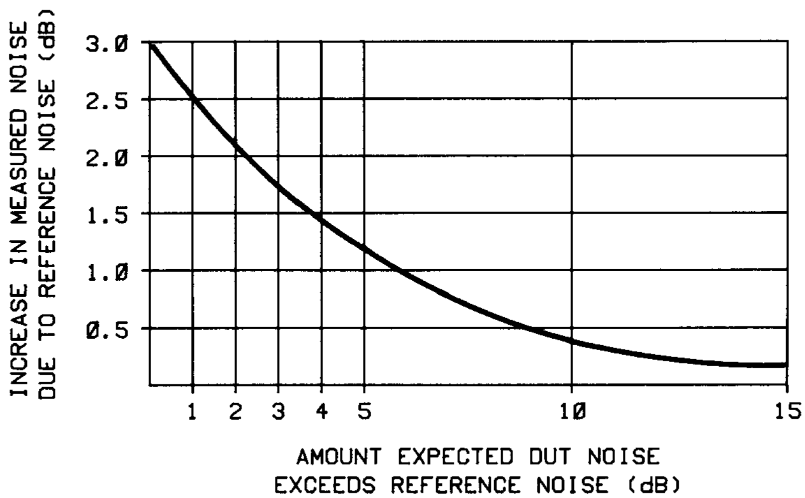


Figure 6-5 Increase in Measured Noise as Reference Source Noise Approaches UUT Noise

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 unit-under-test (UUT). In general, the lower the reference source's noise level is below the expected noise level of the UUT 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 UUT.)

As shown by the graph in Figure 6-6, the further the reference source's noise level is below the noise level of the UUT, the less the reference source's noise will contribute to the measurement results.

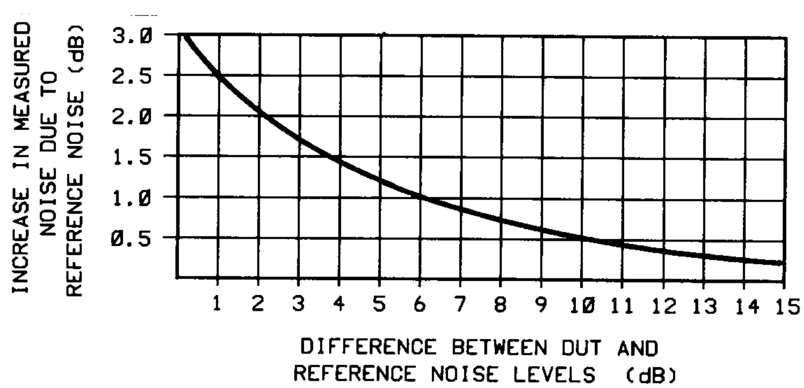


Figure 6-6 Increase in Measured Noise As UUT Noise Approaches Reference Noise

Using a Similar Device

The test system performs best when you are able to use a device similar to the UUT 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 UUT. 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 UUT.

If only one device is available in addition to the UUT, 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 will 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 will also serve as the VCO source for the PLL measurement. (The VCO source can be either the unit-under-test (UUT) or the reference source.) To configure a PLL measurement, you will 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 (ohms)

The primary consideration when evaluating a potential VCO source for your measurement is whether it will provide 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 6-2. This information will help you evaluate your VCO source based on the estimated drift of your sources.)

Table 6-2 lists the tuning parameters for several VCO options.

Table 6-2 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	$5\,E-9 \times \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 k (8662)	Calculate
					600 (8663)	Calculate
Agilent 8642A/B		FM Deviation	0	10	600	Calculate
Agilent 8644B		FM Deviation	0	10	600	Calculate

Table 6-2 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
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 6-7	1 E + 6	Measure

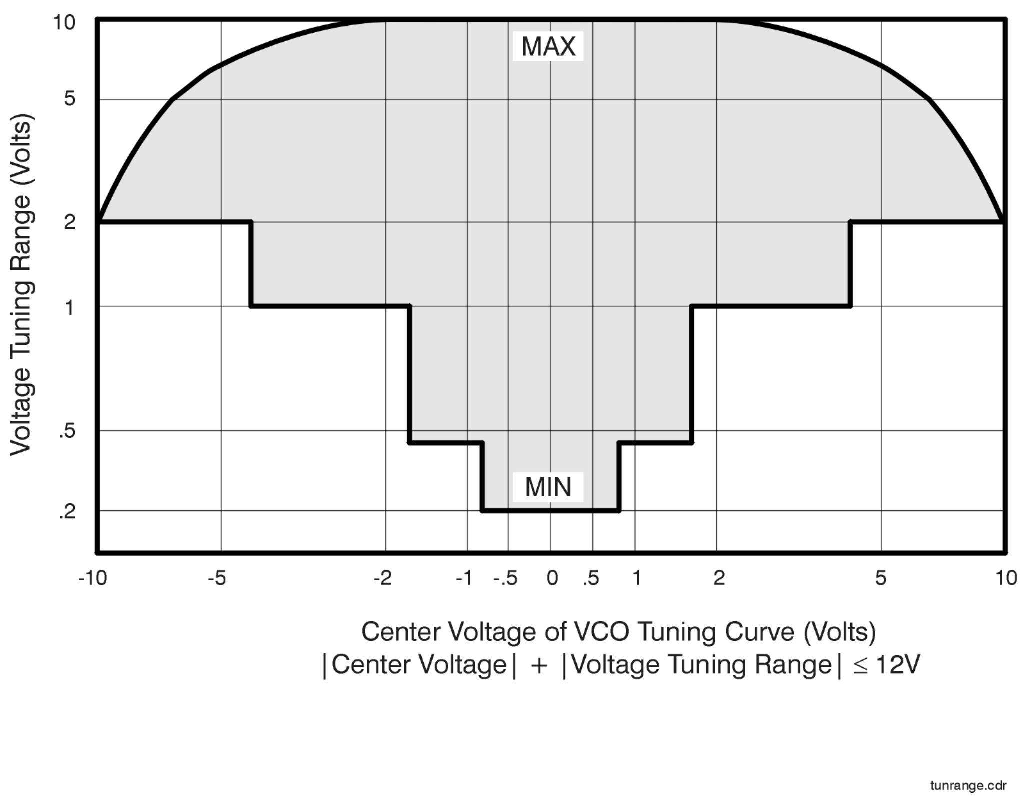


Figure 6-7 Agilent 70420A Voltage Tuning Range Limits Relative to Center Voltage of the VCO Tuning Curve.

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 6-3 lists the calibration method choices and the tuning constant accuracy required for each.

Table 6-3 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.)
Calculate from expected T. Constant	Exact, within 5% of actual. (Also requires that entered Input Resistance value is accurate.)

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 Agilent 70420A 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 will inform you by displaying a message. If the beatnote drifts beyond the drift tracking range during the measurement, the computer will stop 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 will not be 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.)

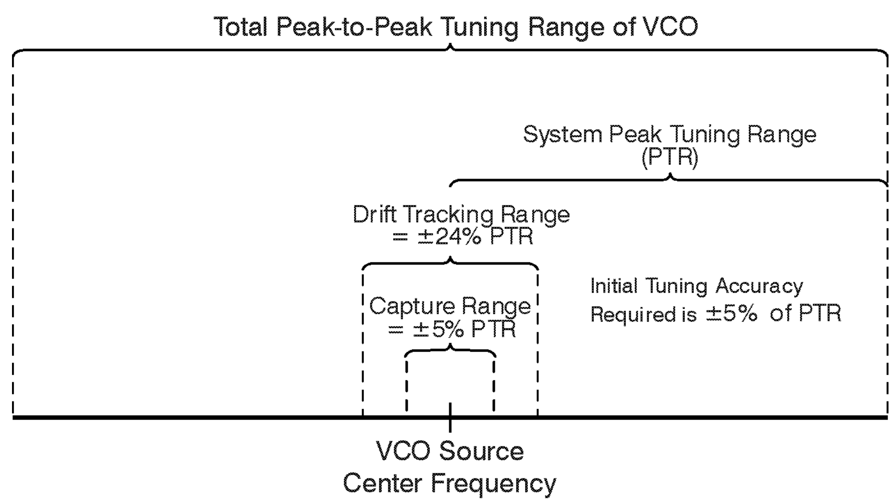
Changing the PTR

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 will be 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.



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 10V 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 Agilent 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 unit-under-test) 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 Agilent 70420A. (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 6-8 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 will disappear. 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 will inform you during the measurement if the possibility of accuracy degradation exists.)

3 Locate the required PLL bandwidth in Figure 6-8 to determine the PTR required for the measurement. (For details on increasing the PTR, refer to Changing the PTR in this section.

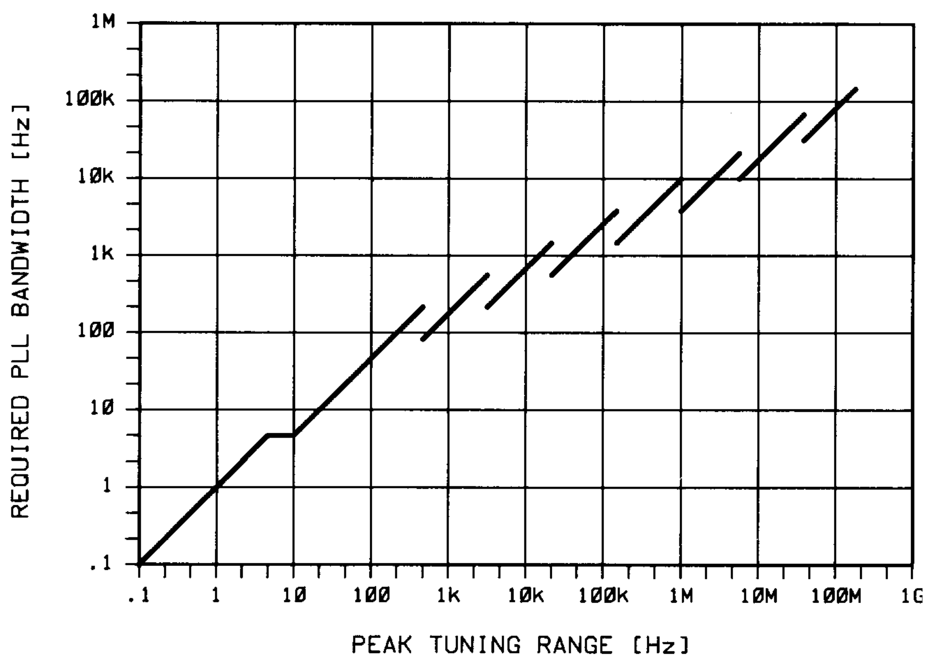


Figure 6-8 Peak Tuning Range (PTR) Required by Injection Locking.

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 unit-under-test (UUT) 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 Agilent 70420A's phase detector input port. The signal level required for the measurement depends on the noise floor level needed to measure the UUT.

Figure 6-9 shows the relationship between the signal level at the R port and the measurement noise floor.

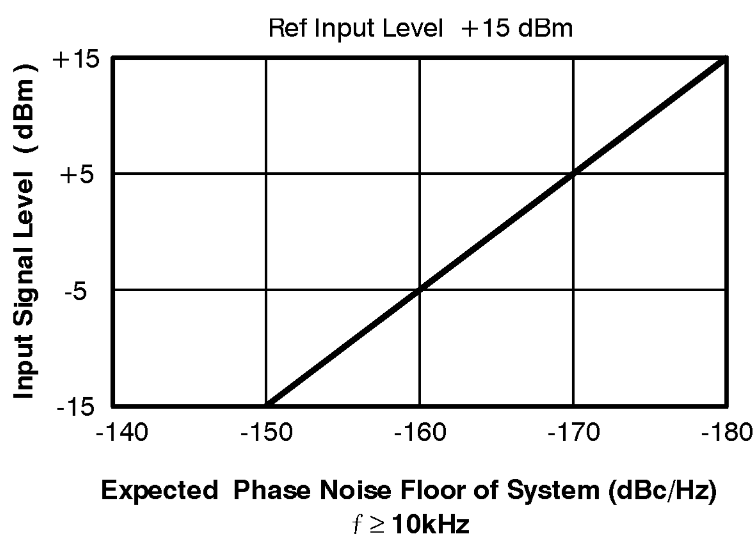


Figure 6-9 Measurement Noise Floor Relative to R Port Signal Level.

An Amplifier

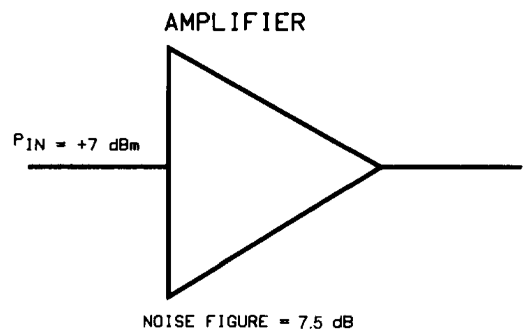
If a source is not able to provide a sufficient output level, or if additional isolation is needed at the output, it may be necessary to insert a low phase-noise RF amplifier at the output of the source.

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

The Agilent 70427A 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 6-10 shows an example.

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



$$\mathcal{L}(f) = -174\ dBm + 7.5\ dB - (+7\ dBm) - 3\ dB$$
$$\mathcal{L}(f) = -176.5 dBc/Hz$$

Figure 6-10 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 6-11.

Observing the Beatnote

If the beatnote frequency is below XXX kHz it will appear 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 XXX kHz or it does not exist.

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

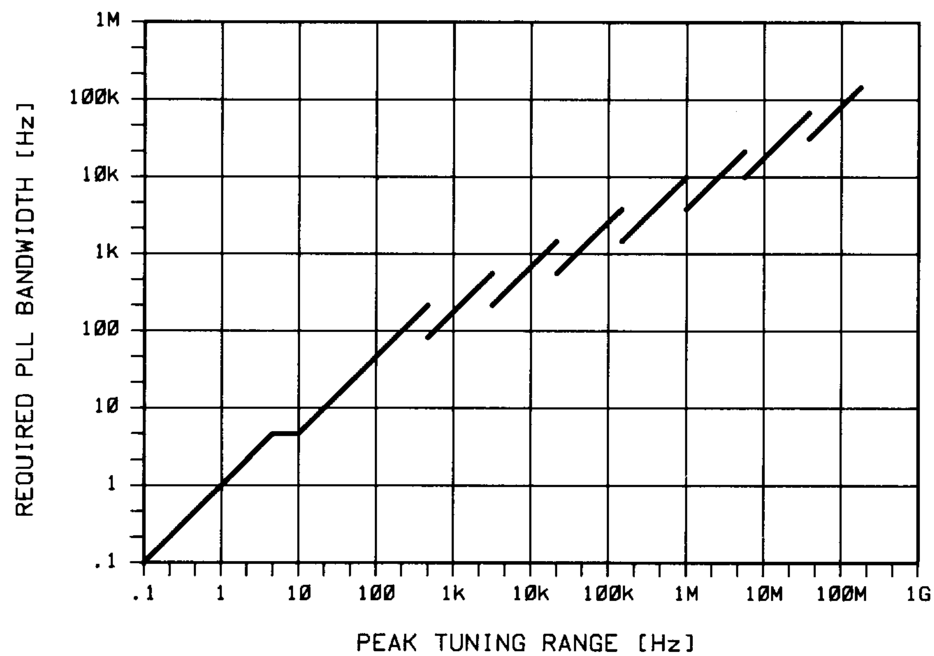


Figure 6-11 Graph of Phase Lock Loop Bandwidth Provided by the Peak Tuning Range

1. Once the beatnote is displayed, press the press [[RANGE]], press [[AUTO RANGE OFF]], 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 6-17 for recommended actions.

3. Press the [[AVG]] key, and then the RMS key. Wait for the trace to return and then press [[MKR]] and MKR to Peak.

4 Press [[REL MKR]], and MKR REF.

5 Press the [[DEFINE TRACE]] press the [[and the MATH FUNCTION keys.

6 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 will still be correct. To increase the vertical scale, press [[VERT SCALE]] press [[, DEFINE DB/DIV, and enter 20 dB.)

7 Compare the average noise level at the PLL bandwidth offset to the small angle criterion level shown on the graph in Figure 6-12. 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 will not degrade measurement accuracy provided they do not exceed -40 dBc.)

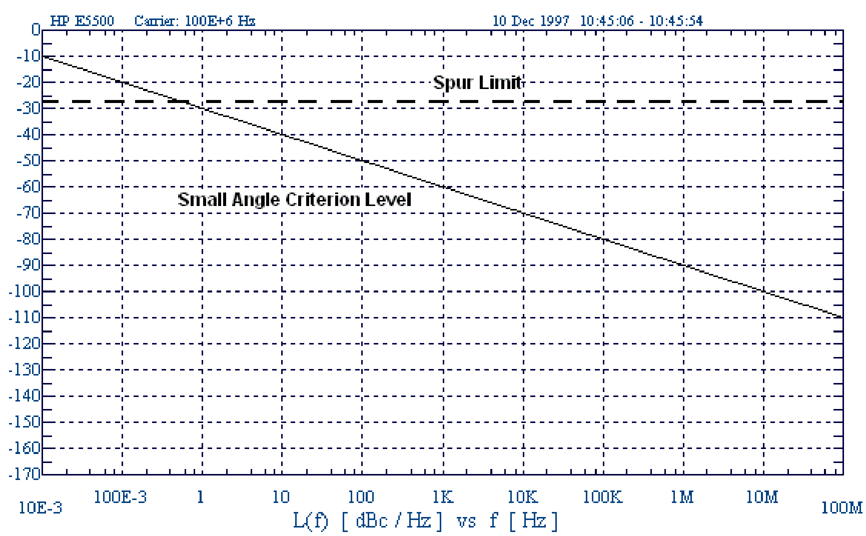


Figure 6-12 Graph of Small Angle Line and Spur Limit

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

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

10 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 6-13 to determine the Peak Tuning Range (PTR) necessary to provide a sufficient PLL bandwidth to make the measurement.

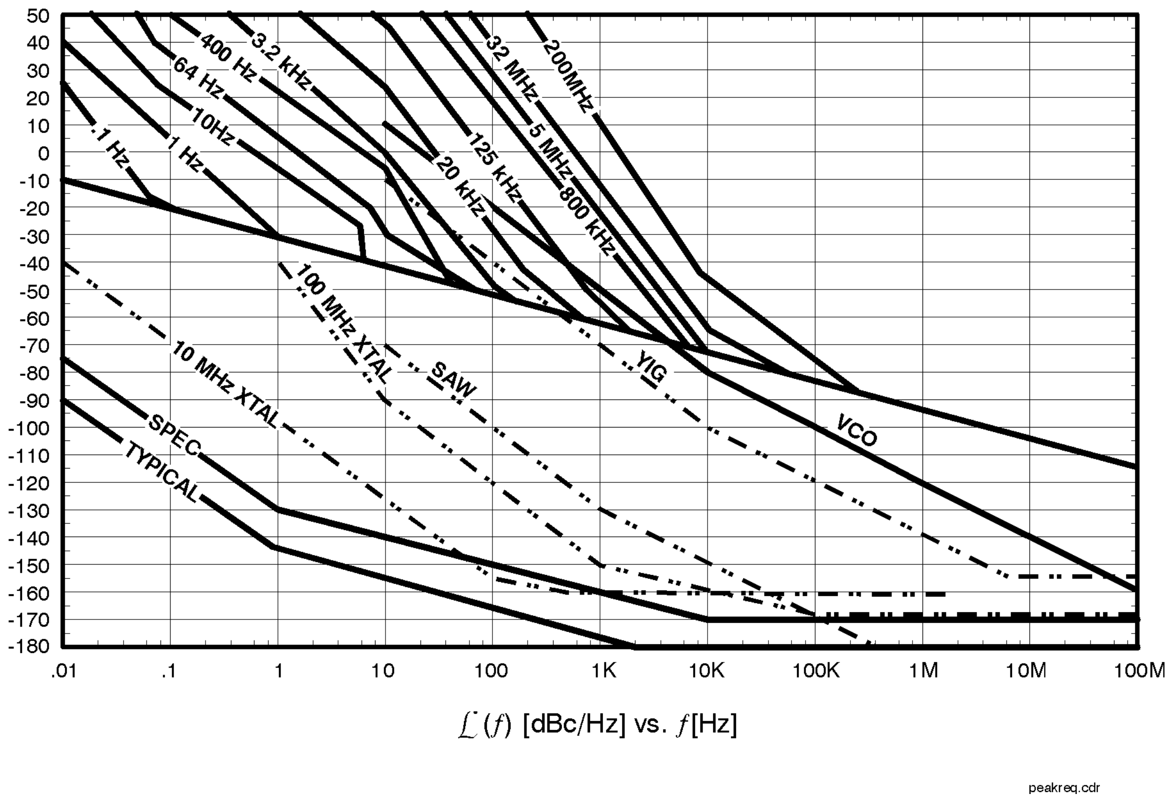


Figure 6-13 Graph Showing Peak Tuning Range Requirements for Noise that Exceeds the Small Angle Limit

Measurement Options

If the observed level exceeded the small angle line at any point beyond the PLL bandwidth set for the measurement, you will 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.

7

Absolute Measurement Examples

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 Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 7-3. Apply the input signal when the connection diagram appears.

Required Equipment

Table 7-1 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 7-1 Required Equipment for the Stable RF Oscillator Measurement Example

Equipment	Quantity	Comments
VCO Reference Source	1	Refer to Chapter 6, “Selecting a Reference” for more information about reference source requirements
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

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 7-1.

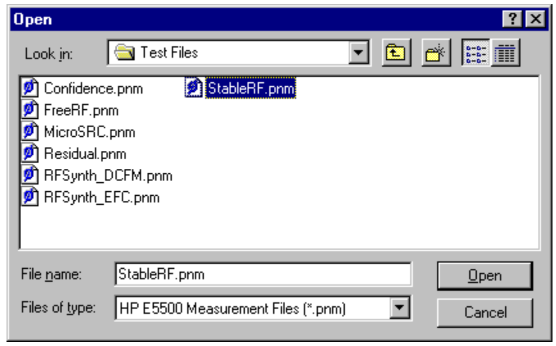


Figure 7-1 Select the Parameters Definition File

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 7-4 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 7-4 may not be appropriate for the reference source you are using. To change these values, refer to Table 7-2, then continue with step 5 below. Otherwise, go to "Beginning the Measurement" on page 7-9:

5 Using Figure 7-2 as a guide, navigate to the **Sources** tab.

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

b Enter the VCO (Nominal) Tuning Constant (see Table 7-2).

c Enter the Tune Range of VCO (see Table 7-2).

d Enter the Center Voltage of VCO (see Table 7-2).

e Enter the Input Resistance of VCO (see Table 7-2)

.

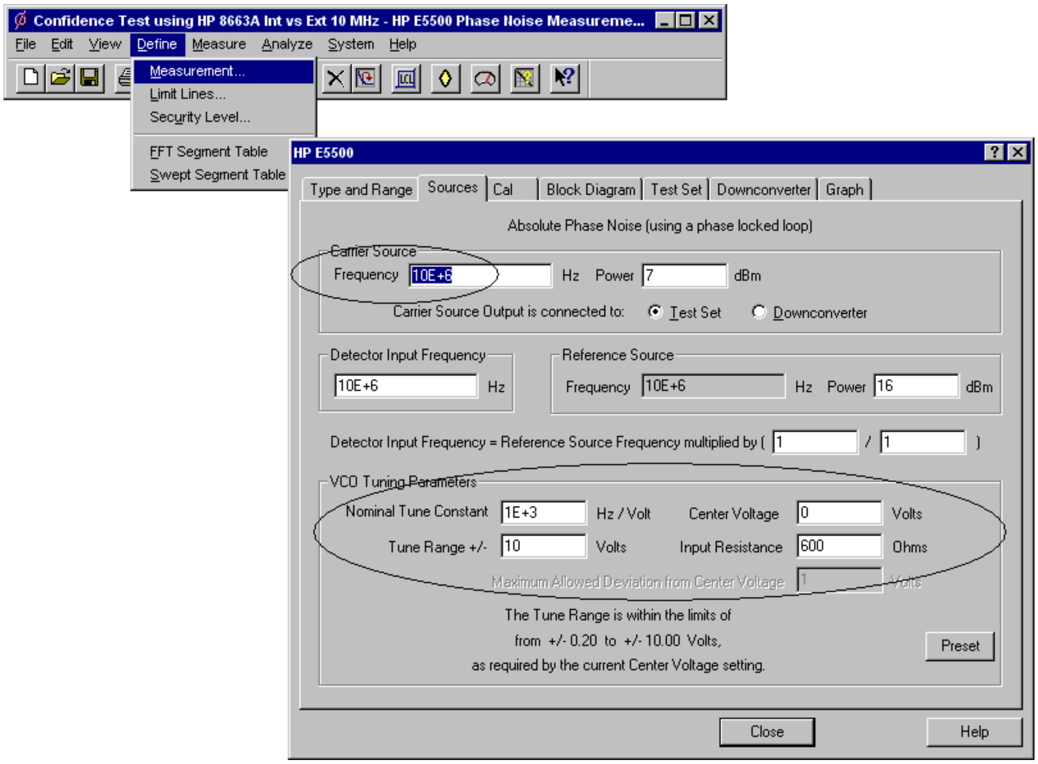


Figure 7-2 Enter Source Information

Table 7-2 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	$5\,E-9 \times \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662)	Compute
					600 (8663)	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 7-3 as a guide, navigate to the **Block Diagram** tab.

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

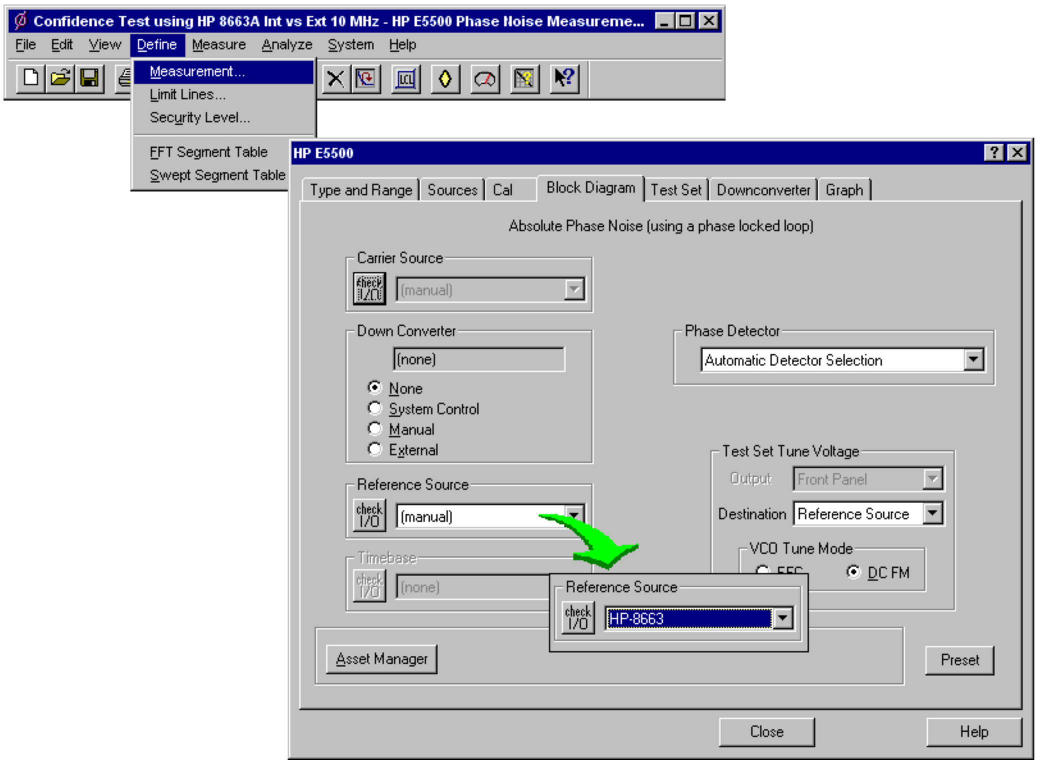


Figure 7-3 Selecting a Reference Source

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

Selecting Loop Suppression Verification

1 Using Figure 7-4 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**.

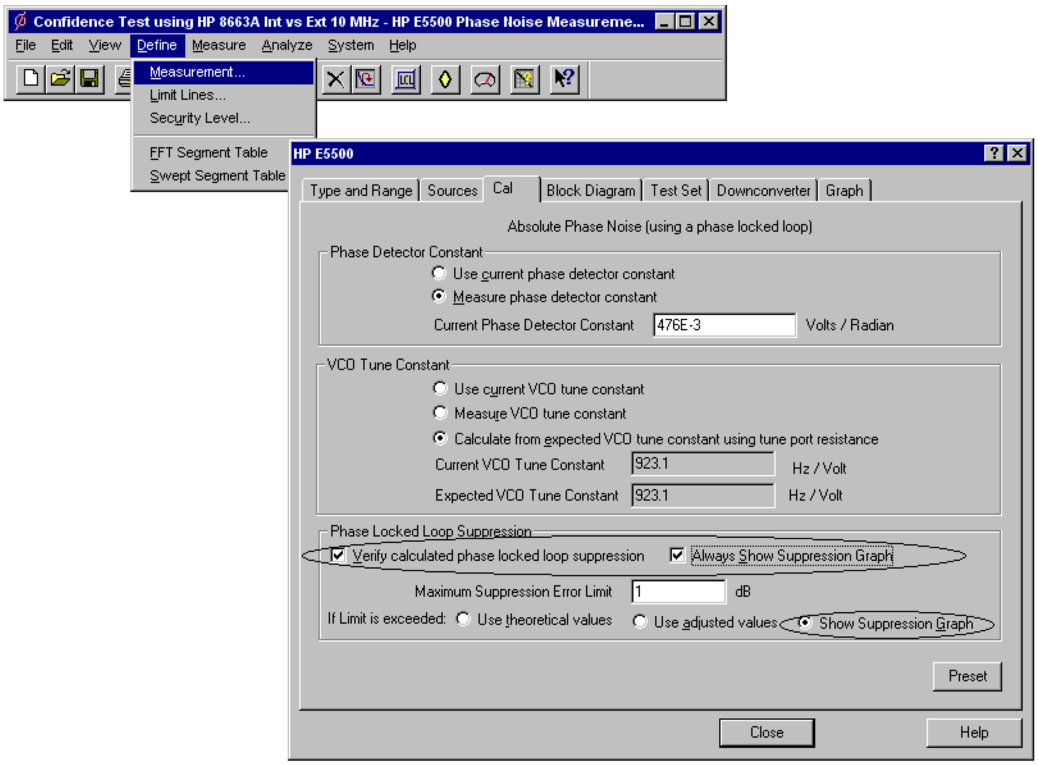


Figure 7-4 Selecting Loop Suppression Verification

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

Setup Considerations for the Stable RF Oscillator Measurement

Measurement Noise Floor

The signal amplitude at the R input (Signal Input) port on the Agilent 70420A sets the measurement noise floor level. Use Figure 7-5and Figure 7-6 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The Checking the Beatnote procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your UUT will provide.)

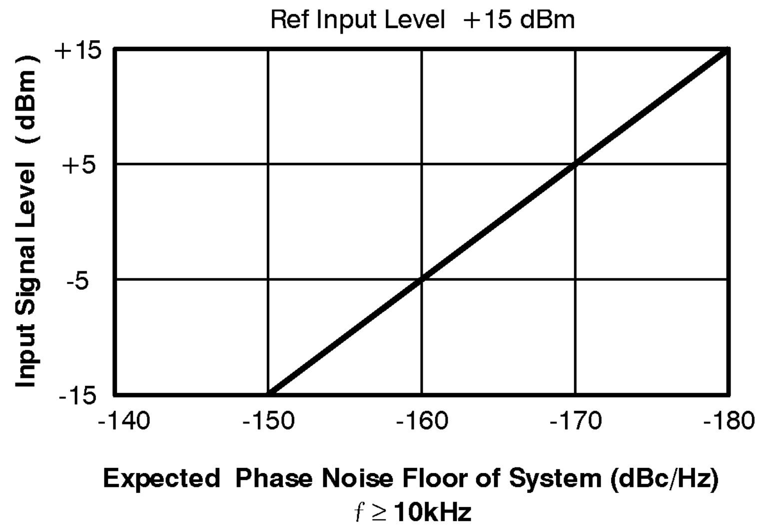


Figure 7-5 Noise Floor for the Stable RF Oscillator Measurement

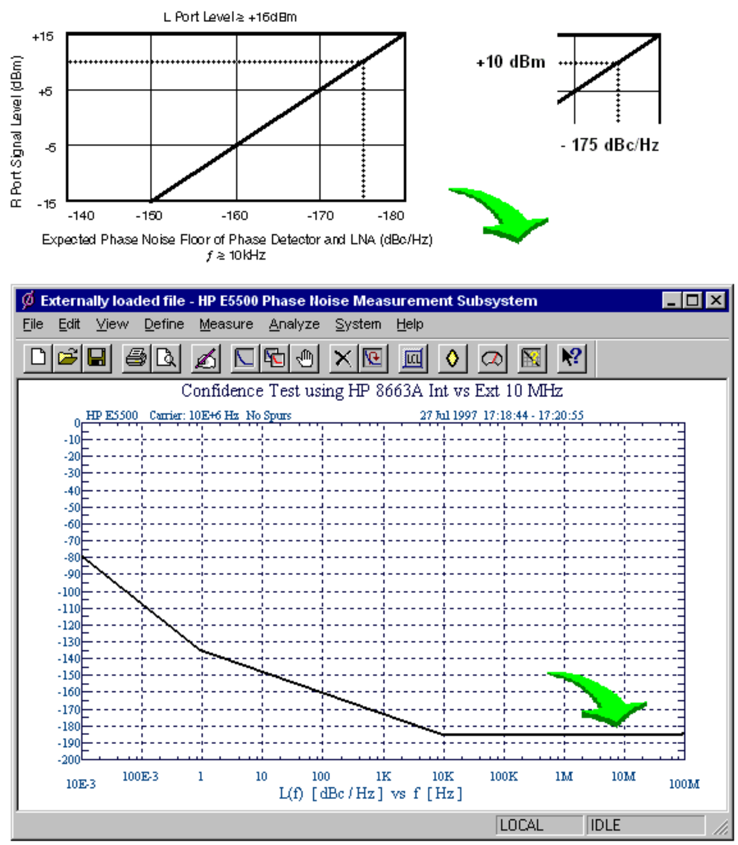


Figure 7-6 Noise Floor Calculation Example

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low-noise amplifier between the UUT and the test set. Refer to “Inserting an Device” in Chapter 6, “Absolute Measurement Fundamentals” for details on determining the effect the amplifiers noise will have on the measured noise floor.

VCO Reference Source

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

Beginning the Measurement

1 From the **Measurement** menu, choose **New Measurement**. See Figure 7-7.

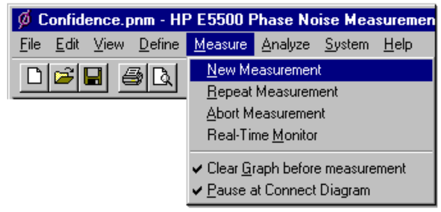


Figure 7-7 Selecting a New Measurement

1 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK.**

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

3 Confirm your connections as shown in the connect diagram. At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 7-3 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set’s hardware components, the input signal must not be applied to the test set’s signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics:	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

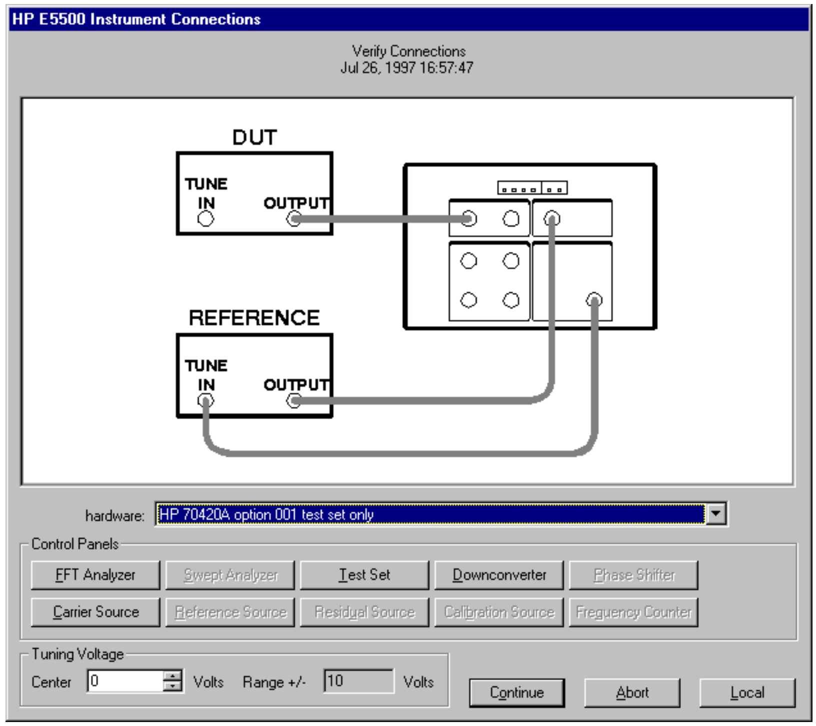


Figure 7-8 Connect Diagram for the Stable RF Oscillator Measurement

4 Refer to the following system connect diagram examples in Chapter 18, “Connect Diagrams” of this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-1, “E5501A Standard Connect Diagram,” on page 18-3
- Figure 18-14, “E5501B Standard Connect Diagram,” on page 18-16
- Figure 18-6, “E5502A Opt. 001 Connect Diagram,” on page 18-8
- Figure 18-21, “E5503B Opt. 001 Connect Diagram,” on page 18-23
- Figure 18-13, “E5504A Opt. 201 Connect Diagram,” on page 18-15
- Figure 18-25, “E5504B Opt. 201 Connect Diagram,” on page 18-27

Checking the Beatnote

While the connect diagram is still displayed, use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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.

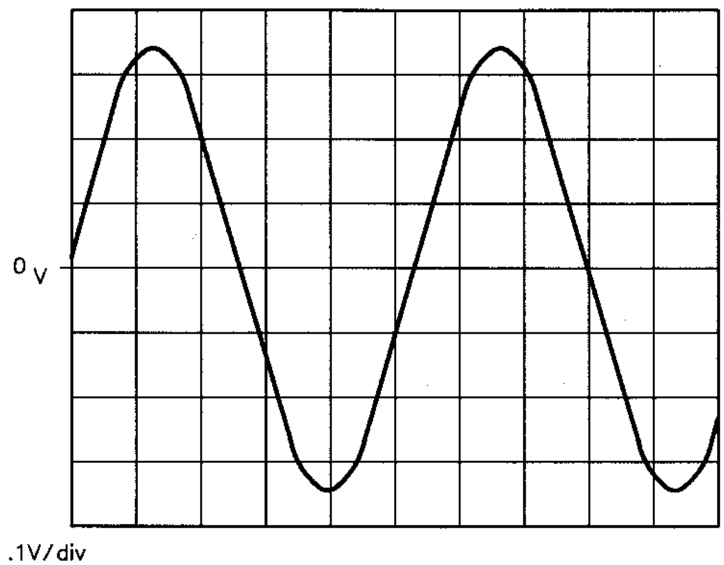


Figure 7-9 Oscilloscope Display of a Beatnote from the Agilent 70420A Monitor Port

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 7-10.

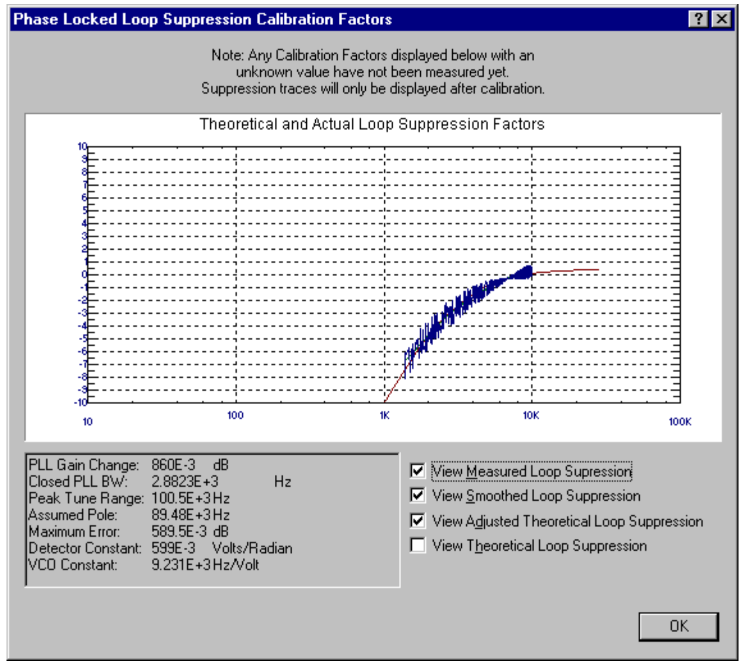


Figure 7-10 Selecting Suppressions

Four different curves are available for this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

- **a** “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 7-11 shows a typical phase noise curve for a stable RF Oscillator.

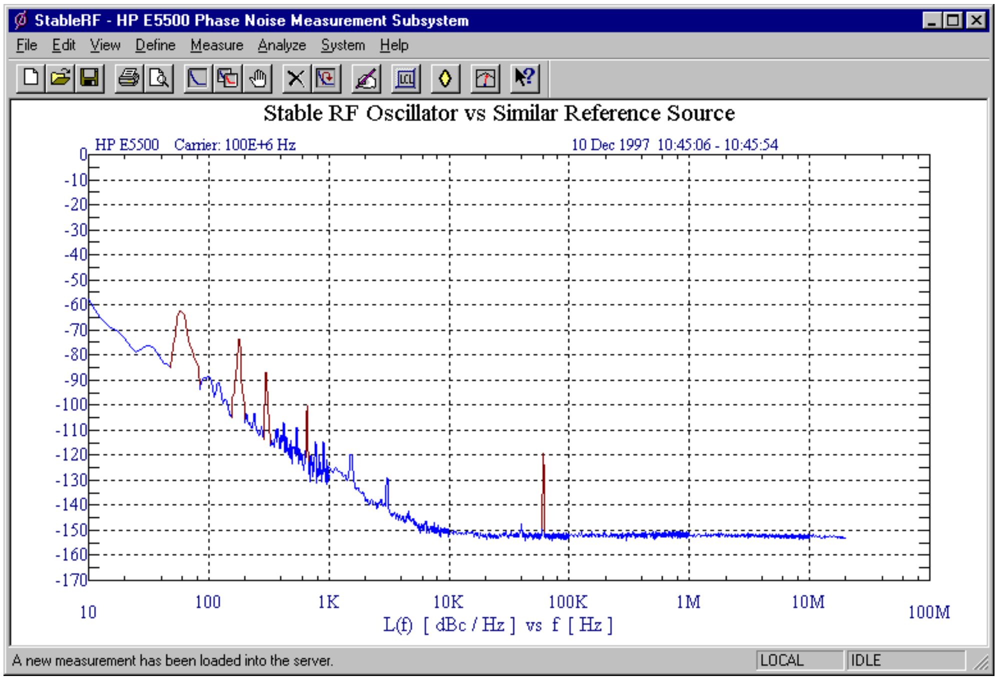


Figure 7-11 Typical Phase Noise Curve for a Stable RF Oscillator

Table 7-4 Parameter Data for the Stable RF Oscillator Measurement

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

Table 7-4 Parameter Data for the Stable RF Oscillator Measurement

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 Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 7-7. Apply the input signal when the connection diagram appears.

Required Equipment

Table 7-5 shows the equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 7-5 Required Equipment for the Free-Running RF Oscillator Measurement Example

Equipment	Quantity	Comments
Agilent 8644B	1	Refer to the "Chapter 6, "Absolute Measurement Fundamentals" for more information about reference source requirements
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

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 7-12

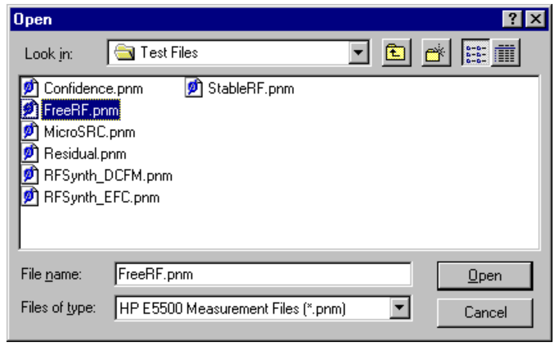


Figure 7-12 Select the Parameters Definition File

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 7-8 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 7-8 may not be appropriate for the reference source you are using. To change these values, refer to Table 7-6, then continue with step 5 below. Otherwise, go to "Beginning the Measurement" on page 7-25.

---

5 Using Figure 7-13 as a guide, navigate to the **Sources** tab.

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

f Enter the VCO (Nominal) Tuning Constant (see Table 7-6).

g Enter the Tune Range of VCO (see Table 7-6).

h Enter the Center Voltage of VCO (see Table 7-6).

i Enter the Input Resistance of VCO (see Table 7-6).

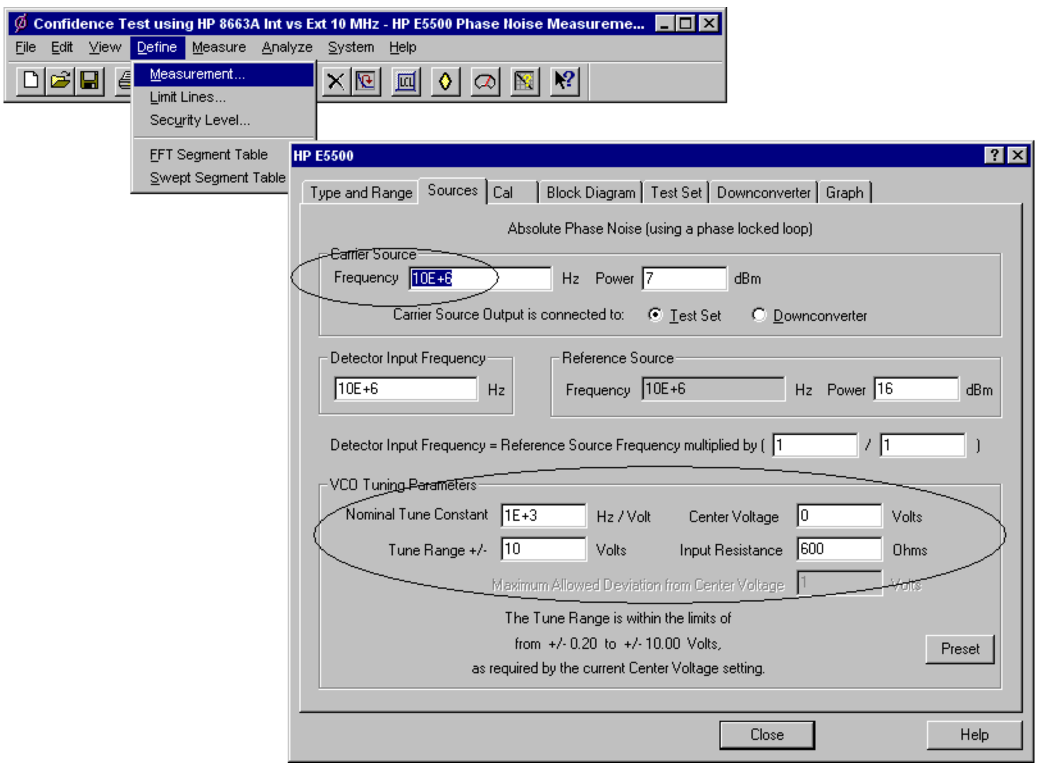


Figure 7-13 Enter Source Information

Table 7-6 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	$5\ E - 9 \times \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662)	Compute
					600 (8663)	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 7-14 as a guide, navigate to the **Block Diagram** tab.

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

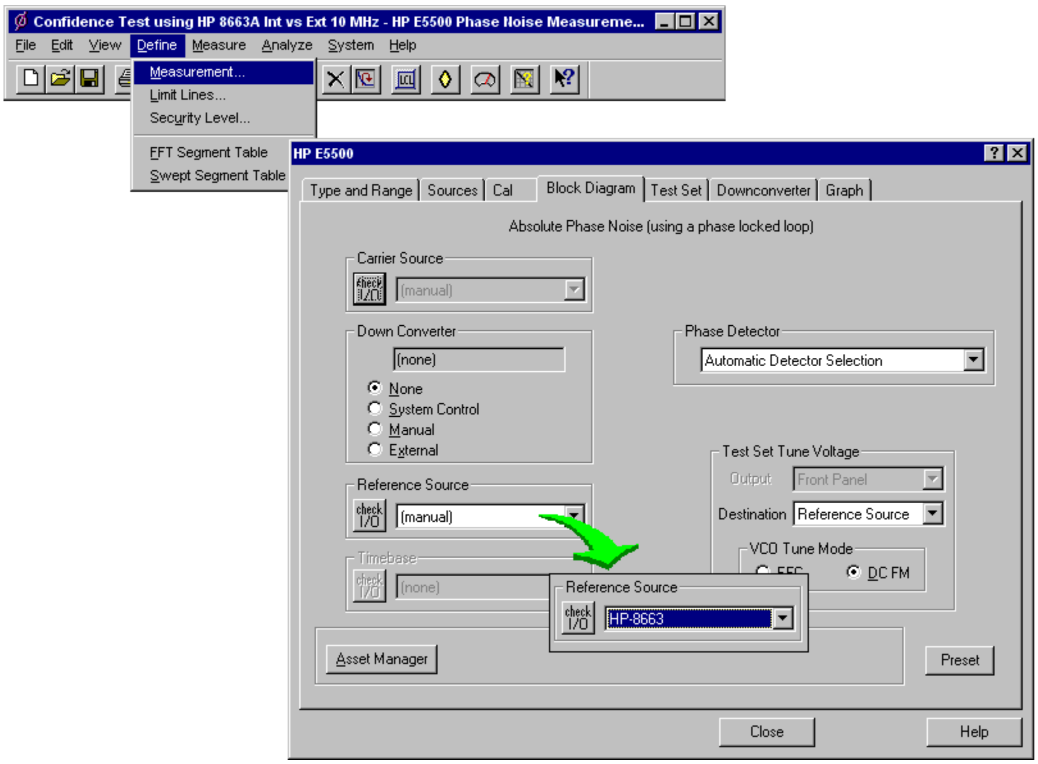


Figure 7-14 Selecting a Reference Source

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

Selecting Loop Suppression Verification

1 Using Figure 7-15 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**.

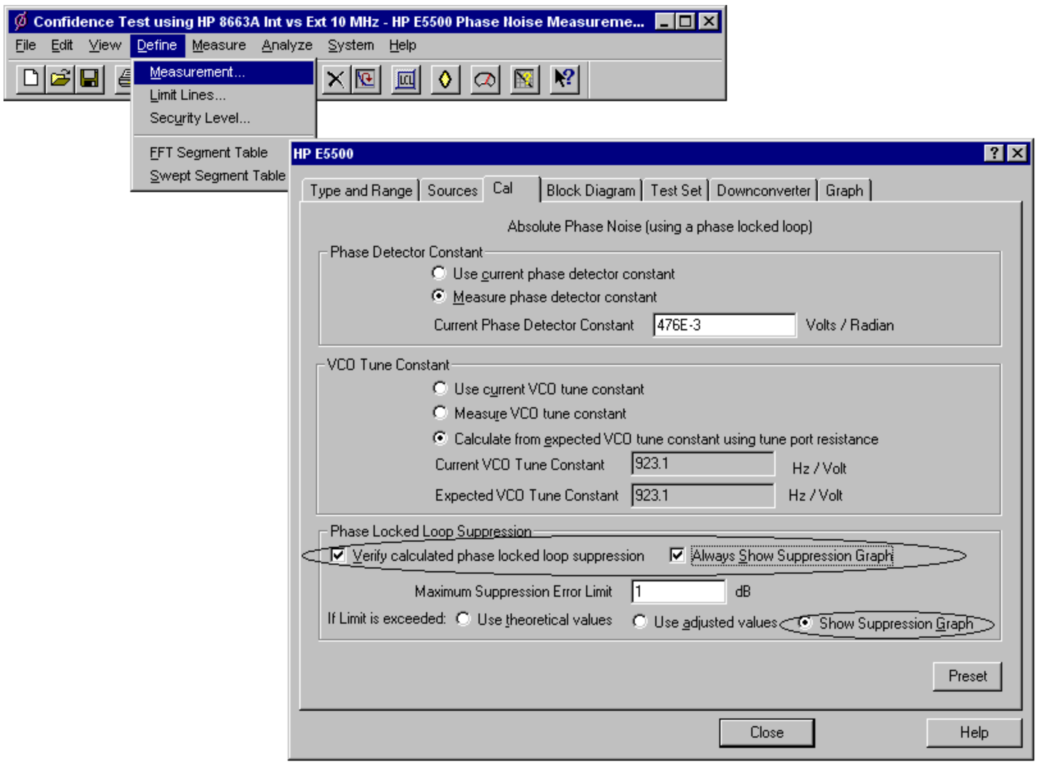


Figure 7-15 Selecting Loop Suppression Verification

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 R input (Signal Input) port on the Agilent 70420A sets the measurement noise floor level. Use Figure 7-16 and Figure 7-17 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The Checking the Beatnote procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your UUT will provide.)

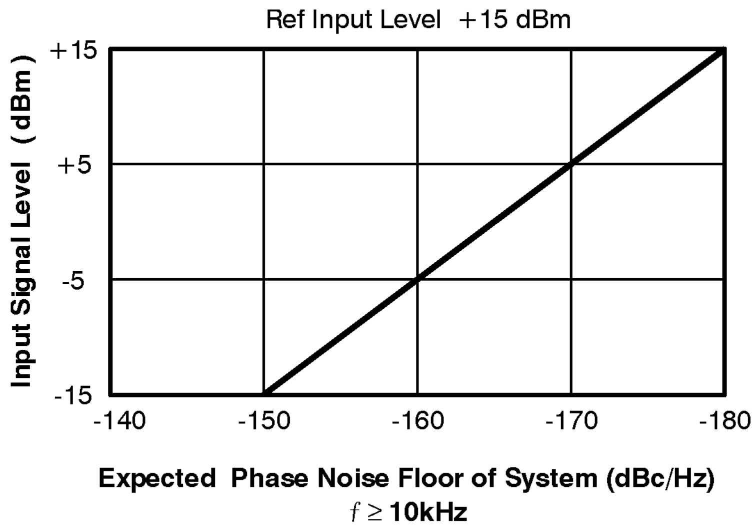


Figure 7-16 Noise Floor for the Free-Running RF Oscillator Measurement

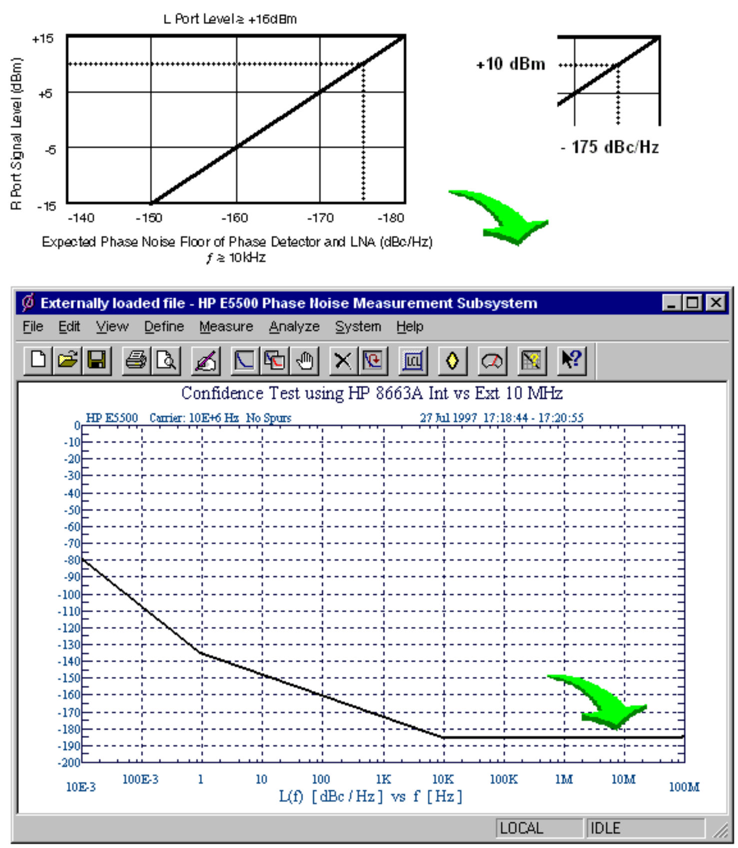


Figure 7-17 Noise Floor Calculation Example

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low-noise amplifier between the UUT and the test set. Refer to “Inserting an Device” in Chapter 6, “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 UUT, the noise level of the reference source should be below the expected noise level of the UUT.

Beginning the Measurement

1 From the **Measurement** menu, choose **New Measurement**. See Figure 7-18

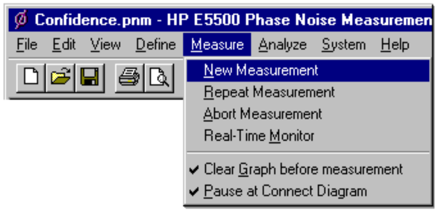


Figure 7-18 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

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

Confirm your connections as shown in the connect diagram. At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set’s signal input is subject to the following limits and characteristics:

Table 7-7 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics:	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

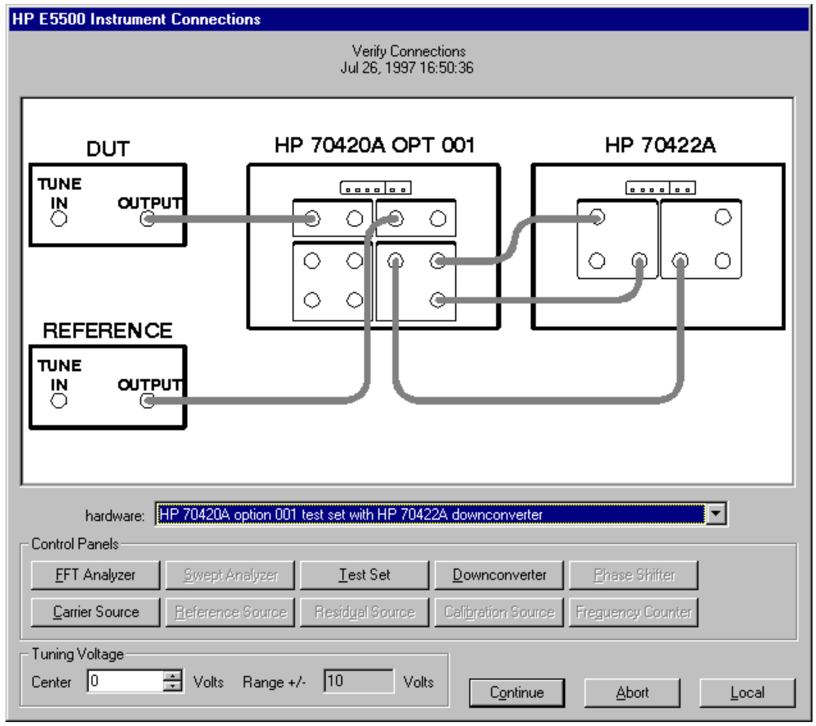


Figure 7-19 Connect Diagram for the Free-Running RF Oscillator Measurement

4 Refer to the following system connect diagram examples in Chapter 18, “Connect Diagrams” of this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-1, “E5501A Standard Connect Diagram,” on page 18-3
- Figure 18-14, “E5501B Standard Connect Diagram,” on page 18-16
- Figure 18-6, “E5502A Opt. 001 Connect Diagram,” on page 18-8
- Figure 18-22, “E5503B Opt. 201 Connect Diagram,” on page 18-24
- Figure 18-13, “E5504A Opt. 201 Connect Diagram,” on page 18-15
- Figure 18-25, “E5504B Opt. 201 Connect Diagram,” on page 18-27

Checking the Beatnote

While the connect diagram is still displayed, recommend that you use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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.

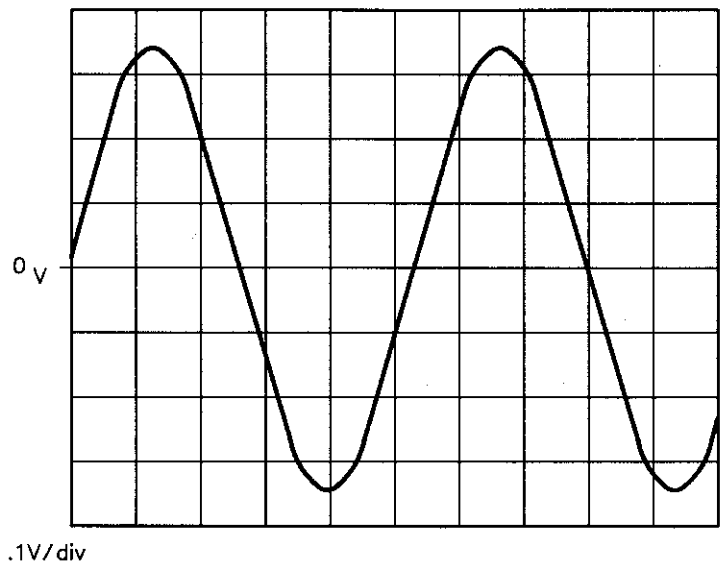


Figure 7-20 Oscilloscope Display of a Beatnote out of the Agilent 70420A Monitor Port

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.

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

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

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 7-21.

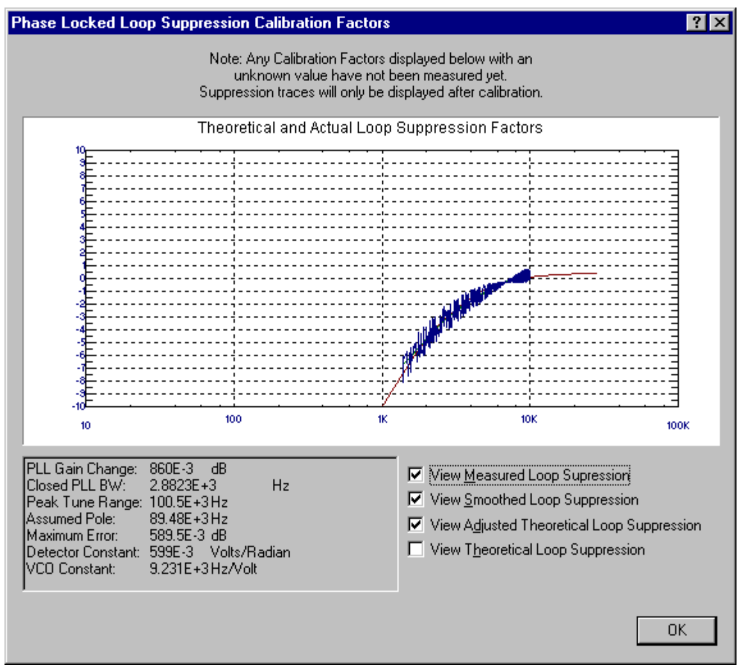


Figure 7-21 Selecting Suppressions

There are four different curves available for the this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

- **a** “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 7-22 shows a typical phase noise curve for a free-running RF Oscillator.

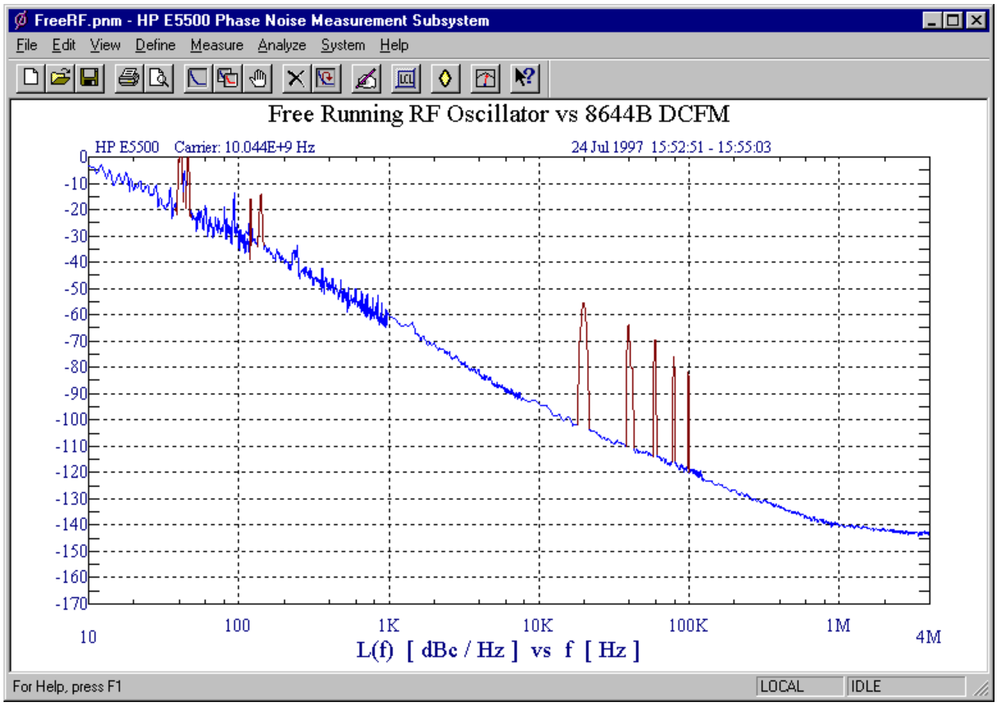


Figure 7-22 Typical Phase Noise Curve for a Free-Running RF Oscillator

Table 7-8 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 70422A
	• Reference Source	• Agilent 8644B (System Control)
	• Timebase	• None
	• Phase Detector	• Automatic Detector Selection
	• Test Set Tune Voltage Destination	• Reference Source
		• DCFM
	• VCO Tune Mode	

Table 7-8 Parameter Data for the Free-Running RF Oscillator Measurement

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	• 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 - 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	• Free Running RF Oscillator vs. 8644B 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 DCFM

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

CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 7-11. Apply the input signal when the connection diagram appears.

Required Equipment

Table 7-9 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 7-9 Required Equipment for the RF Synthesizer using DCFM Measurement

Equipment	Quantity	Comments
Agilent 8663A	1	Must have DCFM Input Port. Refer to the Chapter 6, "Absolute Measurement Fundamentals" for more information about reference source requirements
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

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 7-23.

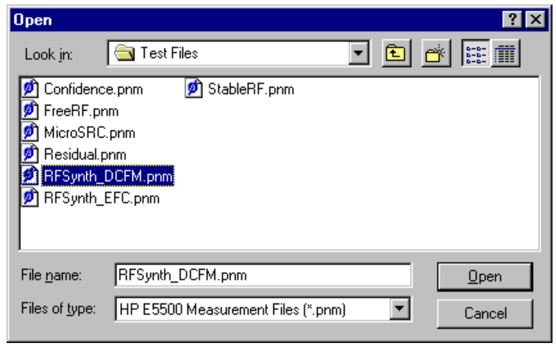


Figure 7-23 Select the Parameters Definition File

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 7-12 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 7-12 may not be appropriate for the reference source you are using. To change these values, refer to Table 7-10, then continue with step 5 below. Otherwise, go to "Beginning the Measurement" on page 7-42:

5 Using Figure 7-24 as a guide, navigate to the **Sources** tab.

- **a** Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 GHz). Enter the same frequency for the detector input frequency.
- **b** Enter the VCO (Nominal) Tuning Constant (see Table 7-10).
- **c** Enter the Tune Range of VCO (see Table 7-10).
- **d** Enter the Center Voltage of VCO (see Table 7-10).
- **e** Enter the Input Resistance of VCO (see Table 7-10).

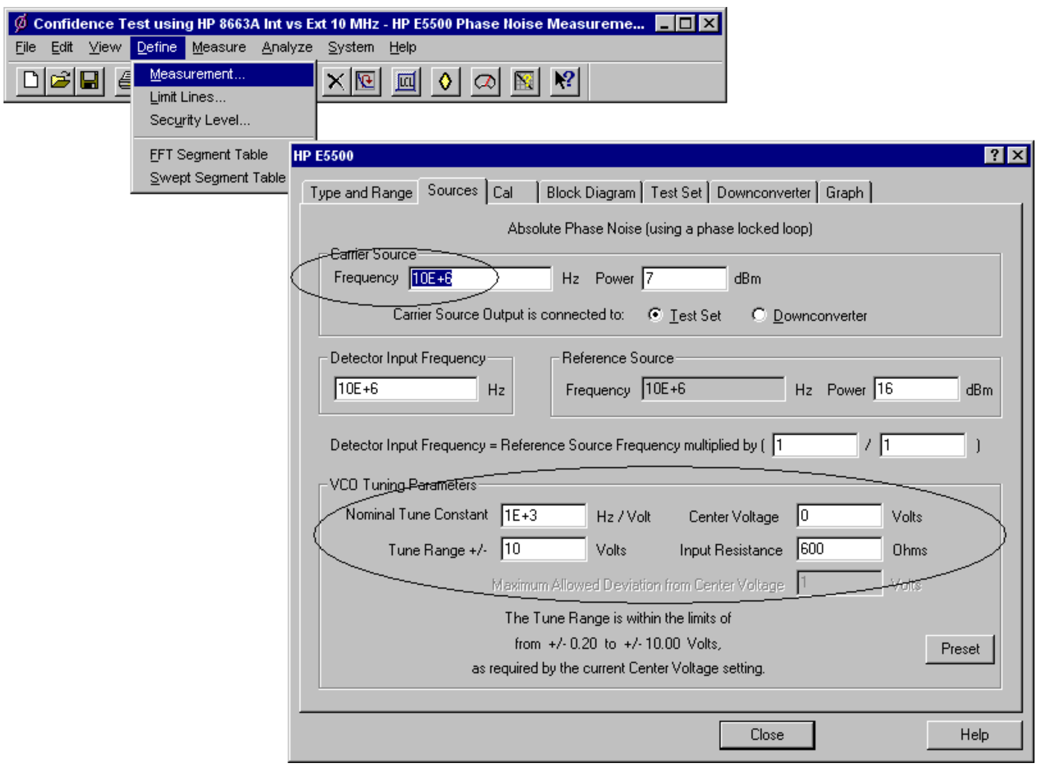


Figure 7-24 Enter Source Information

Table 7-10 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	$5 E - 9 x \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662)	Compute
					600 (8663)	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 7-25 as a guide, navigate to the **Block Diagram** tab.

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

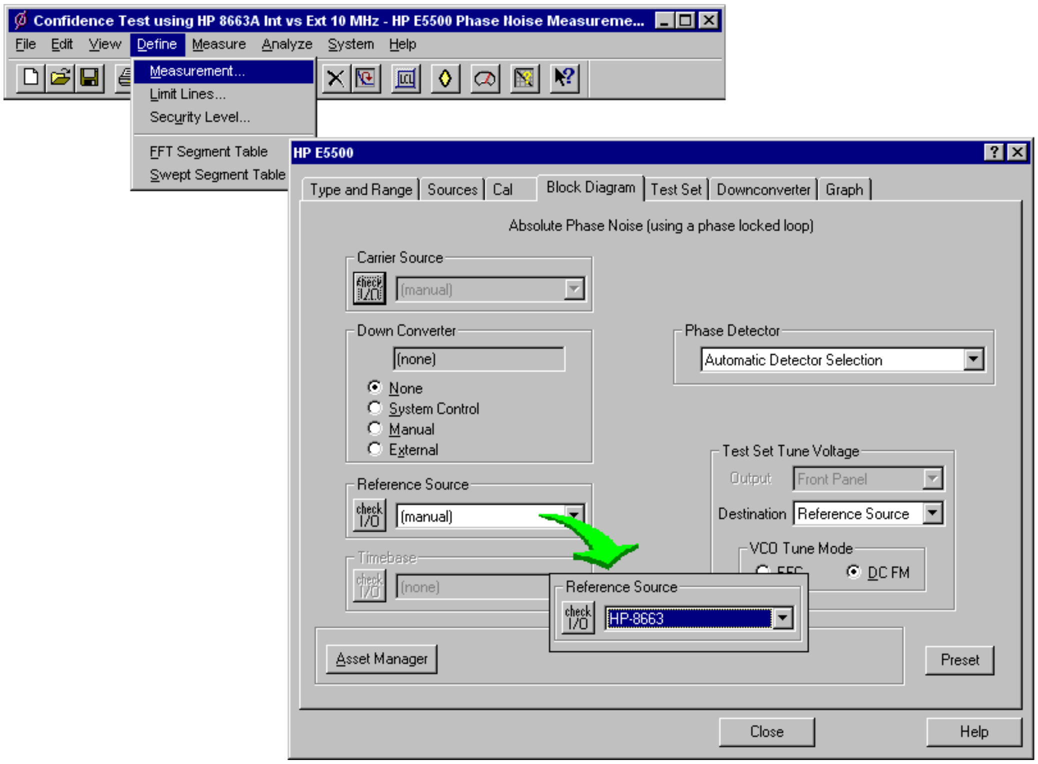


Figure 7-25 Selecting a Reference Source

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

Selecting Loop Suppression Verification

1 Using Figure 7-26 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**.

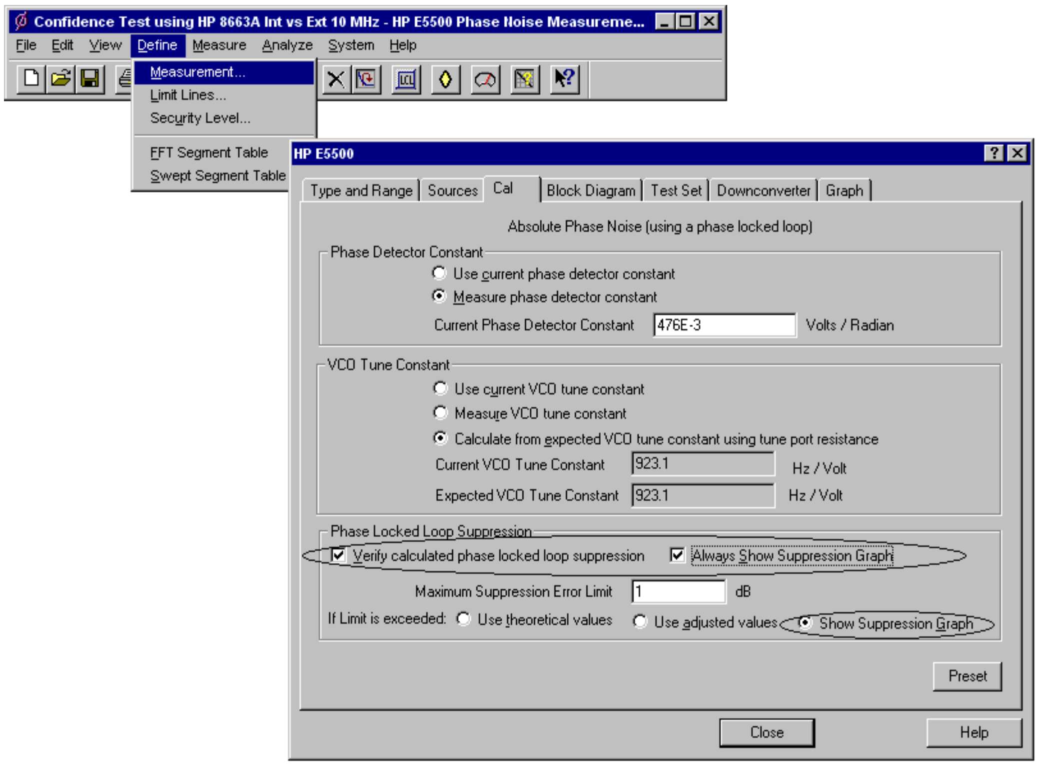


Figure 7-26 Selecting Loop suppression Verification

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 R input (Signal Input) port on the Agilent 70420A sets the measurement noise floor level. Use Figure 7-27 and Figure 7-28 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT.

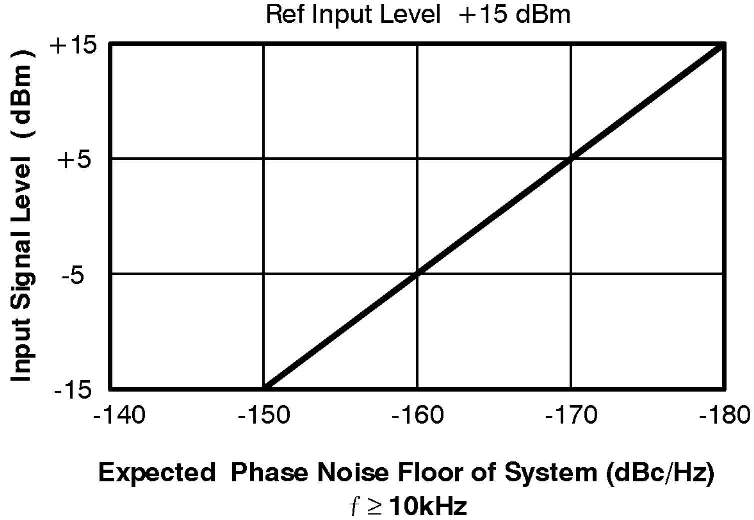


Figure 7-27 Noise Floor for the RF Synthesizer (DCFM) Measurement

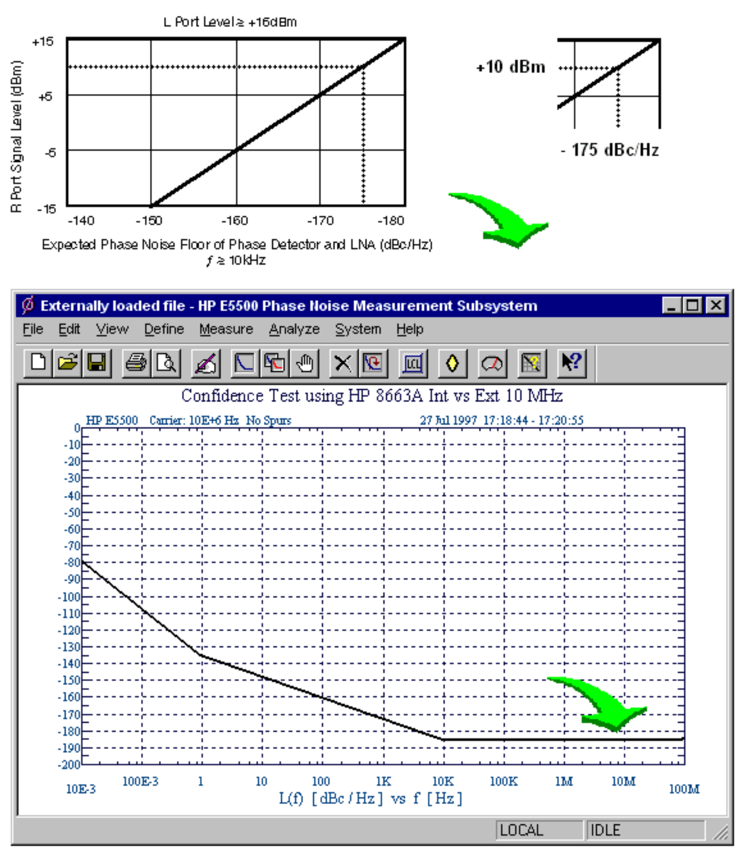


Figure 7-28 Noise Floor Calculation Example

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the Agilent 70420A input. (Refer to “Inserting an Device” in Chapter 6, “Absolute Measurement Fundamentals” 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 Agilent 8663A as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the UUT, the noise level of the reference source should be below the expected noise level of the UUT.

Beginning the Measurement

1 From the **Measurement** menu, choose **New Measurement**. See Figure 7-29

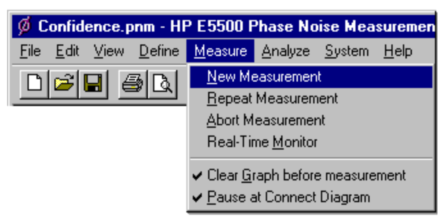


Figure 7-29 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

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

Confirm your connections as shown in the connect diagram. At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set’s signal input is subject to the following limits and characteristics:

Table 7-11 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
1 Characteristics:	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

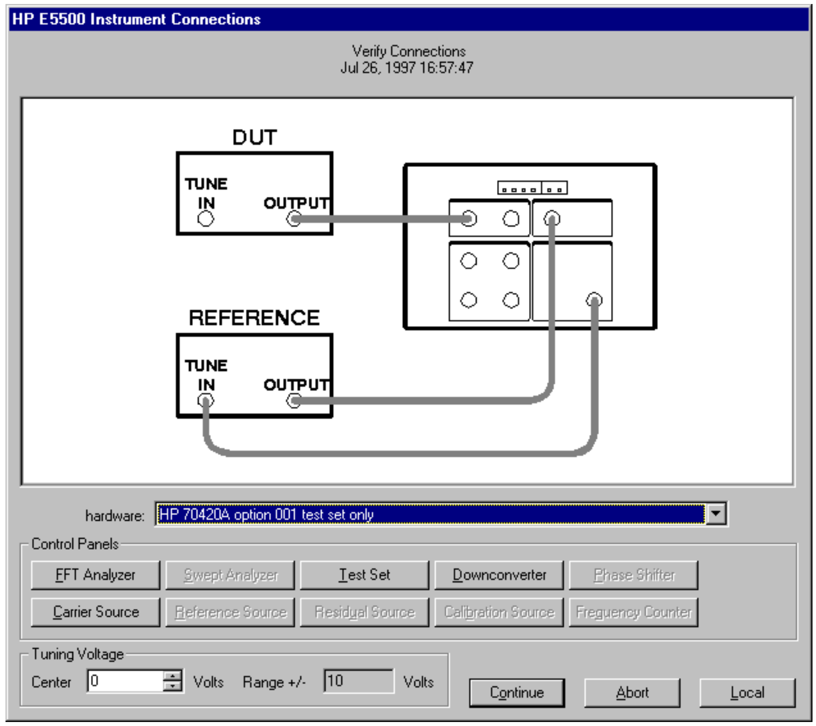


Figure 7-30 Connect Diagram for the RF Synthesizer (DC FM) Measurement

4 Refer to the following system connect diagram examples in Chapter 18, "Connect Diagrams" of this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-1, "E5501A Standard Connect Diagram," on page 18-3
- Figure 18-14, "E5501B Standard Connect Diagram," on page 18-16
- Figure 18-6, "E5502A Opt. 001 Connect Diagram," on page 18-8
- Figure 18-21, "E5503B Opt. 001 Connect Diagram," on page 18-23
- Figure 18-13, "E5504A Opt. 201 Connect Diagram," on page 18-15
- Figure 18-25, "E5504B Opt. 201 Connect Diagram," on page 18-27

NOTE: For additional examples, refer to Chapter 18, “Connect Diagrams”

Checking the Beatnote

While the connect diagram is still displayed, use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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.

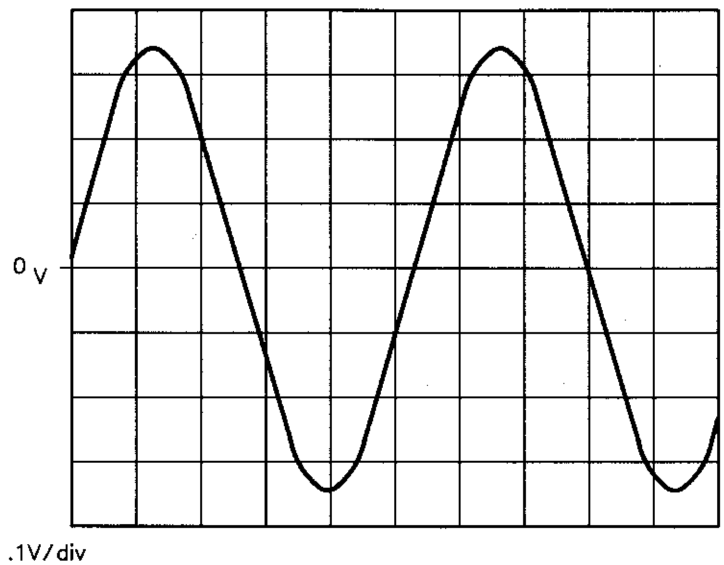


Figure 7-31 Oscilloscope Display of a Beatnote out of the Agilent 70420A Monitor Port

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 7-32.

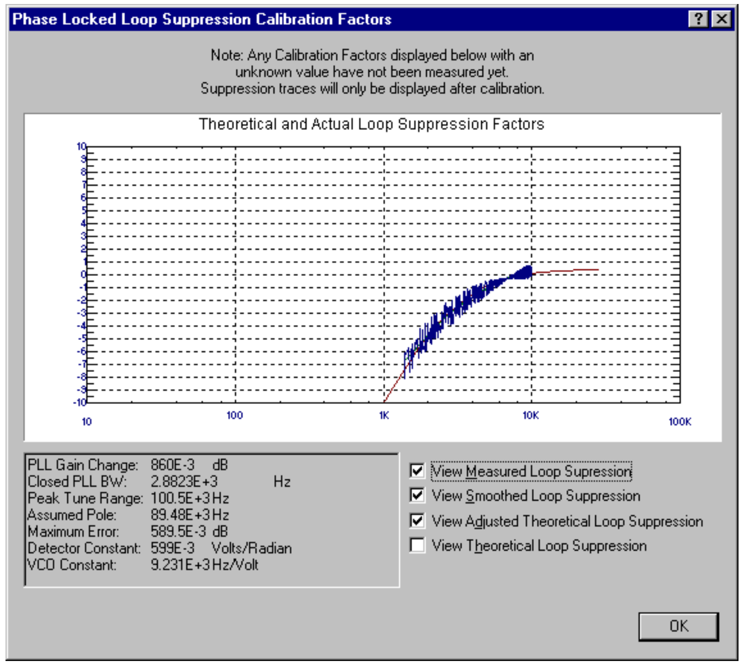


Figure 7-32 Selecting Suppressions

There are four different curves available for the this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

- **a** “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 7-33 shows a typical phase noise curve for a RF synthesizer using DCFM.

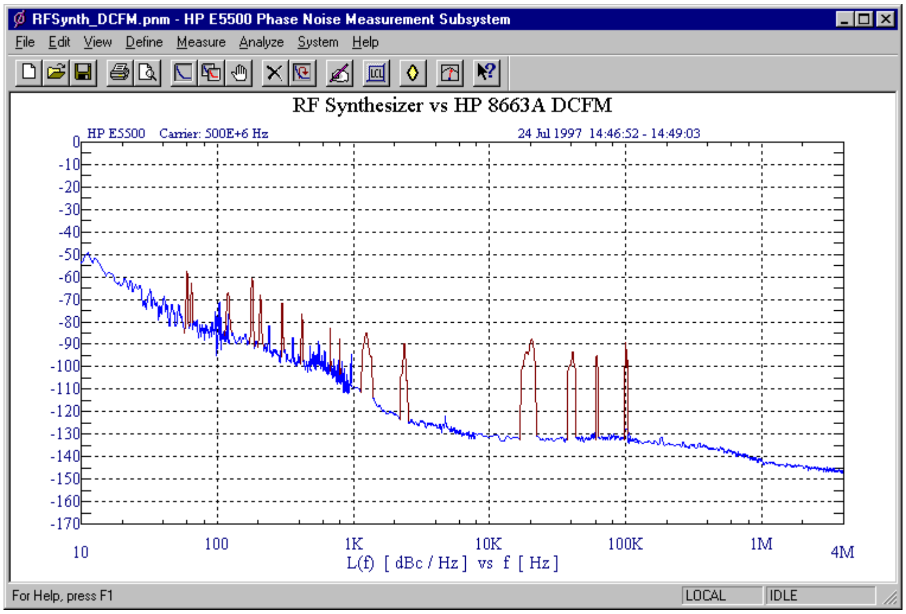


Figure 7-33 Typical Phase Noise Curve for an RF Synthesizer using DCFM.

Table 7-12 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	1 **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 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

Table 7-12 Parameter Data for the RF Synthesizer (DCFM) Measurement

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 Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 7-15. Apply the input signal when the connection diagram appears.

Required Equipment

Table 7-13 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 7-13 Required Equipment for the RF Synthesizer using EFC Measurement

Equipment	Quantity	Comments
Agilent 8663A	1	Must have EFC Input Port. Refer to Chapter 6, "Absolute Measurement Fundamentals" for more information about reference source requirements
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

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 7-34.

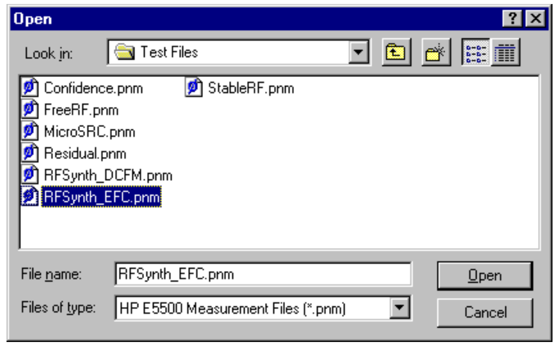


Figure 7-34 Select the Parameters Definition File

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 7-16 lists the parameter data that has been entered for the RF Synthesizer using EFC measurement example.)

NOTE: Note that the source parameters entered for step 2 in Table 7-16 may not be appropriate for the reference source you are using. To change these values, refer to Table 7-14, then continue with step “a”. Otherwise, go to “Beginning the Measurement” on page 7-58:

5 Using Figure 7-35 as a guide, navigate to the **Sources** tab.

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

b Enter the VCO Tuning Constant (see Table 7-14).

c If you are going to use EFC tuning to tune the Agilent 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 7-14).

e Enter the Center Voltage of VCO (see Table 7-14).

f Enter the Input Resistance of VCO (see Table 7-14).

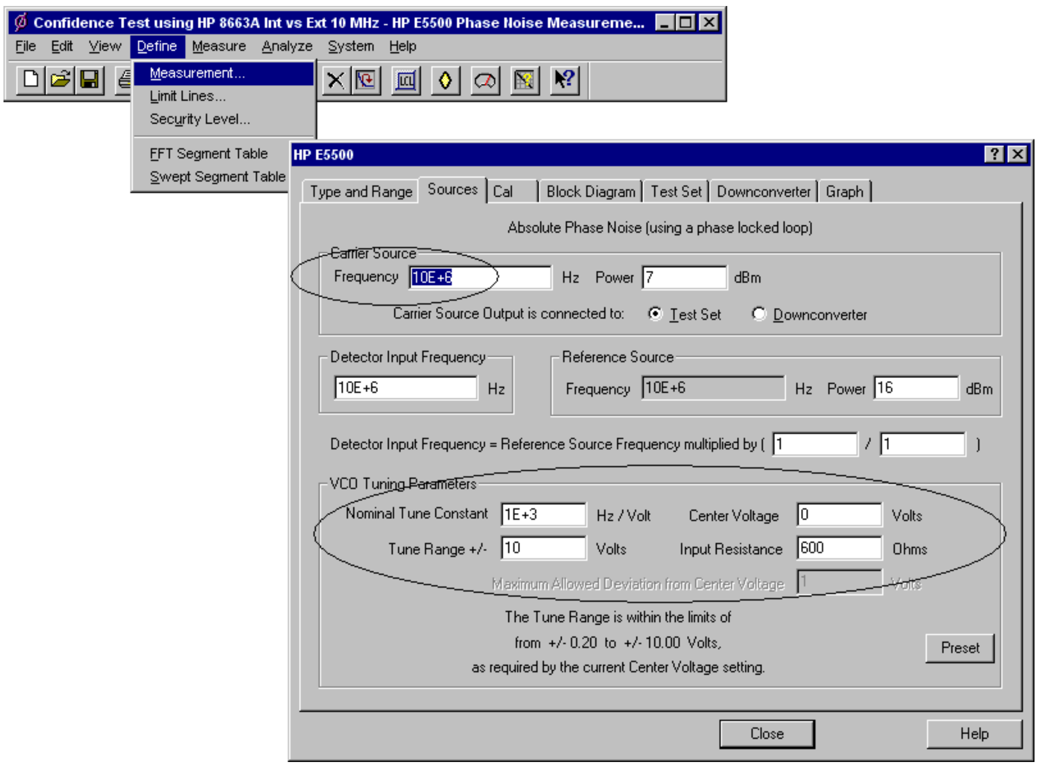


Figure 7-35 Enter Source Information

Table 7-14 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	$5 E - 9 \times \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 K (8662)	Compute
					600 (8663)	Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute

Table 7-14 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
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 7-36 as a guide, navigate to the **Block Diagram** tab.

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

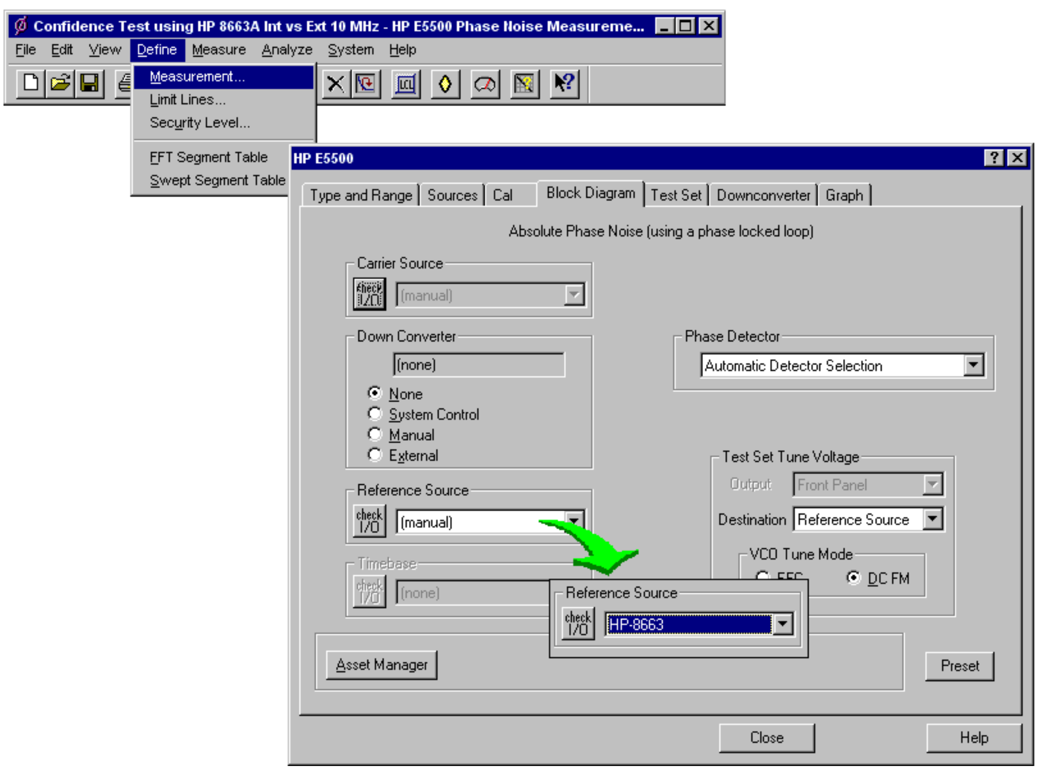


Figure 7-36 Selecting a Reference Source

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

Selecting Loop Suppression Verification

1 Using Figure 7-37 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**.

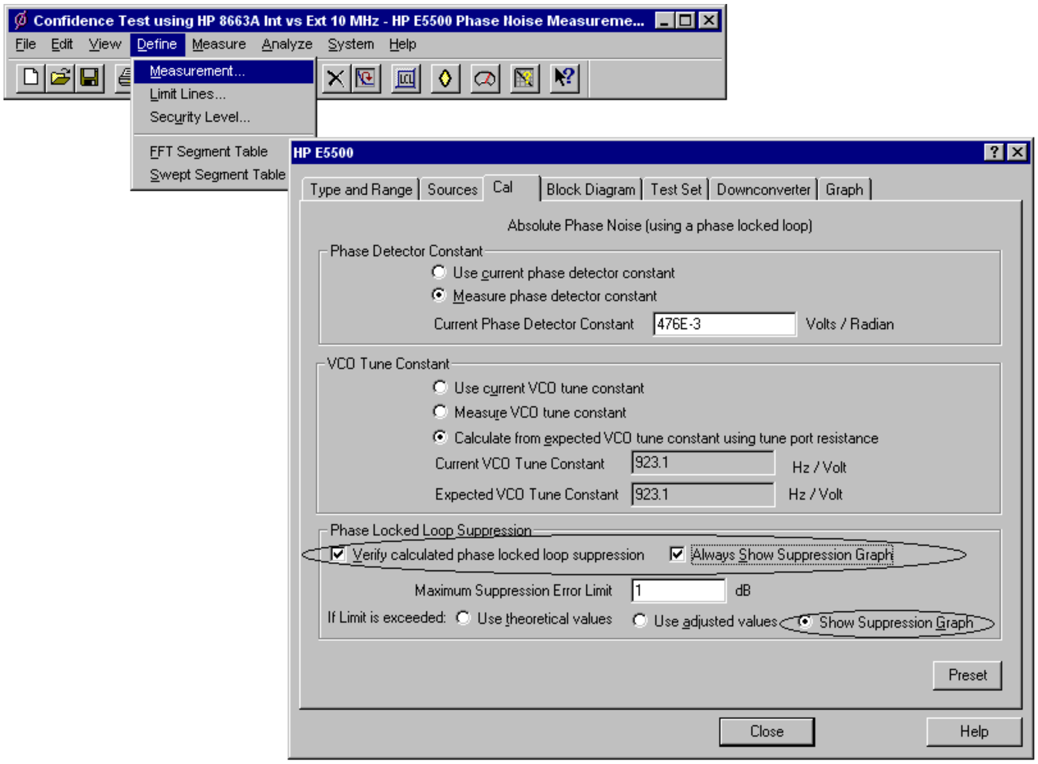


Figure 7-37 Selecting Loop Suppression Verification

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

Setup Considerations for the RF Synthesizer using EFC Measurement

Measurement Noise Floor

The signal amplitude at the R input (Signal Input) port on the Agilent 70420A sets the measurement noise floor level. Use Figure 7-38 and Figure 7-39 to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT.

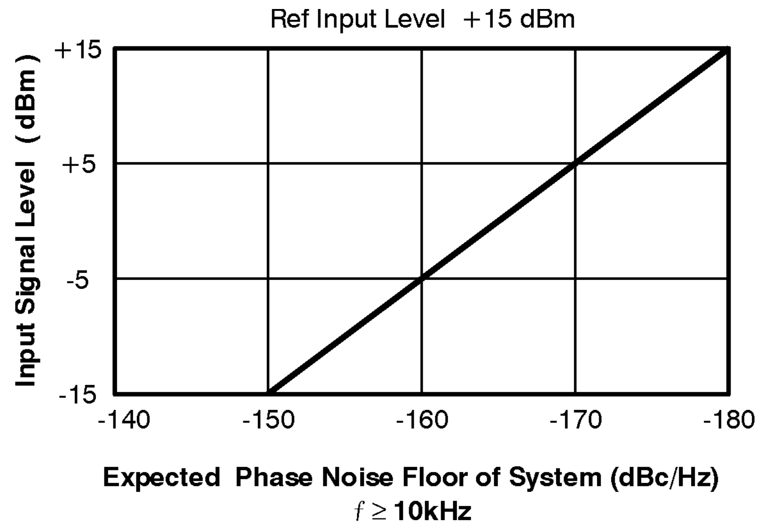


Figure 7-38 Noise Floor for the RF Synthesizer (EFC) Measurement

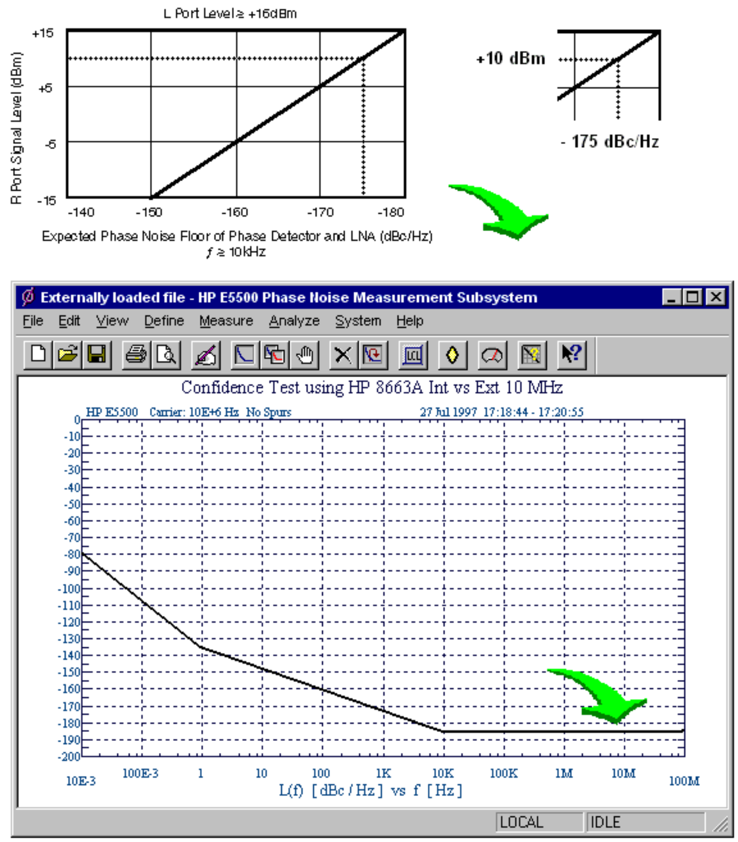


Figure 7-39 Noise Floor Calculation Example

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the Agilent 70420A input. (Refer to “Inserting an Device” in Chapter 6, “Absolute Measurement Fundamentals” 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 Agilent 8663A as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the UUT, the noise level of the reference source should be below the expected noise level of the UUT.

Beginning the Measurement

1 From the **Measurement** menu, choose **New Measurement.** See Figure 7-40.

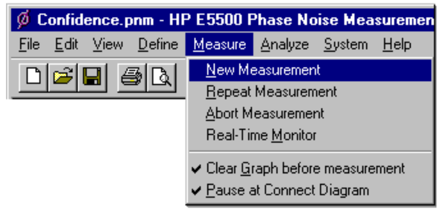


Figure 7-40 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK.**

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

Confirm your connections as shown in Figure 7-41. At this time, connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 7-15 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics:	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

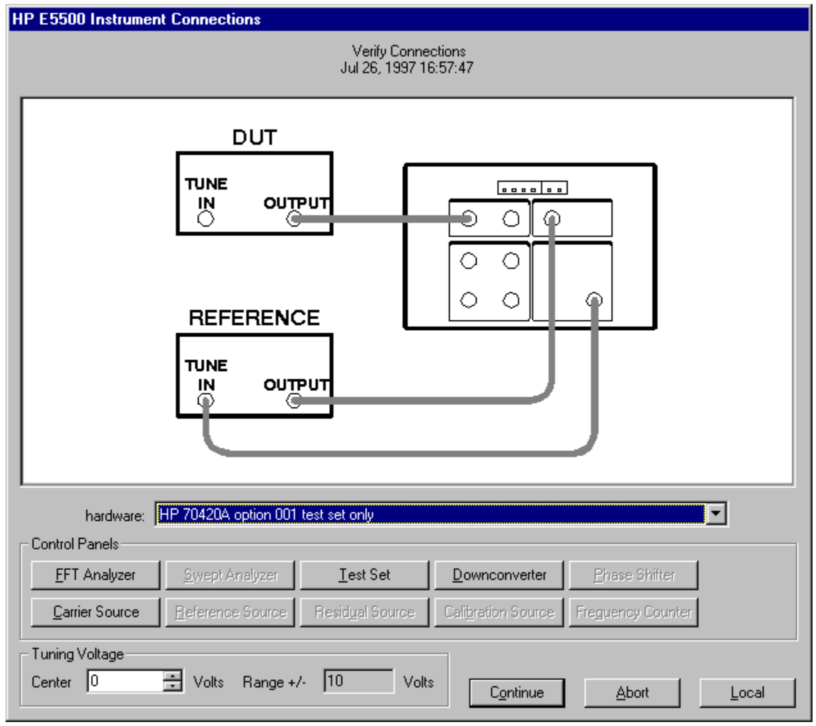


Figure 7-41 Connect Diagram for the RF Synthesizer (EFC) Measurement

4 Refer to the following system connect diagram examples in Chapter 18, “Connect Diagrams” of this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-1, “E5501A Standard Connect Diagram,” on page 18-3
- Figure 18-14, “E5501B Standard Connect Diagram,” on page 18-16
- Figure 18-3, “E5501A Opt. 201, 430, 440 Connect Diagram,” on page 18-5
- Figure 18-21, “E5503B Opt. 001 Connect Diagram,” on page 18-23
- Figure 18-13, “E5504A Opt. 201 Connect Diagram,” on page 18-15
- Figure 18-25, “E5504B Opt. 201 Connect Diagram,” on page 18-27

NOTE: For additional examples, refer to Chapter 18, “Connect Diagrams”

Checking the Beatnote

While the connect diagram is still displayed, recommend that you use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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.

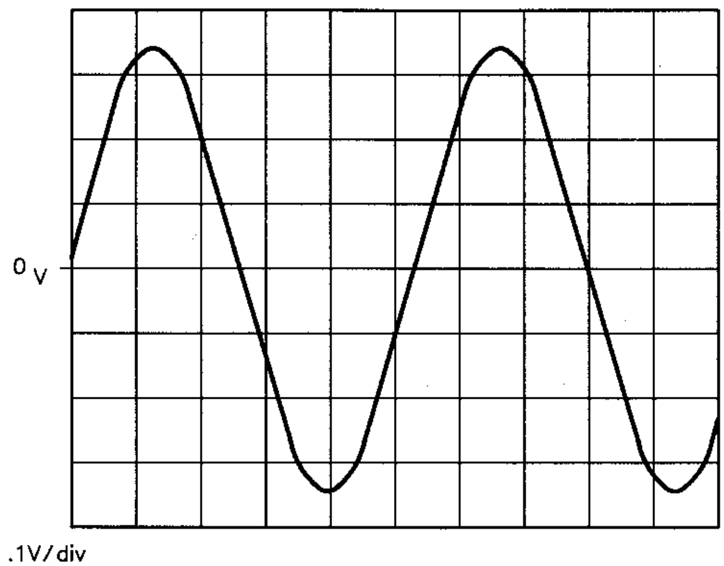


Figure 7-42 Oscilloscope Display of a Beatnote out of the Agilent 70420A Monitor Port

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 7-43.

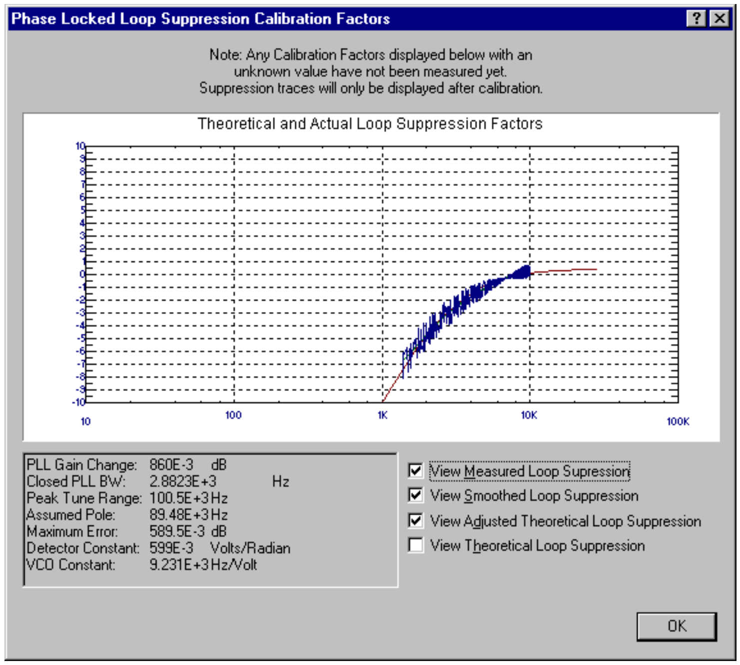


Figure 7-43 Selecting Suppressions

There are four different curves available for the this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

- **a** “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 7-44 shows a typical phase noise curve for a RF synthesizer using EFC.

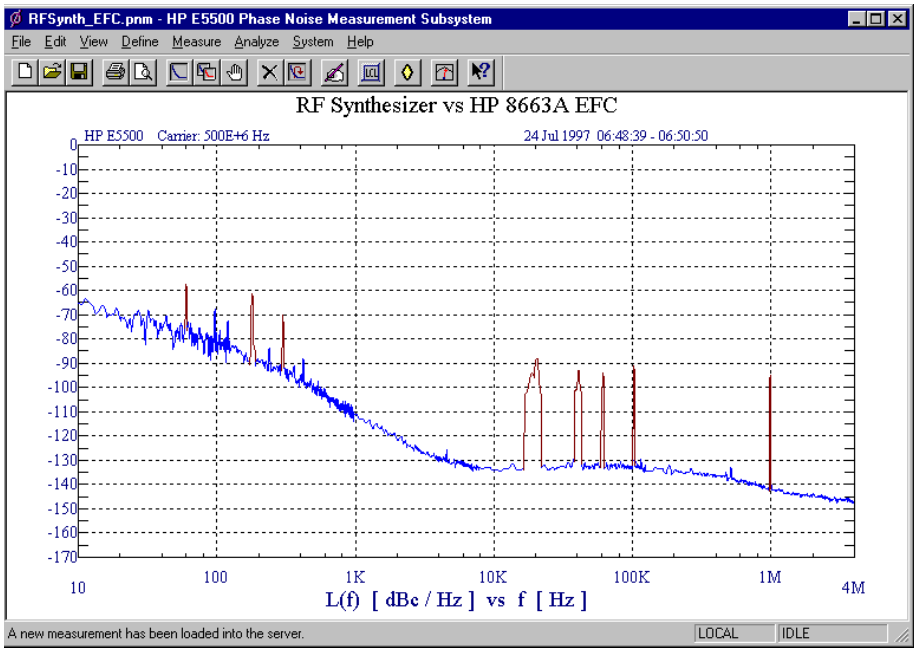


Figure 7-44 Typical Phase Noise Curve for an RF Synthesizer using EFC.

Table 7-16 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 7-16 Parameter Data for the RF Synthesizer (EFC) Measurement

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 Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as shown in Table 7-19. Apply the input signal when the connection diagram appears.

Required Equipment

Table 7-17 shows equipment is required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 7-17 Required Equipment for the Microwave Source Measurement Example

Equipment	Quantity	Comments
Agilent 8644B	1	Must have DCFM Input Port. Refer to Chapter 6, "Absolute Measurement Fundamentals" for more information about reference source requirements
Agilent 70422A	1	Must be entered in the Asset Manager and Server Hardware Connections dialog box.
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

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 7-45.

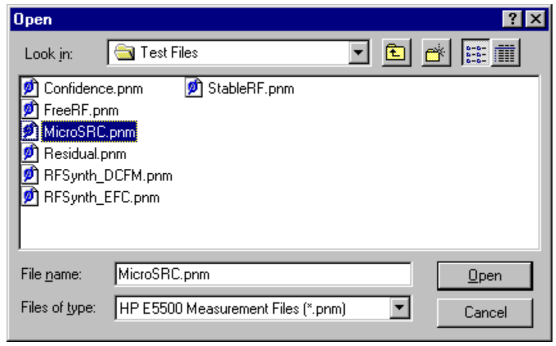


Figure 7-45 Select the Parameters Definition File

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 7-20 lists the parameter data that has been entered for the Microwave Source measurement example.)

NOTE: Note that the source parameters entered for step 2 in Table 7-20 may not be appropriate for the reference source you are using. To change these values, refer to Table 7-18, then continue with step 5 below. Otherwise, go to "Beginning the Measurement" on page 7-73:

---

5 Using Figure 7-46 as a guide, navigate to the **Sources** tab.

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

b Enter the VCO Tuning Constant (see Table 7-18). 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 7-18).

d Enter the Center Voltage of VCO (see Table 7-18).

e Enter the Input Resistance of VCO (see Table 7-18).

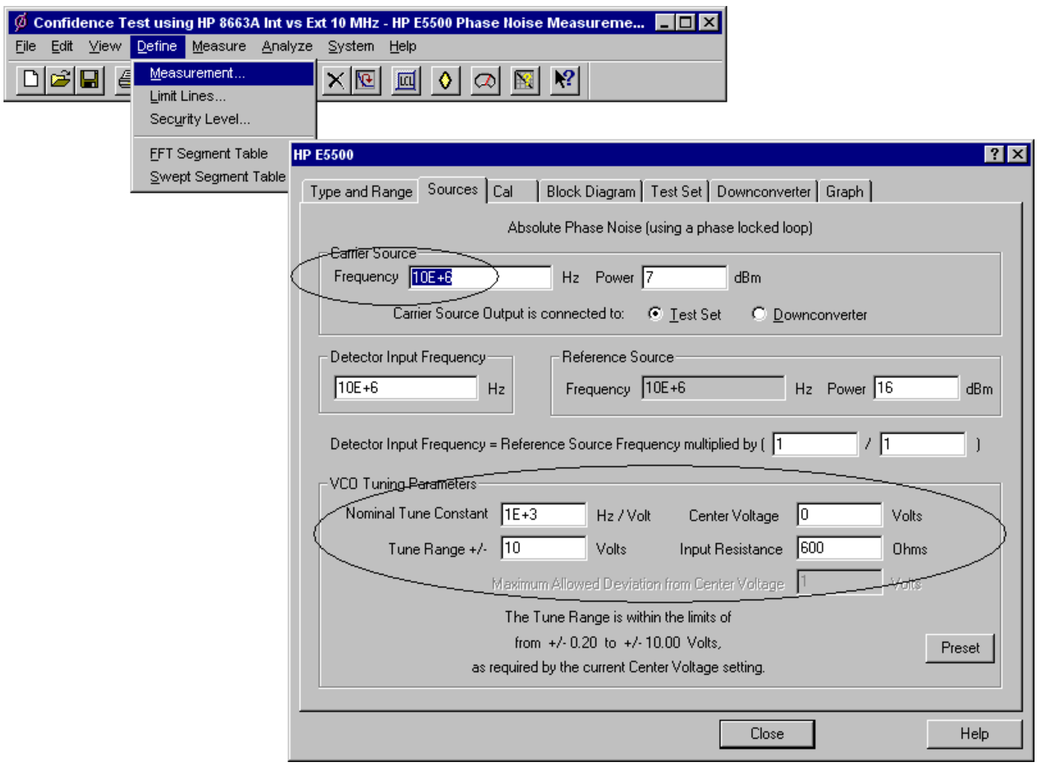


Figure 7-46 Enter Source Information

Table 7-18 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)	Compute
					600 (8663)	Compute
Agilent 8642A/B		FM Deviation	0	10	600	Compute
Agilent 8644B		FM Deviation	0	10	600	Compute

Table 7-18 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
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 7-47, navigate to the **Block Diagram** tab.

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

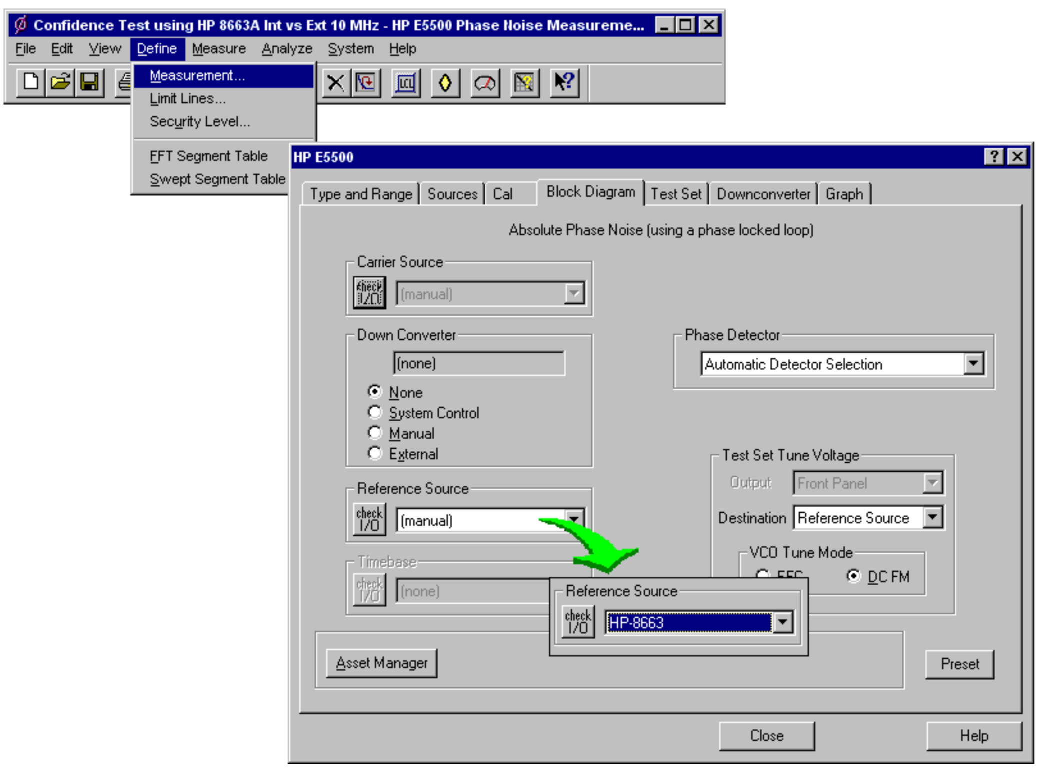


Figure 7-47 Selecting a Reference Source

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

Selecting Loop Suppression Verification

1 Using Figure 7-48 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**.

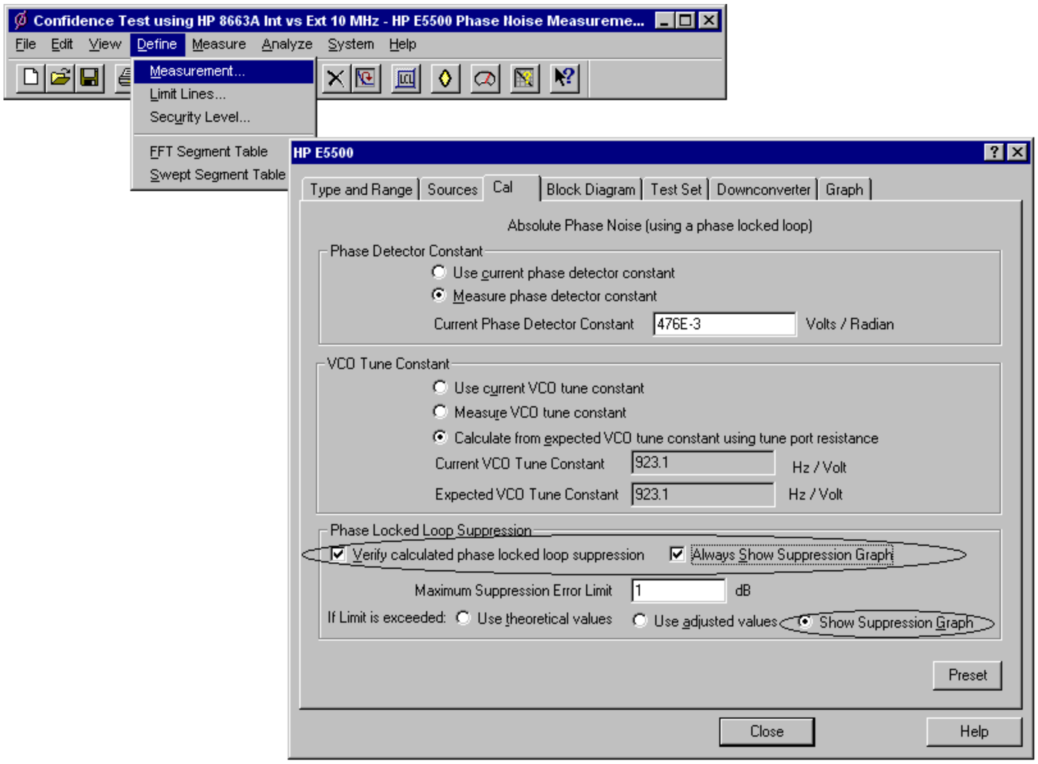


Figure 7-48 Selecting Loop Suppression Verification

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

Setup Considerations for the Microwave Source Measurement

Measurement Noise Floor

Figure 7-49 shows a noise characteristics graph shows a typical noise level for the Agilent 70422A when used with the Agilent 8644B. Use it to help you estimate if the measurement noise floor that it provides is below the expected noise level of your UUT.

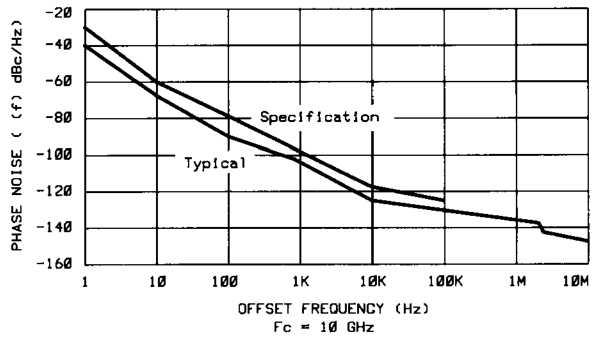


Figure 7-49 Noise Characteristics for the Microwave Measurement

If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the Agilent 70422A input. (Refer to “Inserting an Device” in Chapter 6, “Absolute Measurement Fundamentals” 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 7-50.d

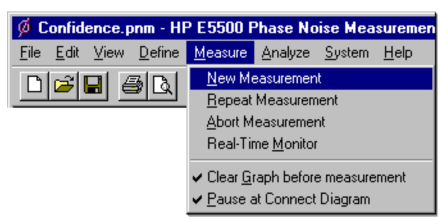


Figure 7-50 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

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

Confirm your connections as shown in Figure 7-51. At this time, connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 7-19 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

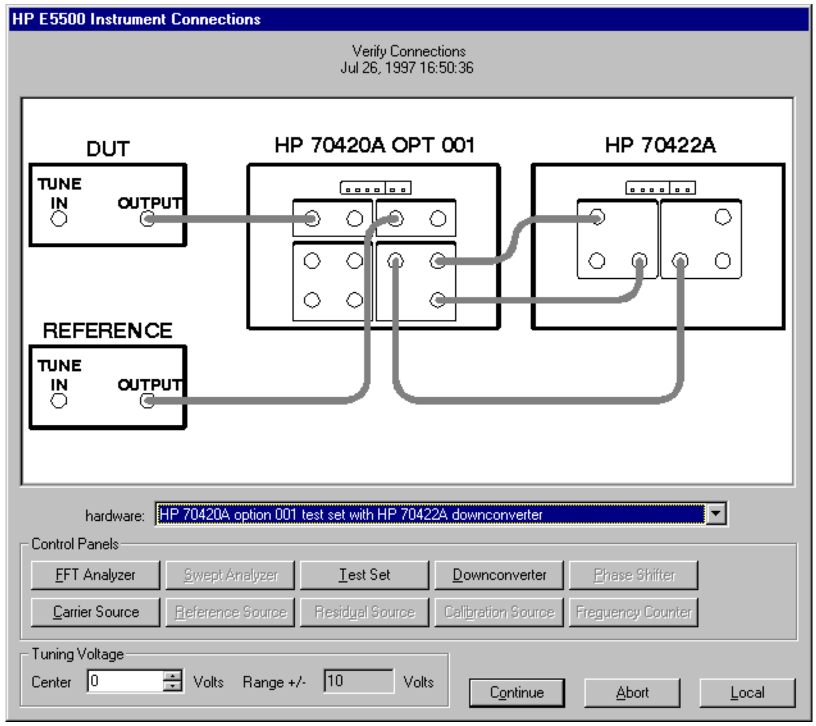


Figure 7-51 Connect Diagram for the Microwave Source Measurement

4 Refer to the following system connect diagram examples in Chapter 18, "Connect Diagrams" of this document for more information about system interconnections. That chapter also contains additional examples.

- Figure 18-9, "E5503A Opt. 001 Connect Diagram," on page 18-11
- Figure 18-21, "E5503B Opt. 001 Connect Diagram," on page 18-23
- Figure 18-13, "E5504A Opt. 201 Connect Diagram," on page 18-15
- Figure 18-25, "E5504B Opt. 201 Connect Diagram," on page 18-27

Checking the Beatnote

While the connect diagram is still displayed, recommend that you use an oscilloscope (connected to the Monitor port on the Agilent 70420A) 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 15, “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 7-52.

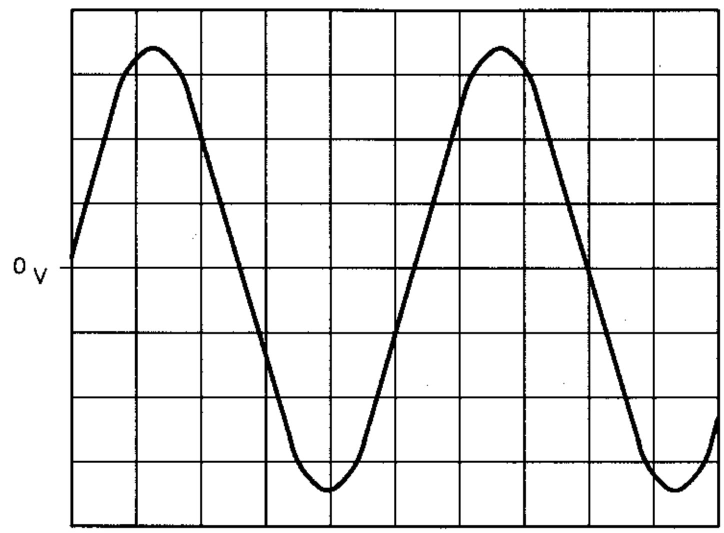


Figure 7-52 Oscilloscope Display of a Beatnote out of the Agilent 70420A Monitor Port

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.

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

$$\textbf{Capture Range (Hz)} = \frac{\_\_\_\_\_\_\textbf{(Hz/V) X}\_\_\_\_\_\_\textbf{(V)}}{\textbf{5}} = \_\_\_\_\_\_\_\_\textbf{(Hz)}$$

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 7-53.

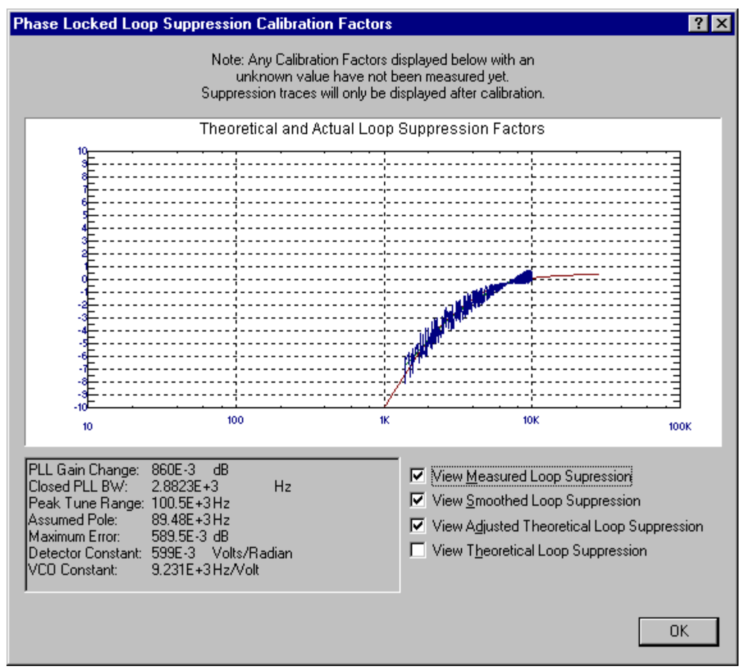


Figure 7-53 Selecting Suppressions

There are four different curves available for the this graph (for more information about loop suppression verification, refer to Chapter 16, “Advanced Software Features”):

a “Measured” loop suppression curve - this is the result of the loop suppression measurement performed by the E5500 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 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results.

Figure 7-54 shows a typical phase noise curve for a microwave source.

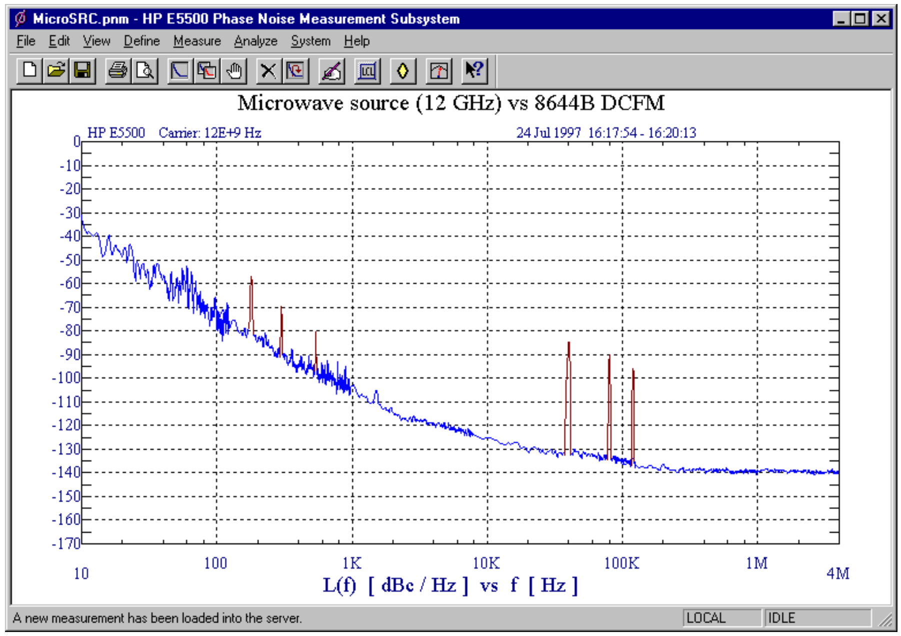


Figure 7-54 Typical Phase Noise Curve for an Microwave Source

Table 7-20 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	• 600 E +6 Hz
	• Frequency	
	Reference Source	• 600 E +6 Hz (same as Carrier Source Frequency)
	• Frequency	• 16 dBm
	• Reference Source Power	
	VCO Tuning Parameters	• 40 E +3 Hz/V
	• Nominal Tune Constant	• +/- 10 Volts
	• Tune Range +/-	• 0 Volts
	• Center Voltage	• 600 ohms
	• Input Resistance	
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 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 7-20 Parameter Data for the Microwave Source Measurement

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 - 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

8

Residual Measurement Fundamentals

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

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 8-1.

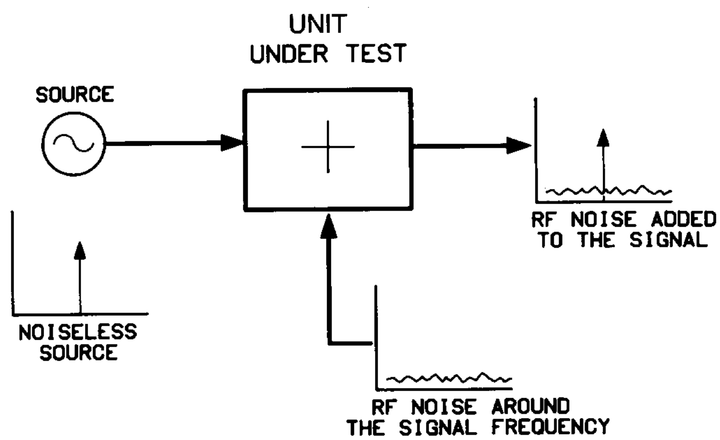


Figure 8-1 Additive Noise Components

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 8-2.

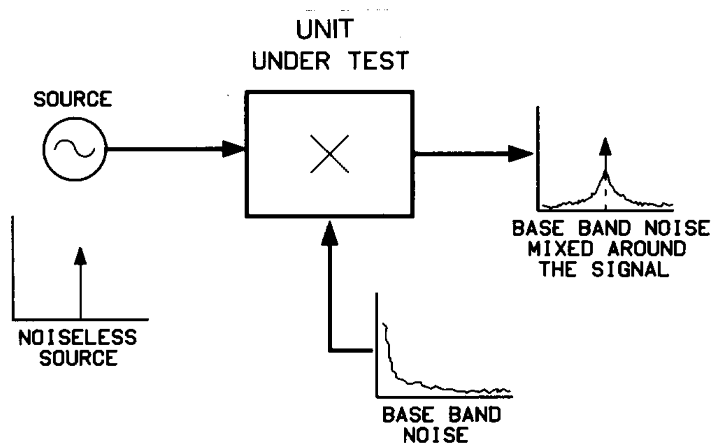


Figure 8-2 Multiplicative Noise Components

Basic Assumptions Regarding 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 UUT.
- 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 UUT 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 unit-under-test (UUT) is connected to either of the two inputs of the Phase Detector, all of the source noise will cancel and only the residual noise of the UUT will be measured. See Figure 8-3.

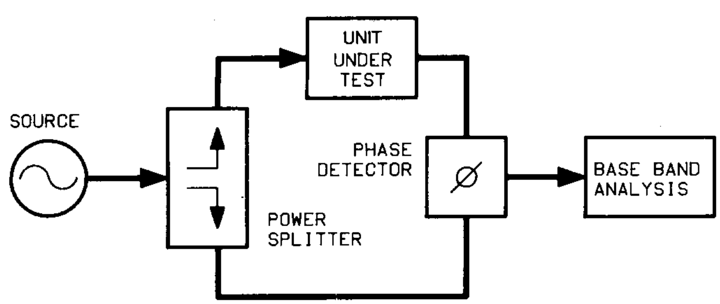


Figure 8-3 Setup for Typical Residual Phase Noise Measurement

Frequency Translation Devices

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

If the UUT's are identical, a possible (but not recommended) assumption is that the noise of each UUT is half the measured result, or 3 dB less. All that really can be concluded is that the noise level of one of the UUT's 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 UUT must also be measured against the other two UUT's. 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 UUT's. See Figure 8-4.

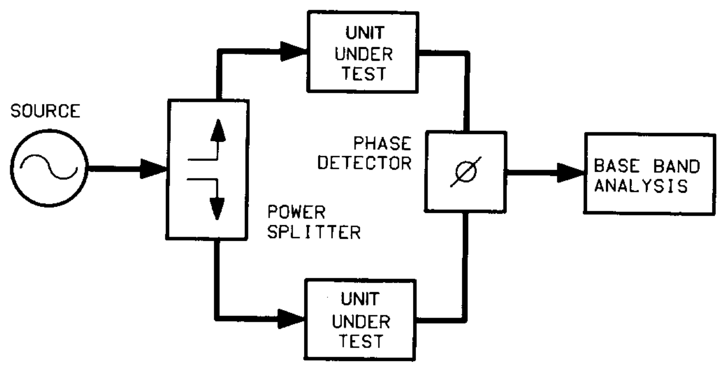


Figure 8-4 Measurement Setup for Two Similar UUTs

Calibrating the Measurement

In the Agilent E5500 Phase Noise Measurement System, residual phase noise measurements are made by selecting Residual Phase Noise (without using a phase locked loop).

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

- User Entry of Phase Detector Constant
- Measured ±DC Peak
- Beatnote
- 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 8-5.

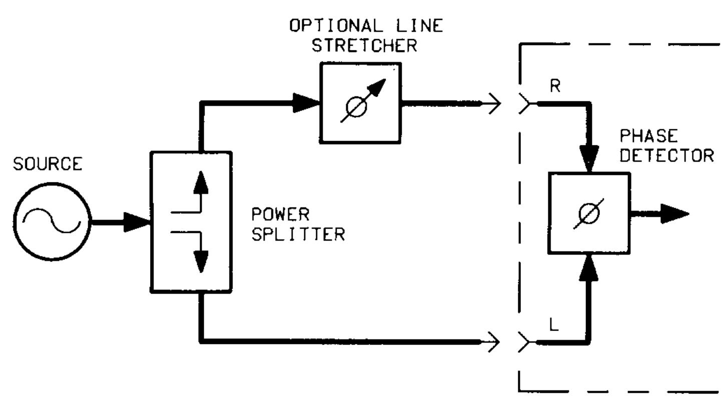


Figure 8-5 General Equipment Setup for Making Residual Phase Noise Measurements

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:

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

$$\text{Where:}$$

$$f = carrier\ offset\ \ frequency$$

$$\pi = 3.14159$$

$$\tau = time\ delay\ (\text{sec.})$$

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.1 of $\frac{1}{2\pi\tau}$, source noise is attenuated 20 dB. Examples of sources which best meet these requirements are the Agilent 8644B and Agilent 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 UUT.

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 UUT 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 UUT 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:

   a It should have the lowest possible noise figure, and the greatest possible dynamic range.

   b The signal level must be kept as high as possible at all points in the setup to minimize degradation from the thermal noise floor.

   c 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.

   d The amplifier’s sensitivity to power supply noise and the power supply noise itself must both be minimized.

Calibration Options

There are five 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 8-6, and tighten all connections.

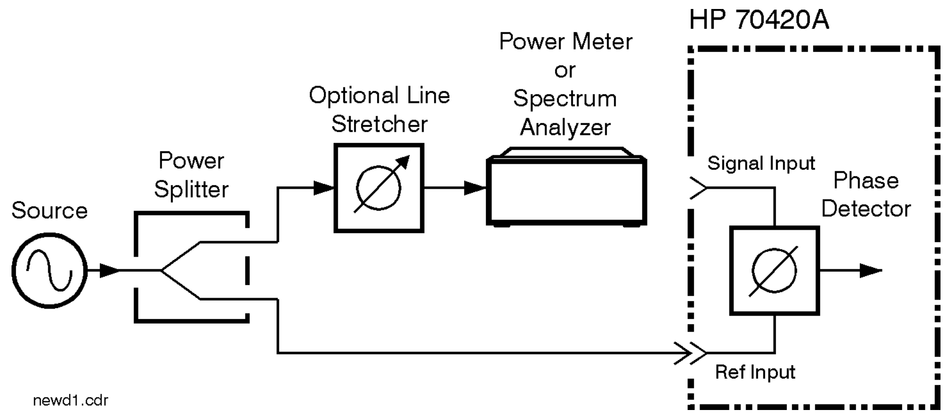


Figure 8-6 Measuring Power at Phase Detector Signal Input Port

2 Measure the power level that will be applied to the signal input of the Agilent 70420A's Phase Detector. Table 8-1 shows the acceptable amplitude ranges for the Agilent 70420A Phase Detectors.

Table 8-1 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz*	
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

* Agilent 70420A 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 8-7). 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.)

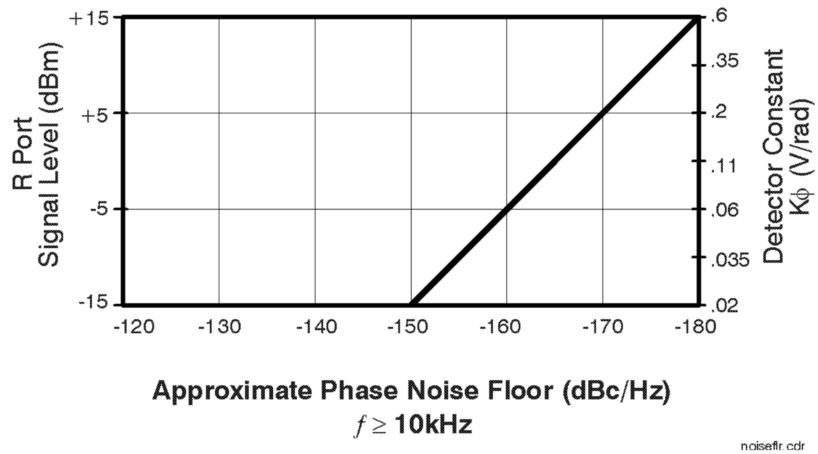


Figure 8-7 Phase Detector Sensitivity

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 8-9.

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 8-8). 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.

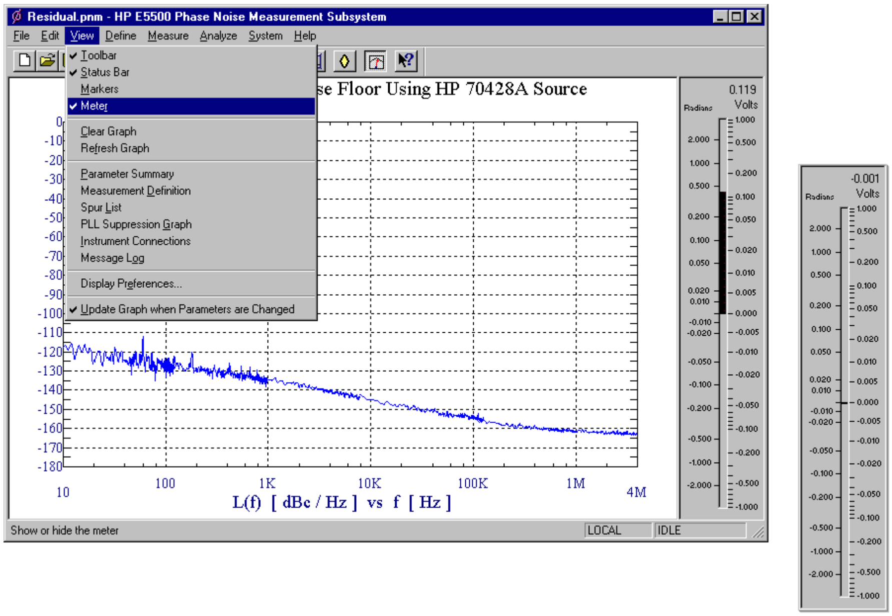


Figure 8-8 Adjust for Quadrature

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.

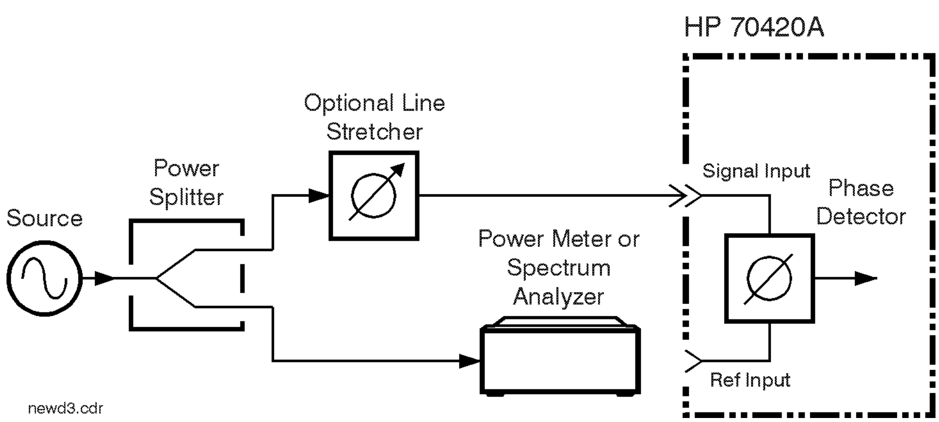


Figure 8-9 Measuring Power at Phase Detector Reference Input Port

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 8-10, and tighten all connections.

2 Measure the power level that will be applied to the Signal Input port of the Agilent 70420A's Phase Detector. Table 8-2 shows the acceptable amplitude ranges for the Agilent 70420A Phase Detectors.

Table 8-2 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector	
50 kHz to 1.6 GHz	1.2 to 26.5 GHz*

Table 8-2 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
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

* Agilent 70420A Phase Noise Test Set Options 001 and 201

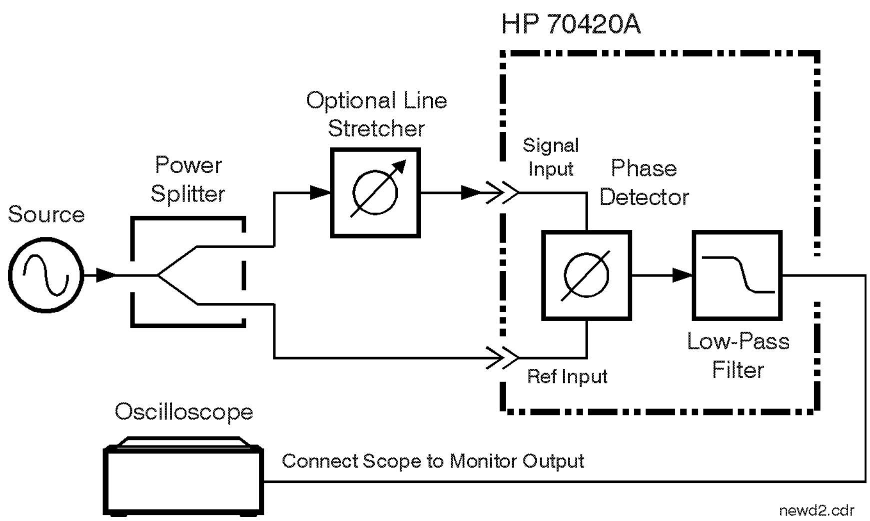


Figure 8-10 Connection to Optional Oscilloscope for Determining Voltage Peaks

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 8-3.

Table 8-3 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.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 8-11, and tighten all connections.

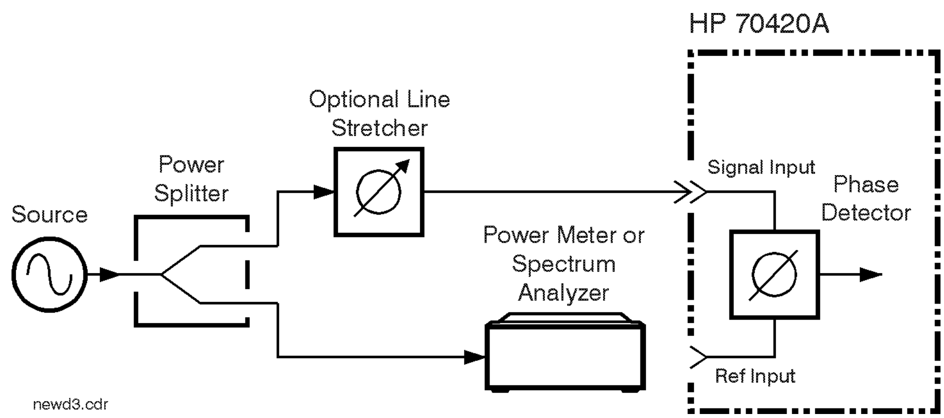


Figure 8-11 Measuring Power from Splitter

2 Measure the power level that will be applied to the Signal Input port of the Agilent 70420A's Phase Detector. Table 8-4 shows the acceptable amplitude ranges for the Agilent 70420A Phase Detectors.

Table 8-4 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz*	
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

* Agilent 70420A 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 8-12.

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.

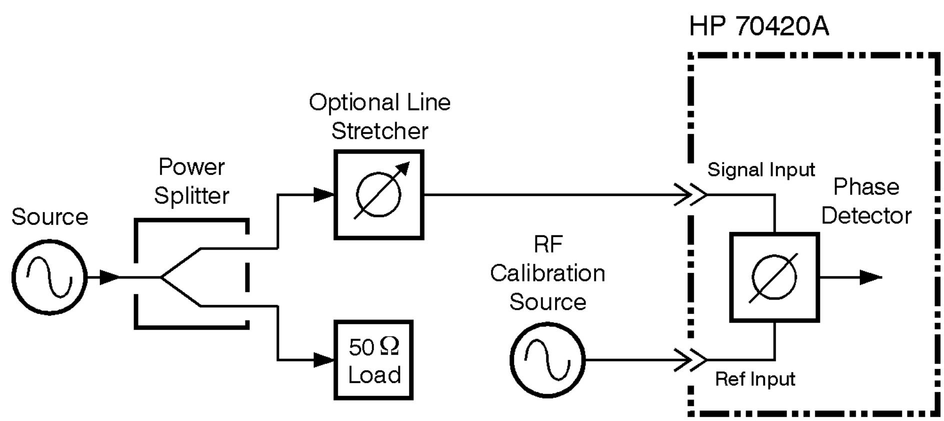


Figure 8-12 Calibration Source Beatnote Injection

Synthesized Residual Measurement using Beatnote Cal

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 8-5.

Table 8-5 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 8-13, and tighten all connections.

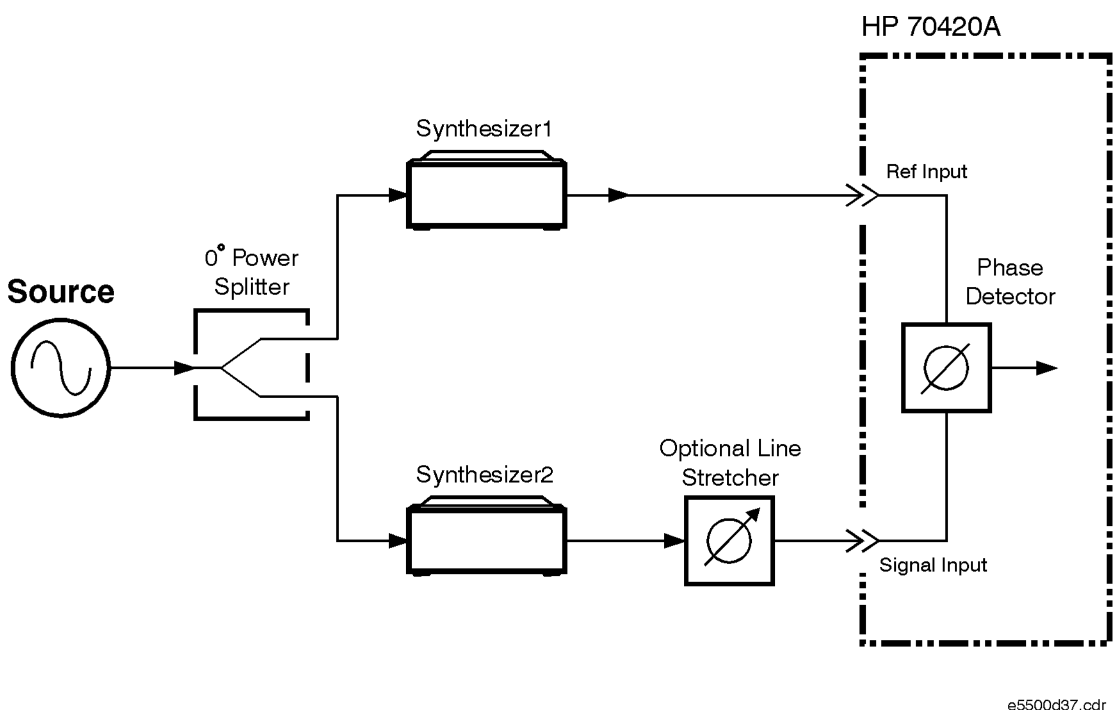


Figure 8-13 Synthesized Residual Measurement using Beatnote Cal

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.

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 8-15).

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 modulators.

Procedure

1 Connect circuit as per Figure 8-14, and tighten all connections.

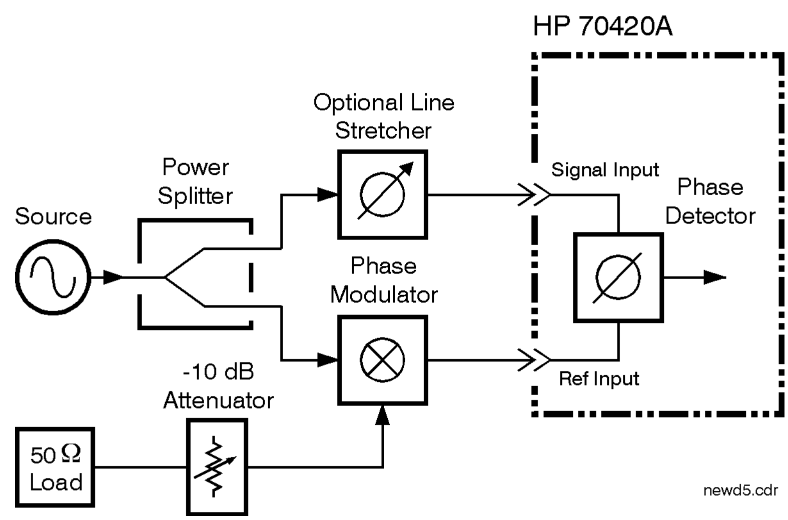


Figure 8-14 Calibration Setup

2 Measure the power level that will be applied to the Signal Input port of the Agilent 70420A's Phase Detector. Table 8-6 shows the acceptable amplitude ranges for the Agilent 70420A Phase Detectors.

Table 8-6 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz*	
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

* Agilent 70420A 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 8-15.

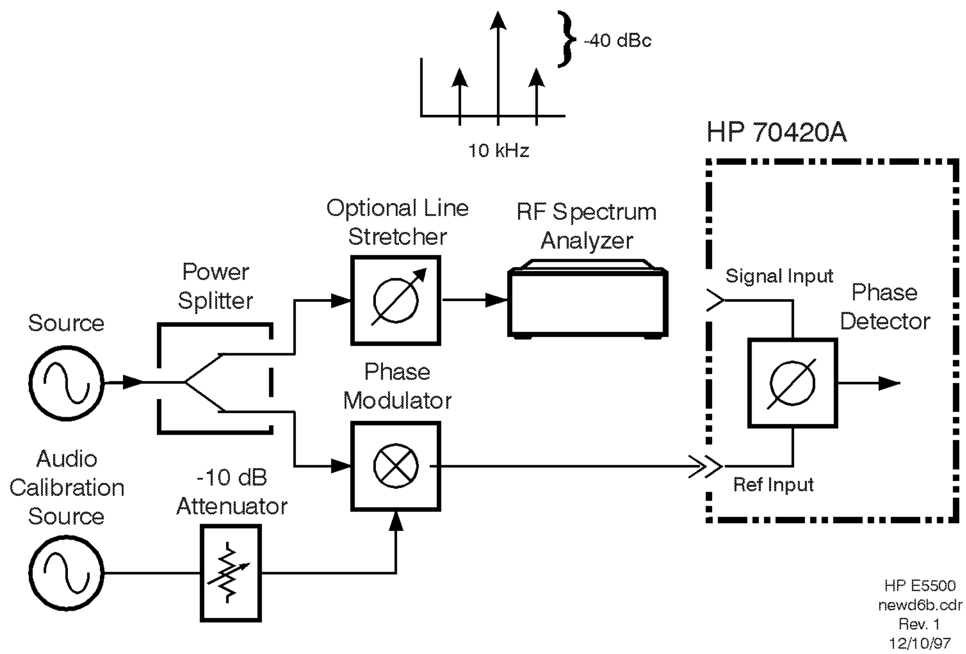


Figure 8-15 Measuring Carrier-to-sideband Ratio of the Modulated Port

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 8-16, and tighten all connections. Note that the input signal into the directional coupler is being supplied to the coupler's output port.

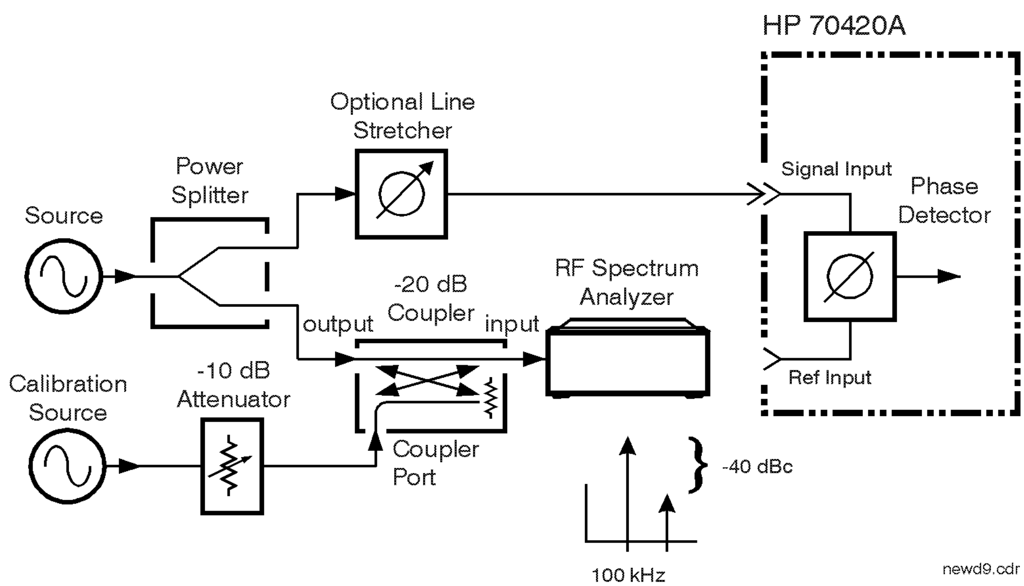


Figure 8-16 Calibration Setup

2 Measure the power level that will be applied to the Signal Input port of the Agilent 70420A's Phase Detector. The following chart shows the acceptable amplitude ranges for the Agilent 70420A Phase Detectors.

Table 8-7 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector	
50 kHz to 1.6 GHz	1.2 to 26.5 GHz*

Table 8-7 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
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

* Agilent 70420A 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 8-17). 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.

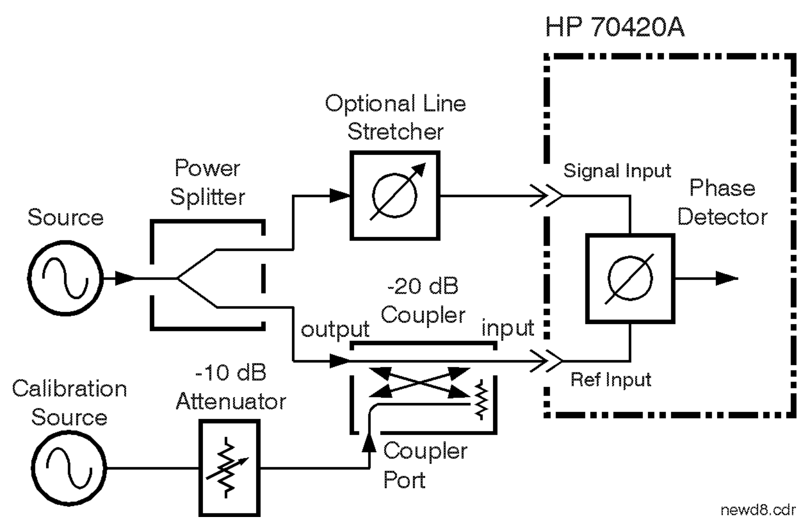


Figure 8-17 Carrier-to-spur Ratio of Modulated Signal

4 Measure the carrier-to-spur ratio of the non-modulated side of the phase detector (Figure 8-18). 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.

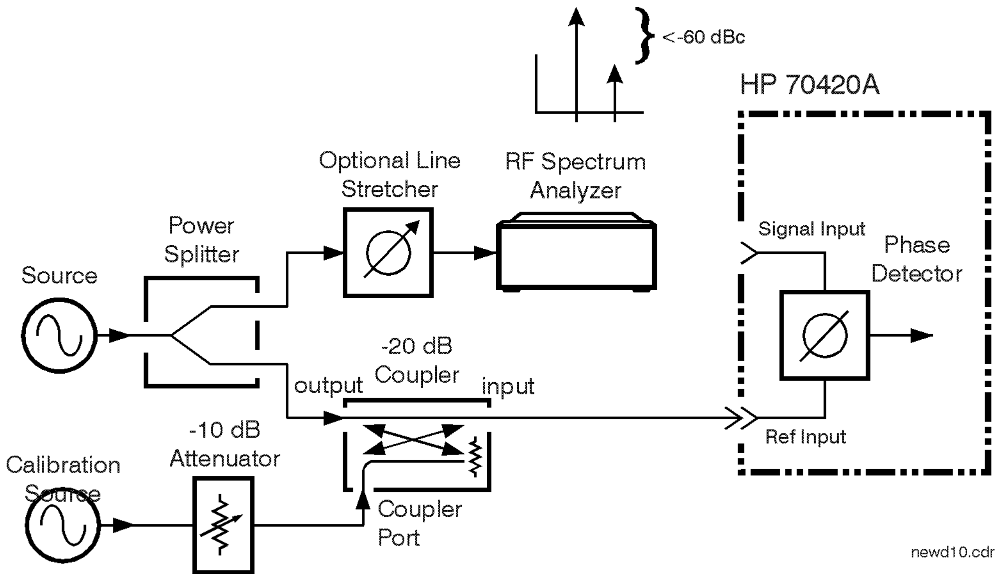


Figure 8-18 Carrier-to-spur Ratio of Non-modulated Signal

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 Agilent 70420A 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 15, "Evaluating Your Measurement Results" contains troubleshooting information to be used after the measurement has been made, and a plot has been obtained.

NOTE: 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 Agilent 70420A Phase Detector Inputs.

9

Residual Measurement Examples

Amplifier Measurement Example

This example contains information about measuring the residual noise of two port devices

This example demostrates a residual phase noise measurement for an RF Amplifier. Refer to Chapter 8, "Residual Measurement Fundamentals" for more information about residual phase noise measurements.

CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 9-2. Apply the input signal when the connection diagram appears.

Required Equipment

Table 9-1 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 9-1 Required Equipment for the Residual Measurement using the Agilent 70420A Measurement Example

Equipment	Quantity	Comments
RF Amplifier	1	
Stimulus Source	1	Frequency of amplitude under test
Power Splitter	1	NARDA 30183
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

The setup for a residual phase noise measurement uses a phase shifter to set quadrature at the phase detector. See Figure 9-1.

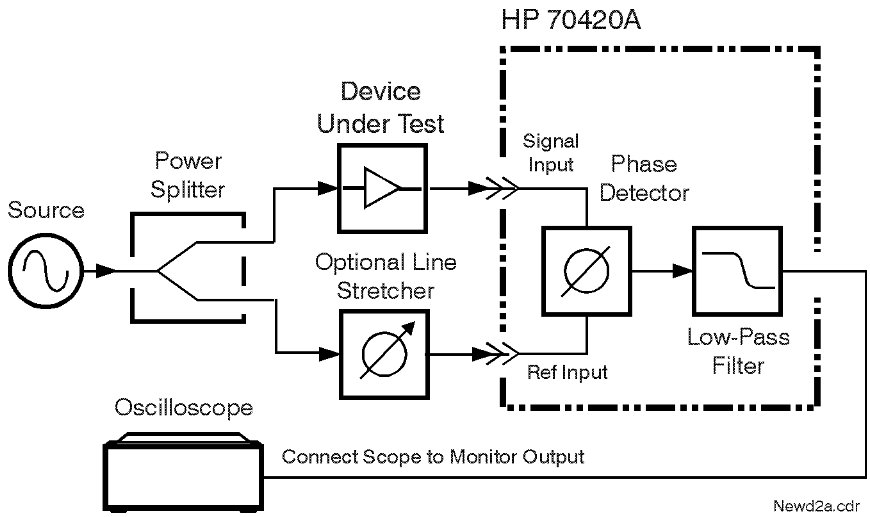


Figure 9-1 Setup for Residual Phase Noise Measurement

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 9-2.

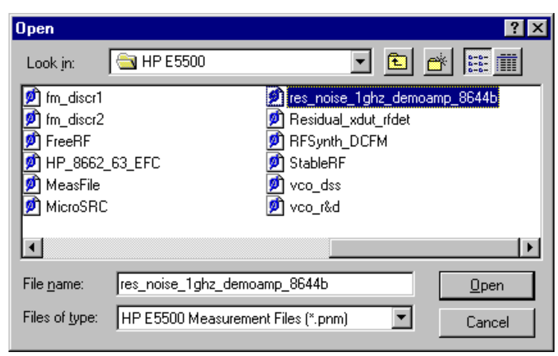


Figure 9-2 Select the Parameters Definition File

4. Click the **Open** button.

   The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 9-4 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 9-3.

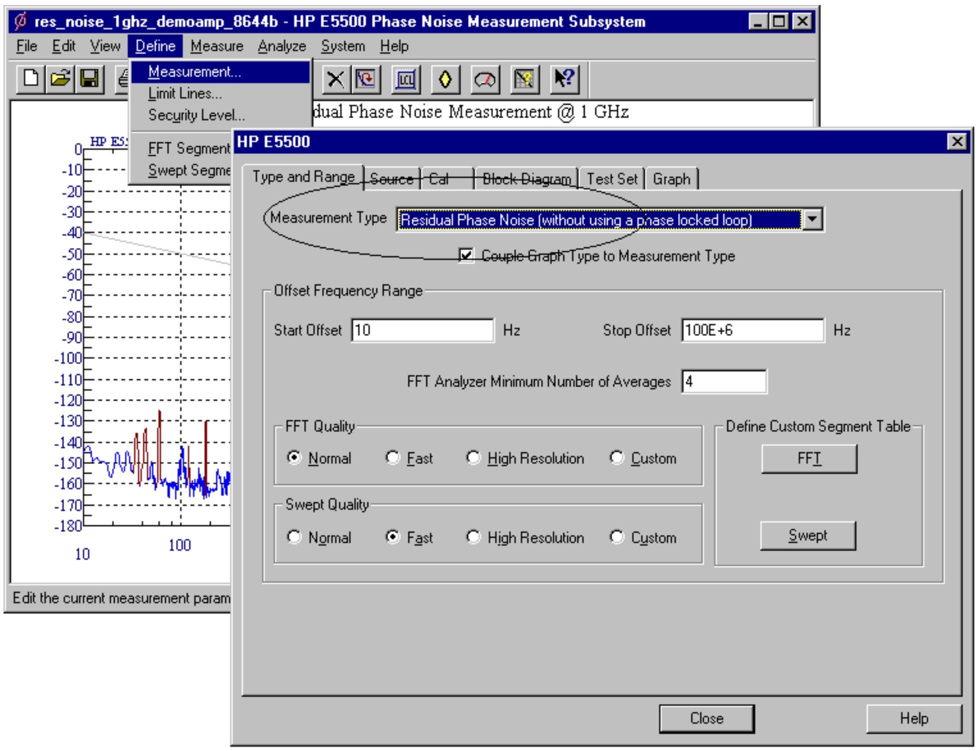


Figure 9-3 Navigate to Residual Phase Noise

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

8 Enter the carrier (center) frequency of your UUT. Enter the same frequency for the detector input frequency. See Figure 9-4.

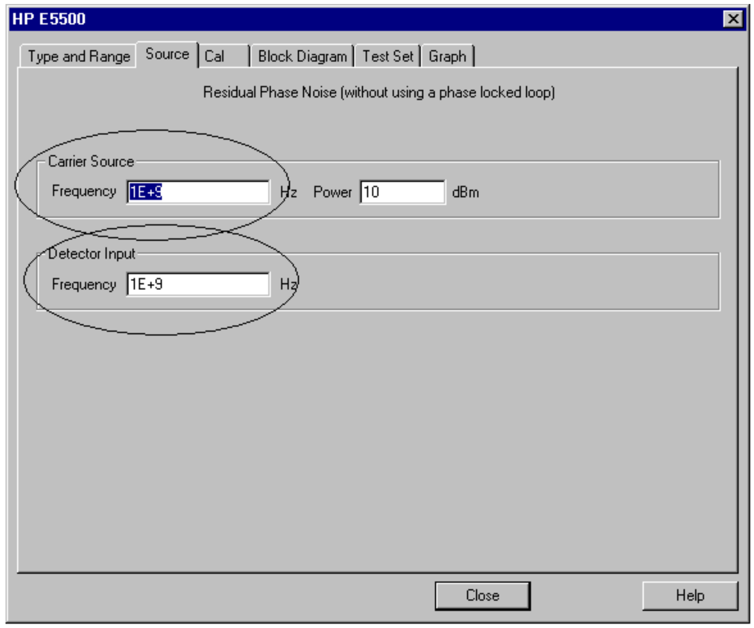


Figure 9-4 Enter Frequencies into Source Tab

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 9-5.

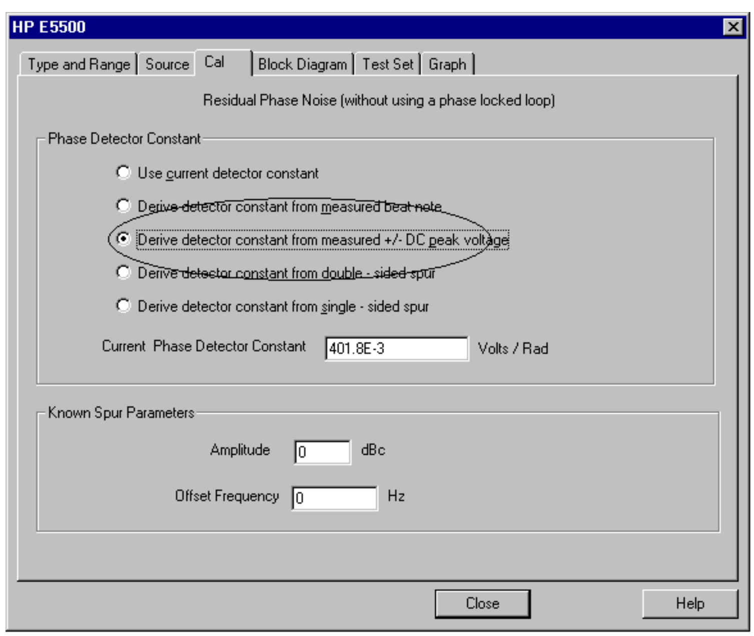


Figure 9-5 Select Constant in the Cal Tab

11 Choose the Block Diagram tab from the Define Measurement window. Refer to Figure 9-6.

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

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

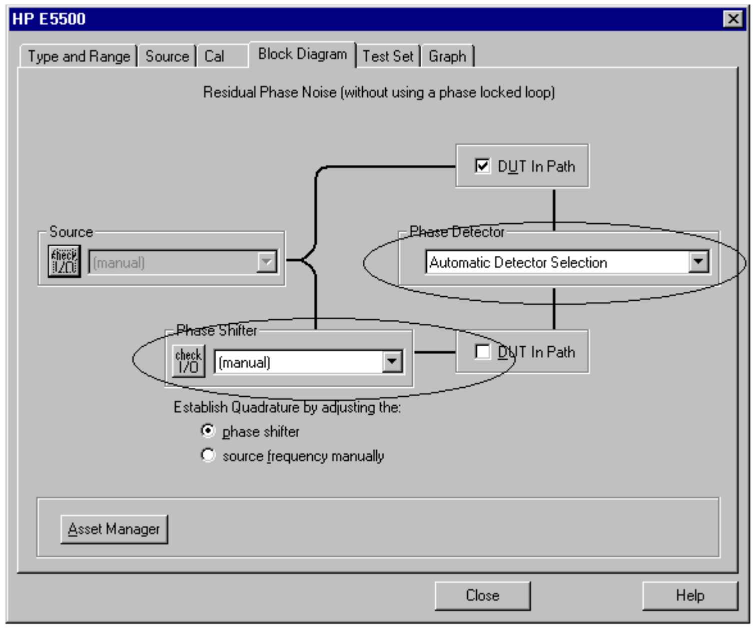


Figure 9-6 Select Parameters in the Block Diagram Tab

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 9-7.

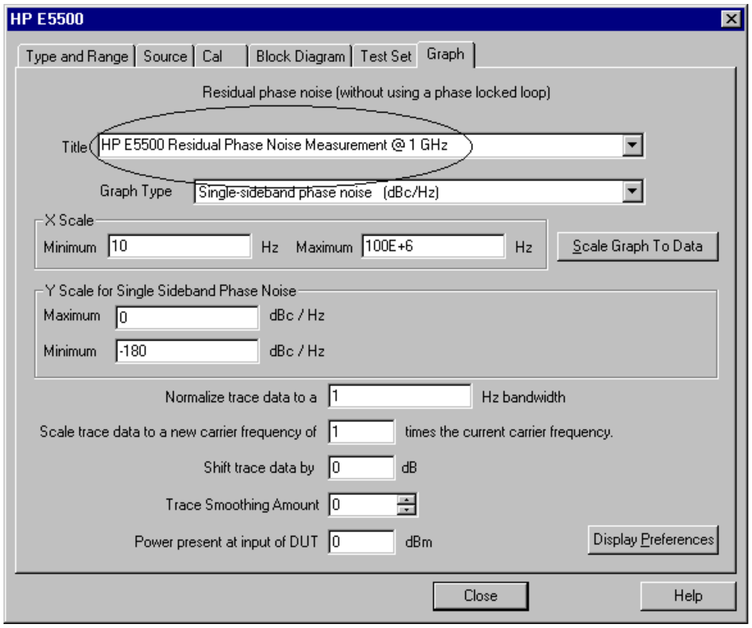


Figure 9-7 Select Graph Description on Graph Tab

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 9-8.

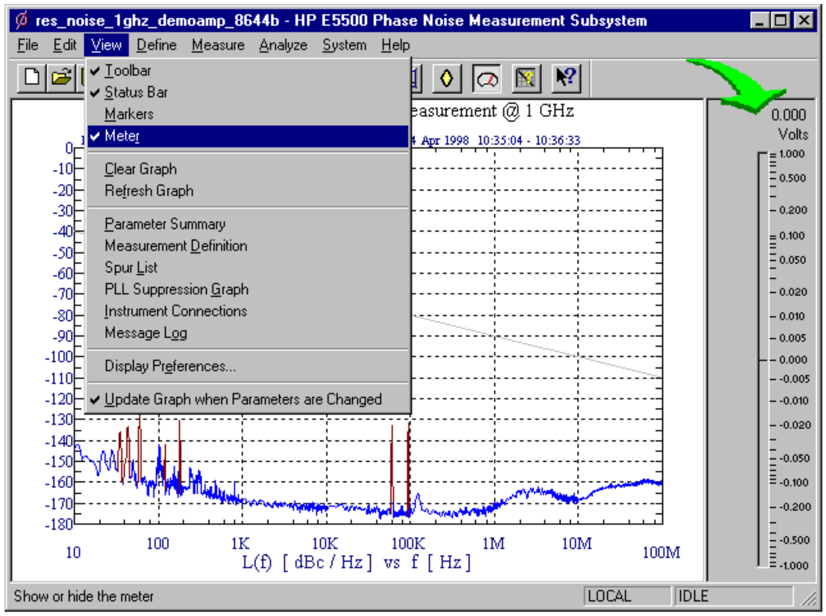


Figure 9-8 Select Meter from View Menu

1 From the **Measure** menu, choose **New Measurement.** See Figure 9-9.

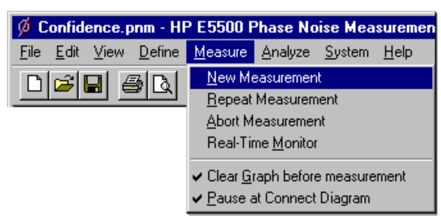


Figure 9-9 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

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 toFigure 9-10.

Confirm your connections as shown in the connect diagram. At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A Test Set's signal input is subject to the following limits and characteristics:

Table 9-2 Agilent 70420A 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)
CAUTION: To prevent damage to the Agilent 70420A Test Set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics	
Input Impedance	50 ohm Nominal

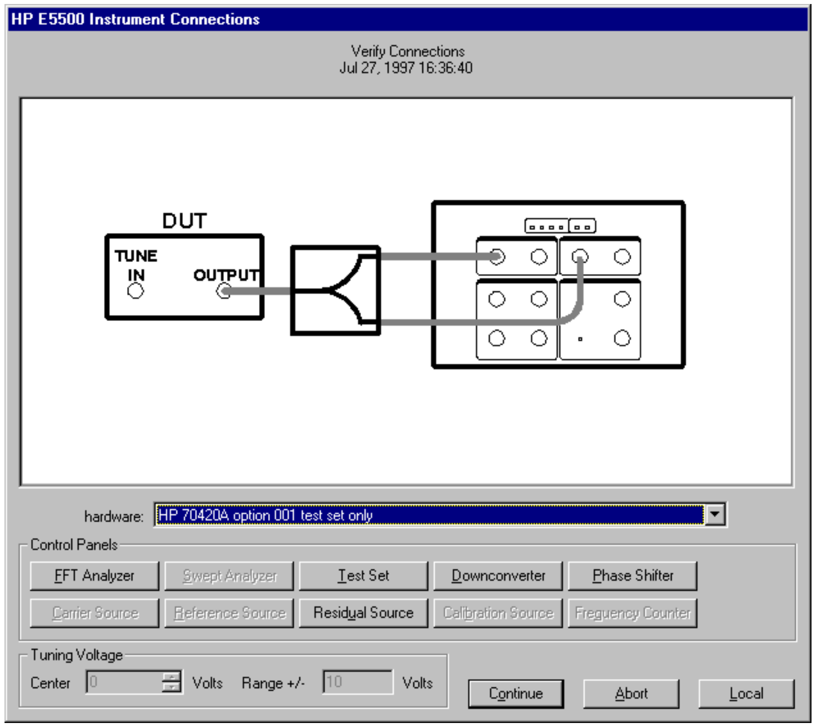


Figure 9-10 Setup diagram for the Agilent 8349A Amplifier Measurement Example

Making the Measurement

Calibrate the Measurement using Measured +/- DC Peak Voltage

Refer to Chapter 8, “Residual Measurement Fundamentals” for more information about residual phase noise measurements calibration types.

Procedure

1 Using Figure 9-11 and Figure 9-12 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 Agilent 70420A's phase detector. Table 9-3 shows the acceptable amplitude ranges for the Agilent 70420A phase detectors.

Table 9-3 Acceptable Amplitude Ranges for the Phase Detectors

Phase Detector			
50 kHz to 1.6 GHz		1.2 to 26.5 GHz*	
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

* Agilent 70420A Phase Noise Test Set Options 001 and 201

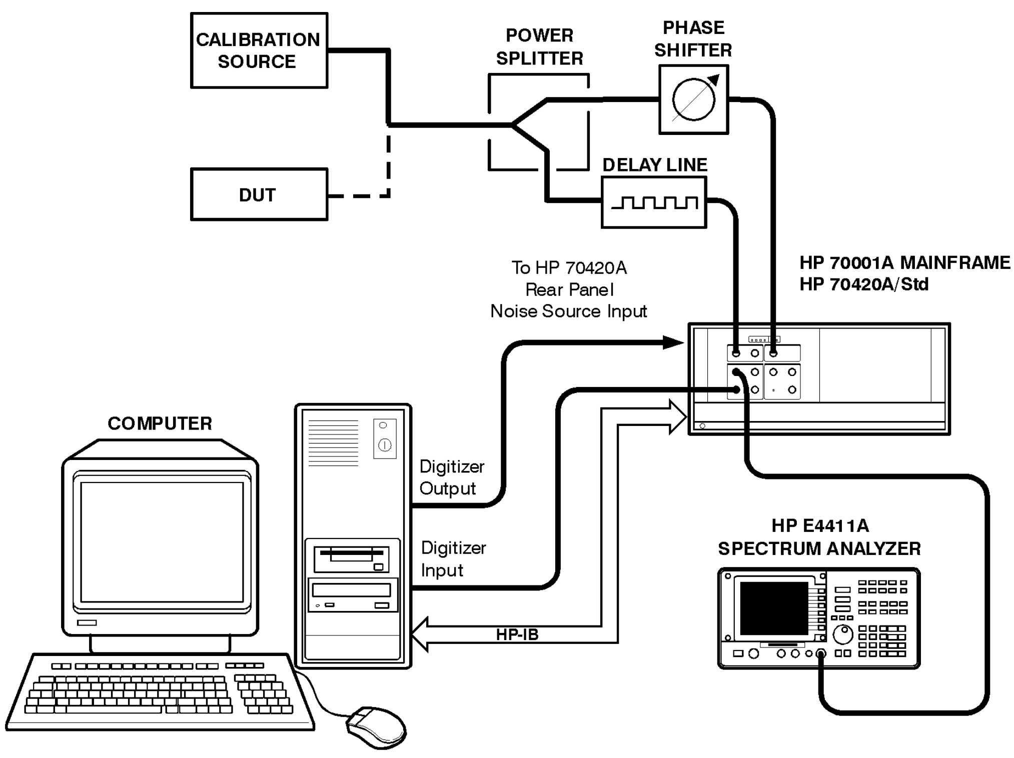


Figure 9-11 Residual Connect Diagram Example

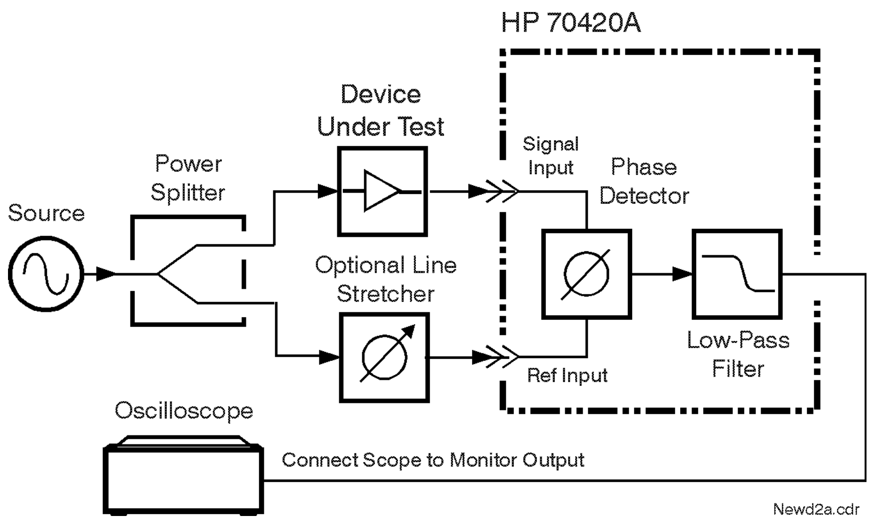


Figure 9-12 Connection to Optional Oscilloscope for Determining Voltage Peaks

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.

1 Press the **Continue** key when ready to calibrate the measurement.

2 Adjust the phase difference at the phase detector as prompted by the phase noise software. See Figure 9-13.

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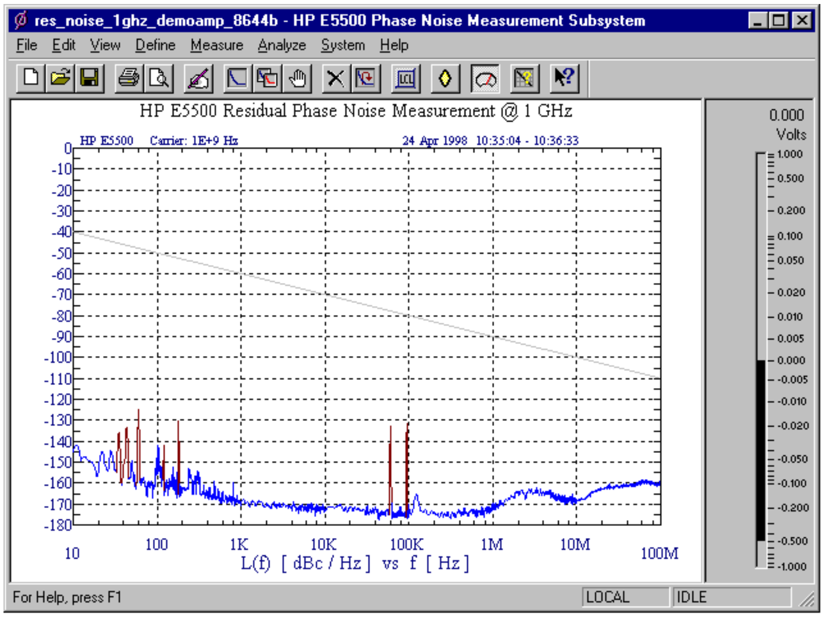

Figure 9-13 Adjust Phase Difference at Phase Detector

3 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.

4 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 9-14.

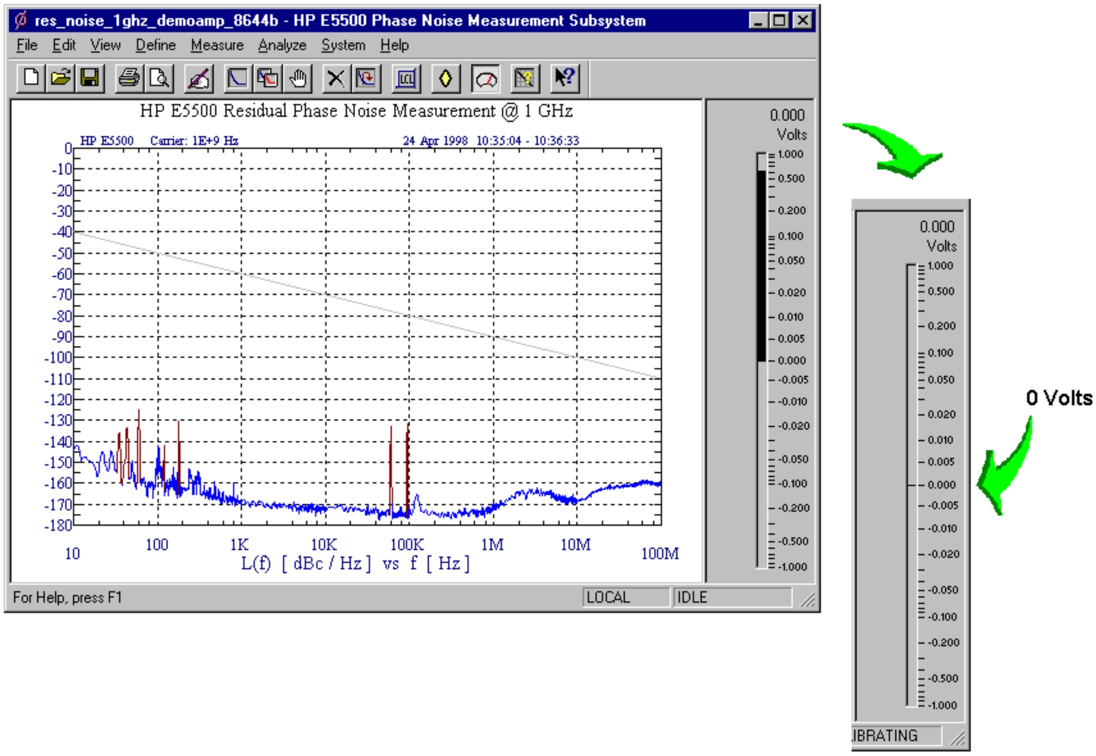

Figure 9-14 Adjust Phase Shifter until Meter Indicates 0 Volts

5 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 15, "Evaluating Your Measurement Results" for help in evaluating your measurement results.

Figure 9-15 shows a typical phase noise curve for an RF Amplifier.

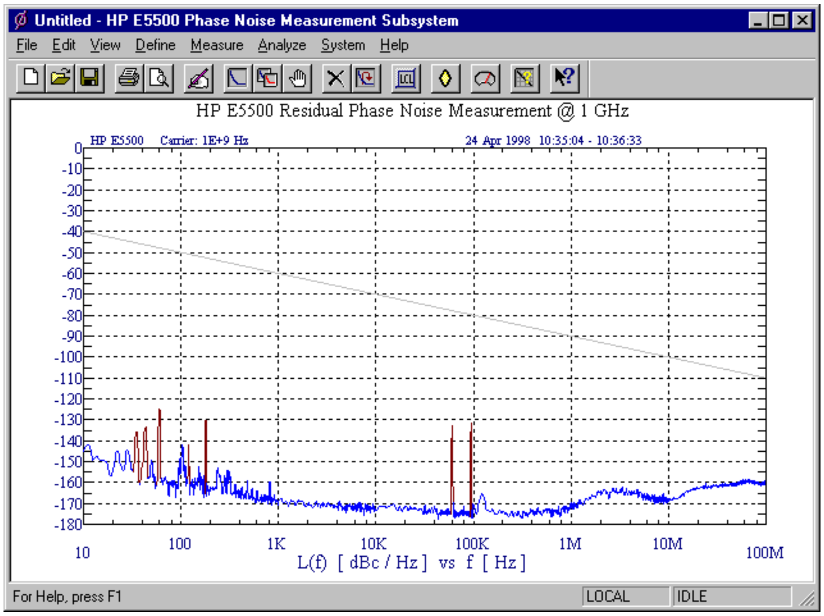

Figure 9-15 Typical Phase Noise Curve for a Residual Measurement

Table 9-4 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)
		• 10 Hz
	• Start Frequency	• 100 E + 6 Hz
	• Stop Frequency	• 4
	• Minimum Number of Averages	• Normal
	FFT Quality	• Fast
	Swept Quality	
2	**Sources Tab**	
	Carrier Source	
	• Frequency	• 1 E + 9 Hz
	• Power	• 10 dBm
	Detector Input	
	• Frequency	• 1 E + 9 Hz

Table 9-4 Parameter Data for the Amplifier Measurement Example

Step	Parameters	Data
3	**Cal Tab** • Phase Detector Constant • Current Phase Detector Constant • Know Spur Parameters • Amplitude • Offset Frequency	 • Derive detector constant from measured +/- DC peak • 410.8 E-3 • 0 dBc • 0 Hz
4	**Block Diagram Tab** • Carrier Source • Phase Shifter • DUT in Path • Phase Detector • Adjust the Quadrature by adjusting the	 • Manual • Manual • checked • Automatic Detector Selection • phase shifter
5	**Test Set Tab** Input Attenuation LNA Low Pass Filter • LNA Gain • DC Block • PLL Integrator Attenuation	 • 0 dB • 20 MHz (Auto checked) • Auto Gain (Minimum Auto Gain - 14 dB) • Not checked • 0 dBm
6	**Dowconverter Tab**	The downconverter parameters do not apply to this measurement example.
7	**Graph Tab** • Title • Graph Type • X Scale Minimum • X Scale Maximum • Y Scale Minimum • Y Scale Maximum • Normalize trace data to a: • Scale trace data to a new carrier frequency of: • Shift trace data DOWN by: • Trace Smoothing Amount • Power present at input of DUT	 • E5500 Residual Phase Noise Measurement @ 1 GHz. • Single-sideband Noise (dBc/Hz) • 10 Hz • 100 E + 6 Hz • 0 dBc/Hz • - 180 dBc/Hz • 1 Hz bandwidth • 1 times the current carrier frequency • 0 dB • 0 • 0 dB

10

FM Discriminator Fundamentals

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 10-1.

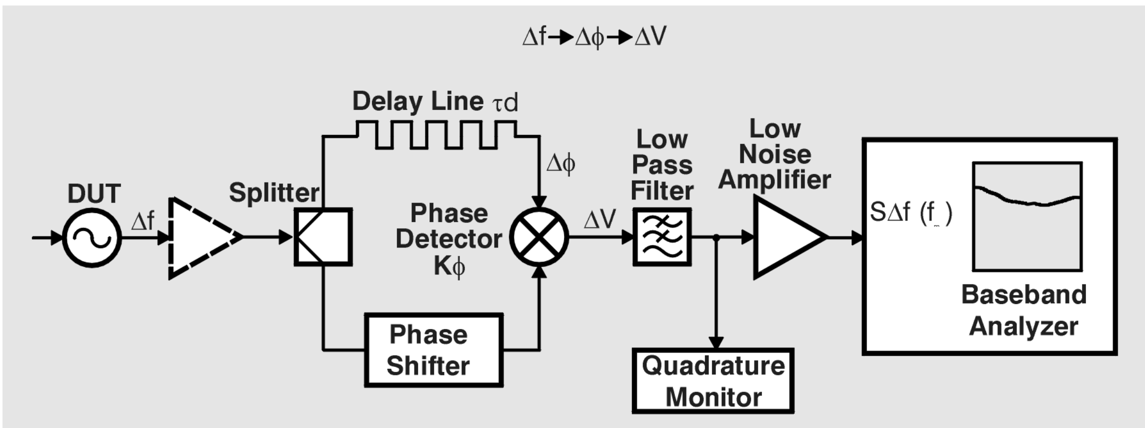

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Figure 10-1 Basic Delay Line/mixer Frequency Discriminator Method

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 Agilent E5500A/B Phase Noise Measurement System and common coaxial cable.

Basic Theory

The delay line implementation of the frequency discriminator (Figure 10-1) converts short-term frequency fluctuations of a source into voltage fluctuations that can be measured by a baseband analyzer. The coversion 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 ($\Delta\phi \rightarrow \Delta V$). 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 $\Delta V(f_m)$ represents the voltage fluctuations out of the discriminator and $\Delta f(fm)$ represents the frequency fluctuations of the device under test (DUT). K_ϕ 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 $K\phi$ 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 $\sin(\pi f_m \tau_d)/(\pi f_m \tau_d)$. This implies that the output response will have peaks and nulls, with the first null occurring at $f_m = 1/\tau_d$. Increasing the rate of a modulation signal applied to the system will cause nulls to appear at frequency multiples of $1/\tau_d$ (Figure 10-2).

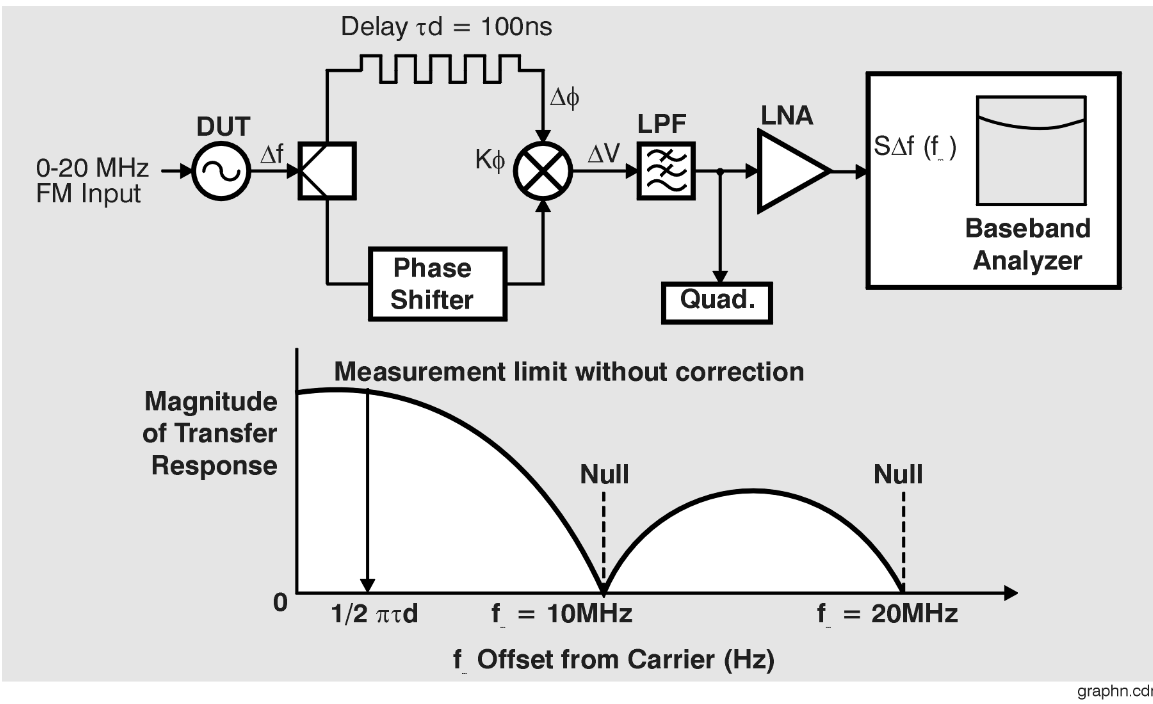


Figure 10-2 Nulls in Sensitivity of Delay Line Discriminator

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 τ_d increases the sensitivity of the system. However, increasing τ_d 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 τ_d, 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 KL is the mixer efficiency and VR is the voltage into the Signal Input port (R port) of the mixer. VR 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 $\Delta V(f_m) = K_d \Delta f(f_m) = K_\phi \pi \tau_d \Delta f(f_m)$

where K_d is the discriminator constant.

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.

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**. 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

$$LZ = 8.7 \text{ dB of attenuation}$$

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 10-1.

Table 10-1 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:

$$\tau_d < \frac{1}{2\pi \times 5 \times 10^6}$$

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.

11

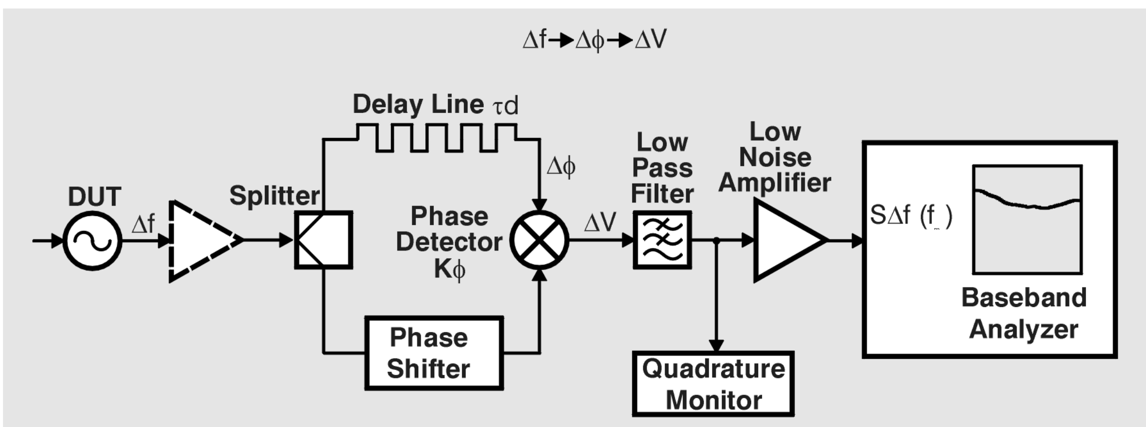
FM Discriminator Measurement Examples

Introduction

These two measurement examples demostrates 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.



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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 decorated 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 10, "FM Discriminator Fundamentals".

FM Discriminator Measurement using Double-Sided Spur Calibration

CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator (Agilent 70420A Option 001) has been correctly set for the desired configuration, as show in Table 11-2. Apply the input signal when the connection diagram appears.

Required Equipment

Table 11-1 shows equipment required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 11-1 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 11-1 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 Agilent 70420A test set Signal and Reference inputs requires +15 ICBM.

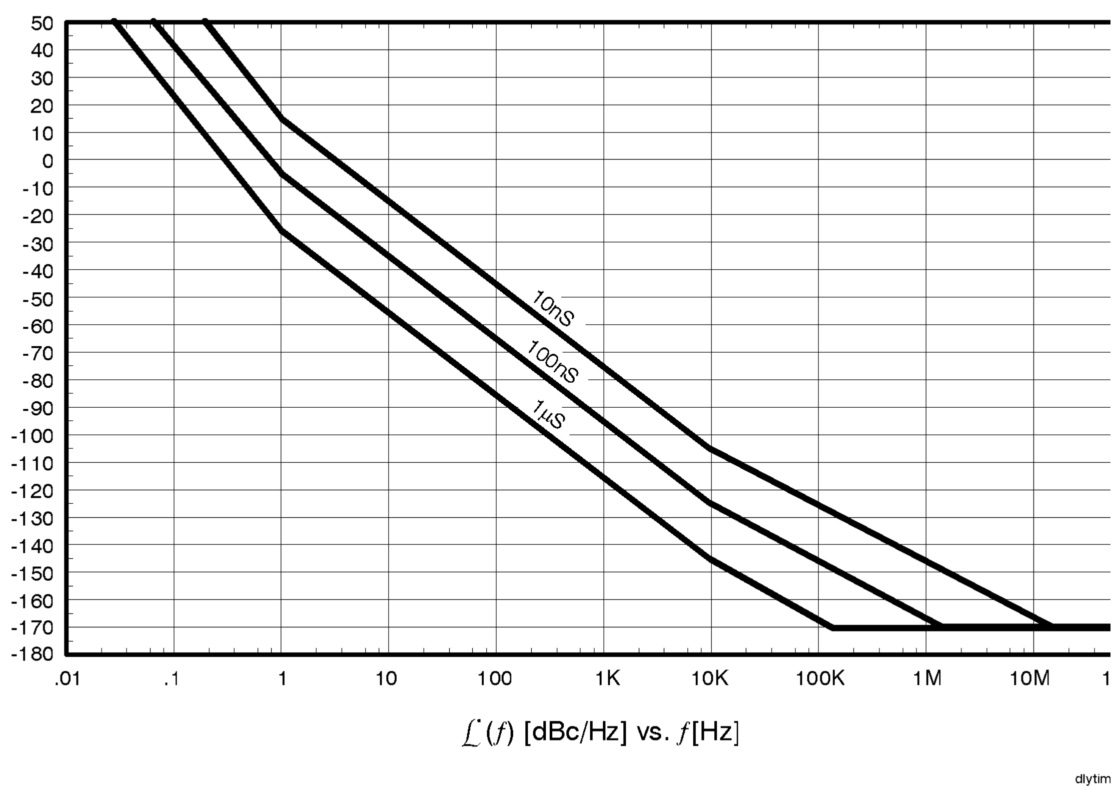

Figure 11-1 Discriminator Noise Floor as a Function of Delay Time

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 11-2.

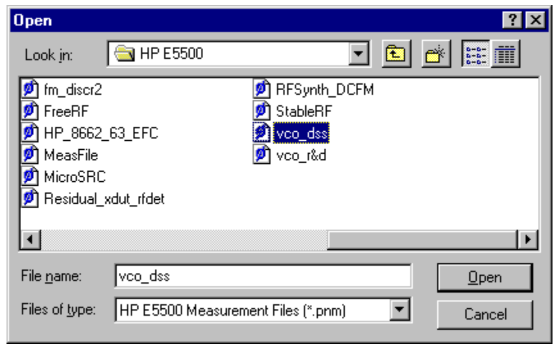

Figure 11-2 Select the Parameters Definition File

4 Click the Open button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 11-3 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 11-3 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).

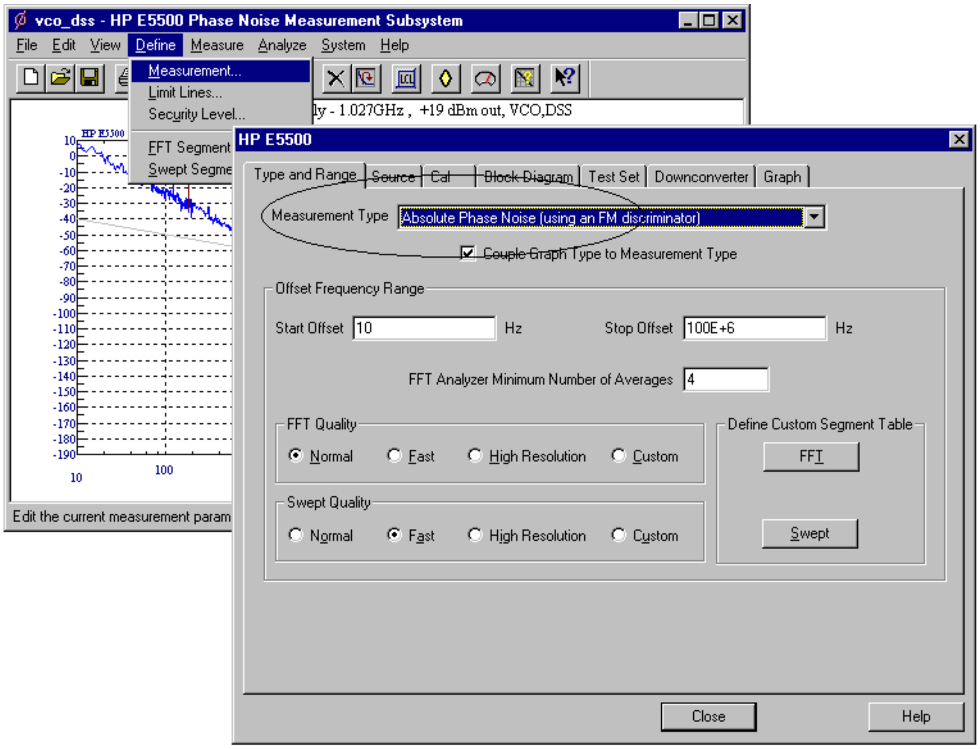

Figure 11-3 Select Measurement Type

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

a Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 Gaze). Enter the same frequency for the detector input frequency. See Figure 11-4.

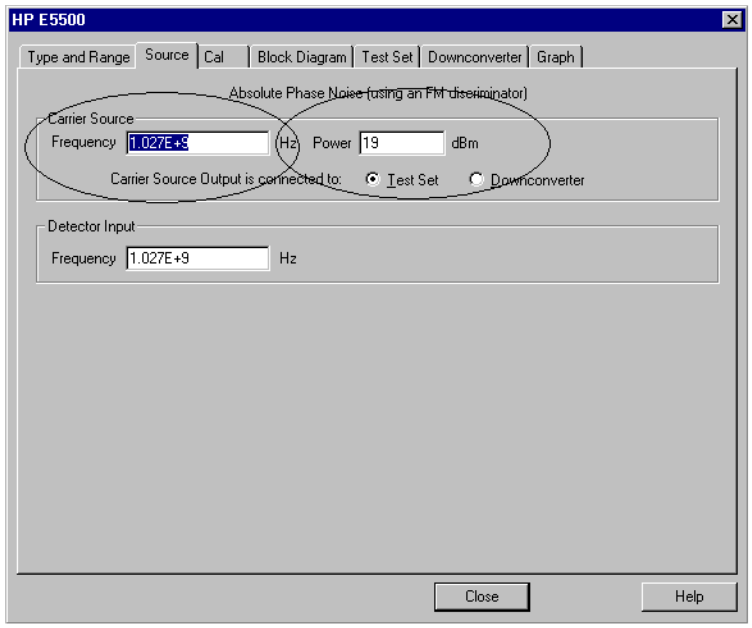

Figure 11-4 Enter Frequencies in Source Tab

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

a Select **Derive constant from double-sided spur** as the calibration method.

Take a modulated calibration source and feed the output into a spectrum analyzer. Measure the 1st modulation sideband frequency and power relative to the carrier's frequency and power. Enter the parameters into the following step.

b 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 11-5.

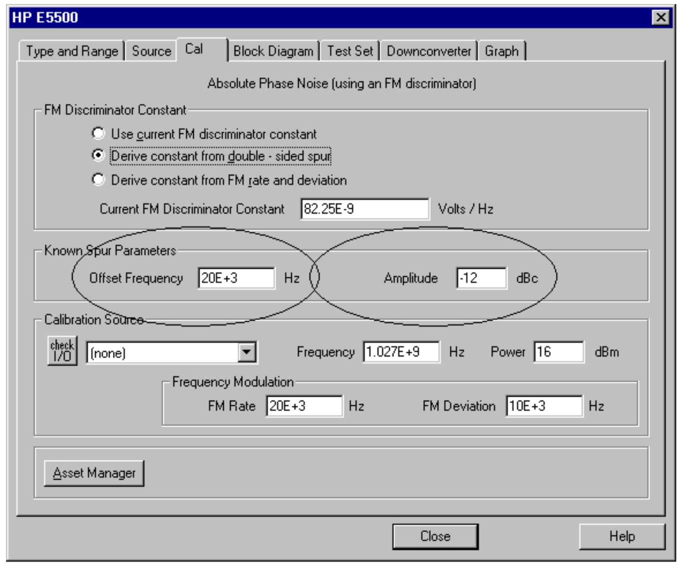

Figure 11-5 Enter Parameters into the Call Tab

8 Choose the **Block Diagram** tab from the **Define Measurement** window.

a From the **Reference Source** pull-down, select **Manual**.

a From the **Phase Detector** pull-down, select **Automatic Detector Selection**. See Figure 11-6.

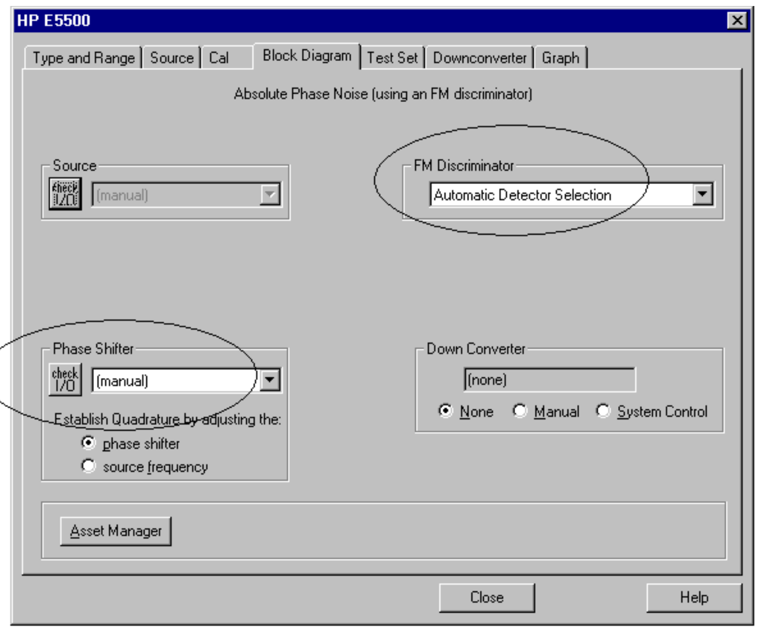

Figure 11-6 Select Parameters in the Block Diagram Tab

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

10 Enter a graph description of your choice. See Figure 11-7

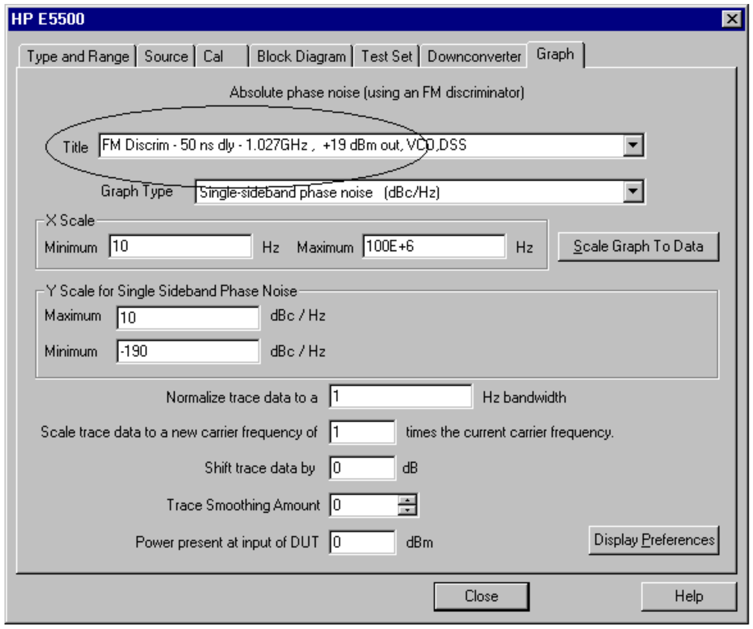

Figure 11-7 Select Graph Description on Graph Tab

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

1 From the **View** menu, choose **Meter** to select the quadrature meter. See Figure 11-8.

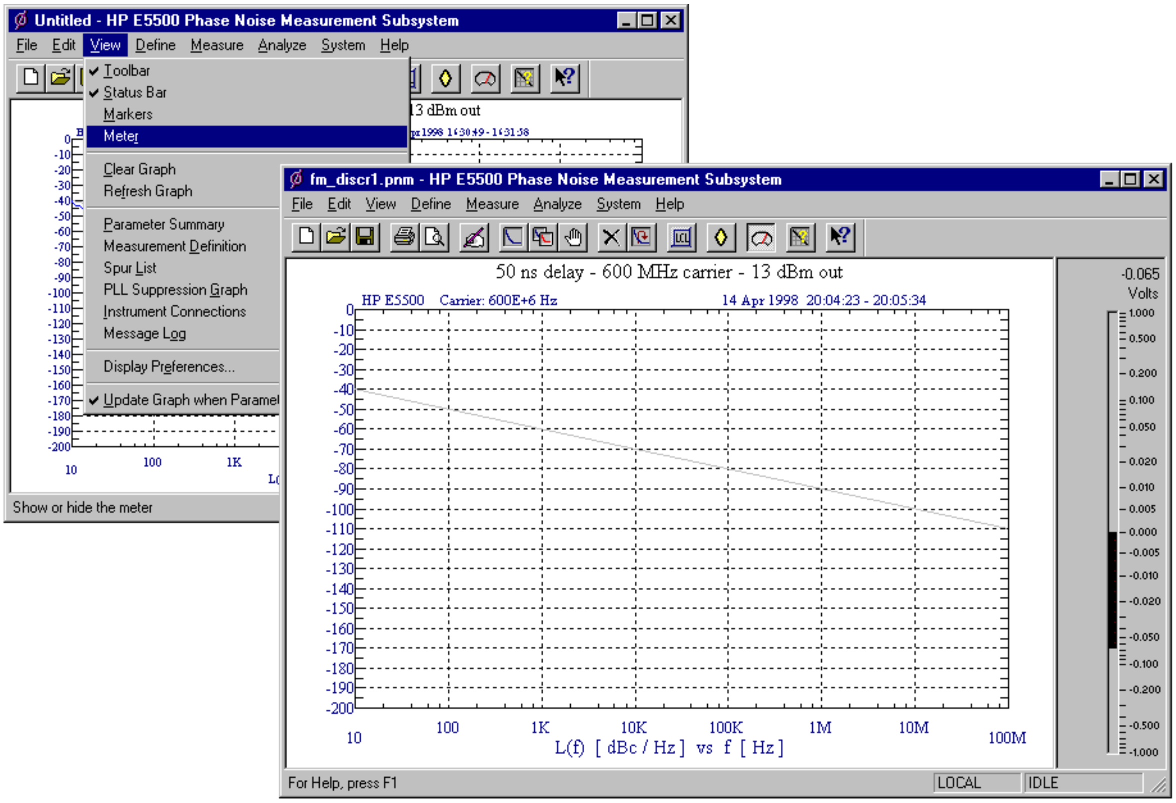

Figure 11-8 Select Meter from View Menu

2 From the **Measurement** menu, choose **New Measurement.** See Figure 11-9**.**

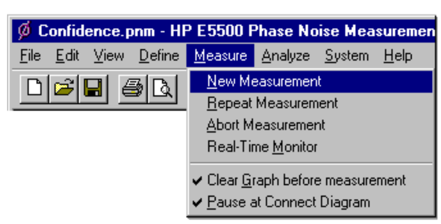

Figure 11-9 Selecting a New Measurement

3 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

4 When the **Connect Diagram** dialog box appears, confirm your connections as shown in the connect diagram. See Figure 11-10. The Agilent 70420A test set's signal input is subject to the limits and characteristics shown in Table 11-2:

Table 11-2 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

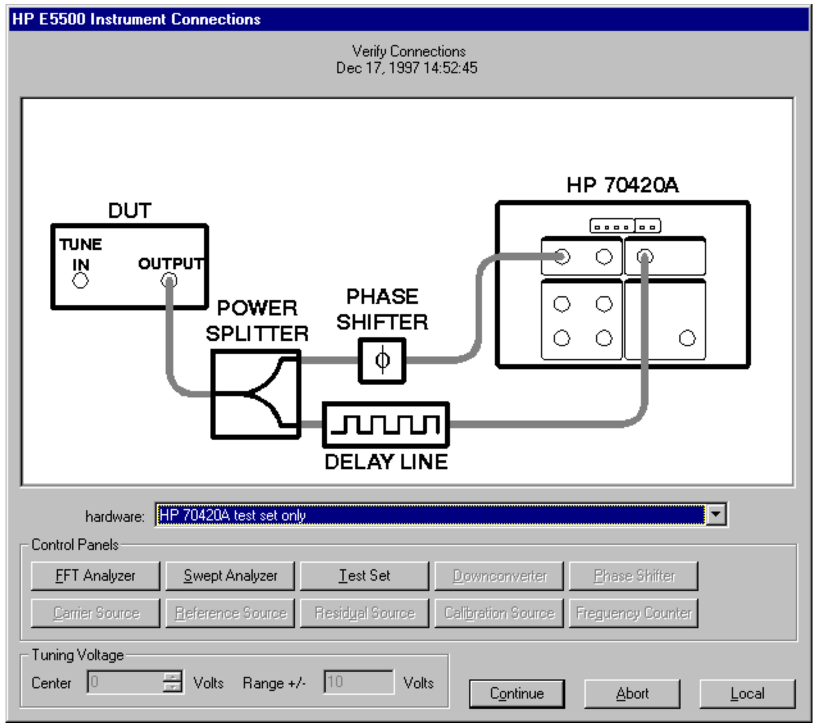

Figure 11-10 Setup Diagram for the FM Discrimination Measurement Example

5 Refer to Figure 11-11 for more information about system interconnections:.

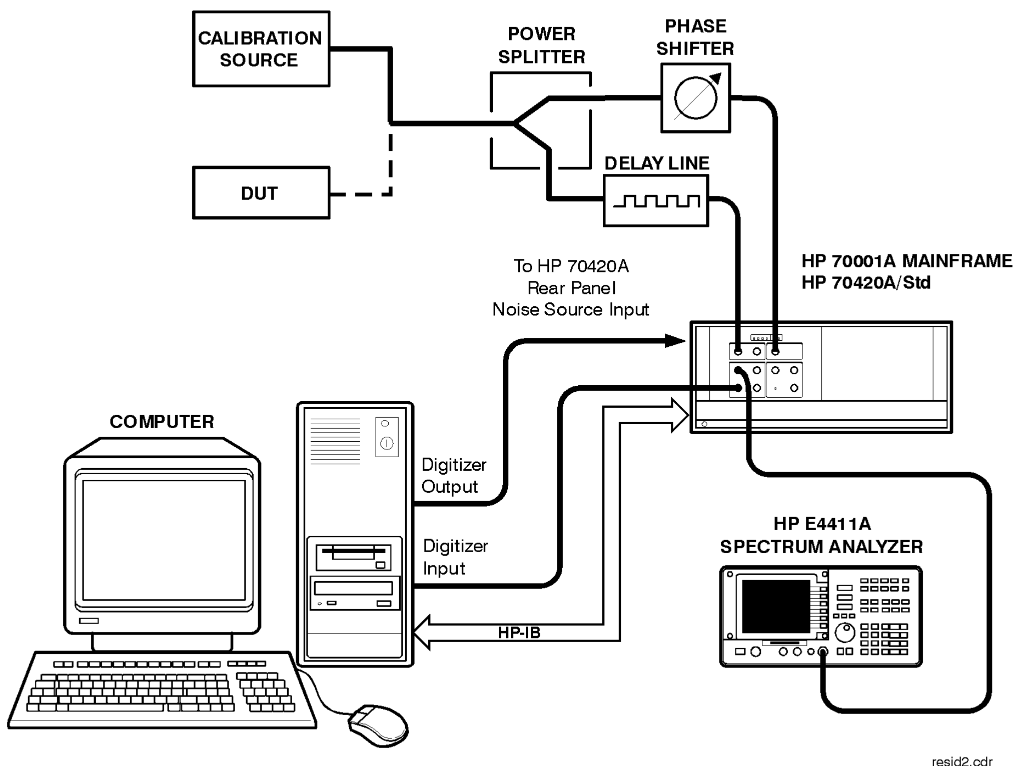

Figure 11-11 Connect Diagram Example

Making the Measurement

1 Press the **Continue** key 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 11-12 through Figure 11-16.

NOTE: Note that the system must be operating in quadrature during calibration.

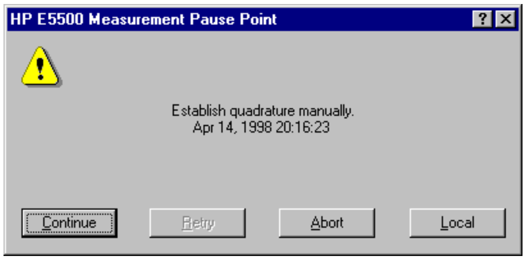

Figure 11-12

2 First establish quadrature by adjusting the phase shifter until the meter indicates 0 volts, then press Continue.

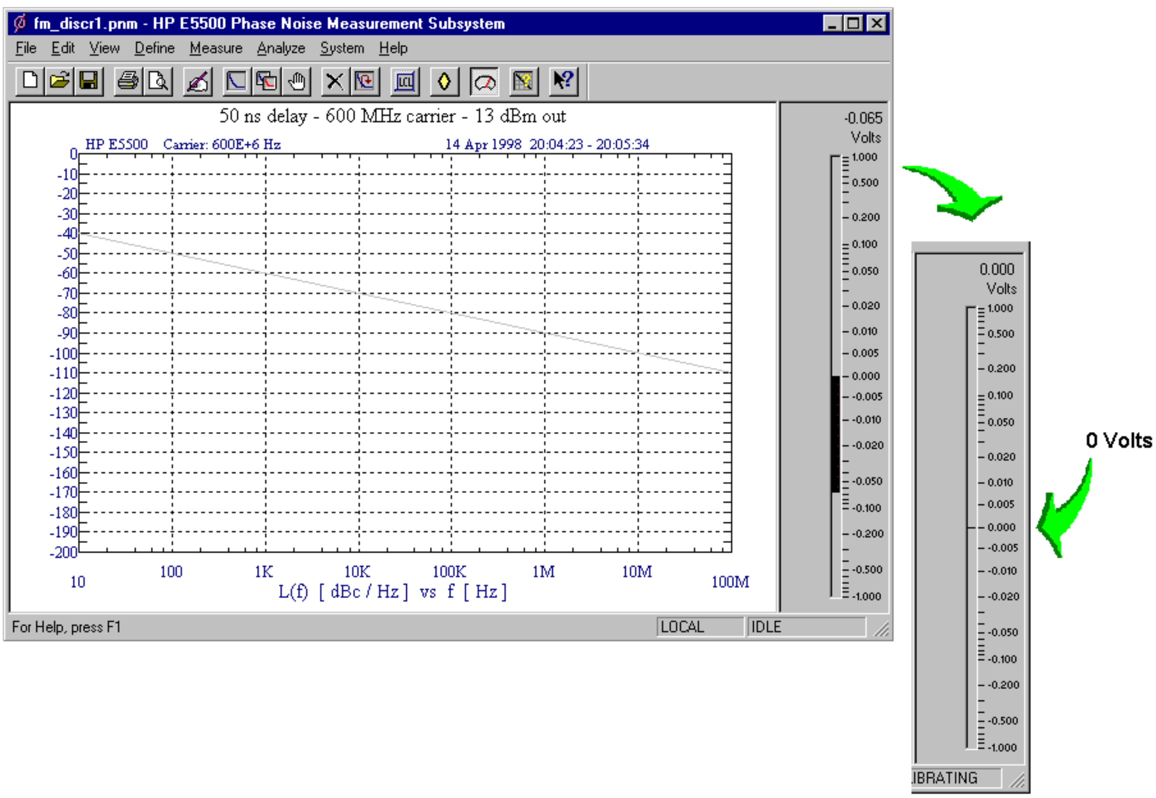

Figure 11-13

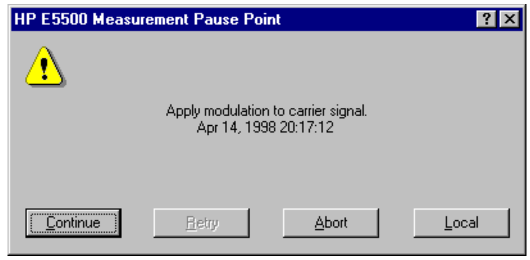

Figure 11-14

3 Next, apply modulation to the carrier signal, then press **Continue**.

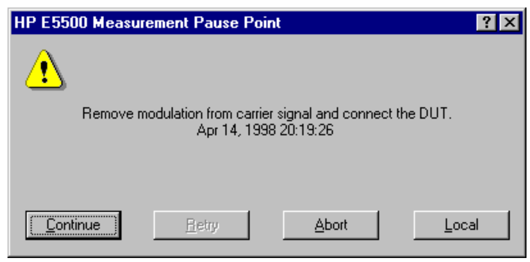

Figure 11-15

Remove the modulation from the carrier and connect your DUT.

4 The system can now run the measurement. at the appropriate point, re-establish quadrature and continue the measurement.

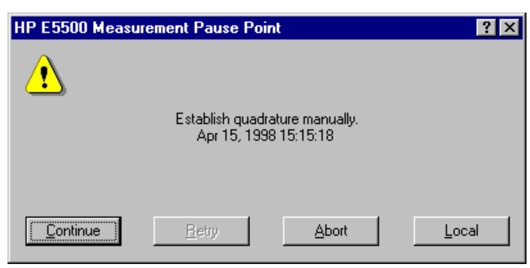

Figure 11-16

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 15, “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 11-17 shows a typical absolute measurement using FM discrimination.

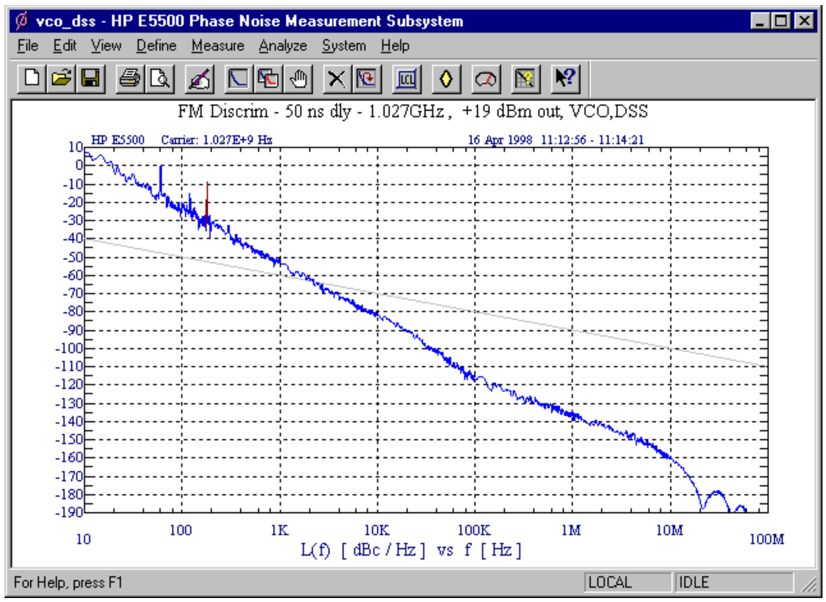

Figure 11-17 Typical Phase Noise Curve using Double-Sided Spur Calibration.

Table 11-3 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
	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	
	• Frequency	• 1.027 E + 9 Hz
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 11-3 Parameter Data for the Double-Sided Spur Calibration Example

Step	Parameters	Data
6	**Dowconverter 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 Agilent 70420A test set's hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator (Agilent 70420A Option 001) has been correctly set for the desired configuration, as show in Table 11-5. 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 11-4 shows equipment is required for this example in addition the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 11-4 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

Table 11-4 Required Equipment for the FM Discriminator Measurement Example

Equipment	Quantity	Comments
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 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 Agilent 70420A test set Signal and Reference inputs requires +15 ICBM.

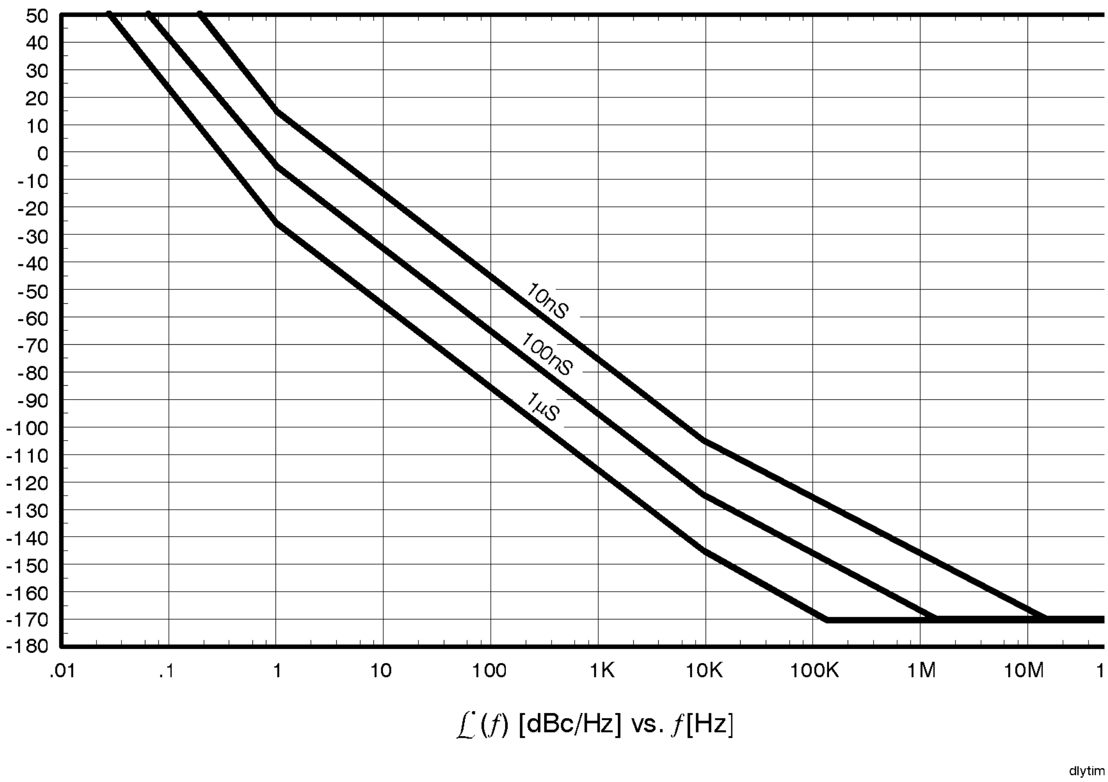

Figure 11-18 Discriminator Noise Floor as a Function of Delay Time

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 11-19.

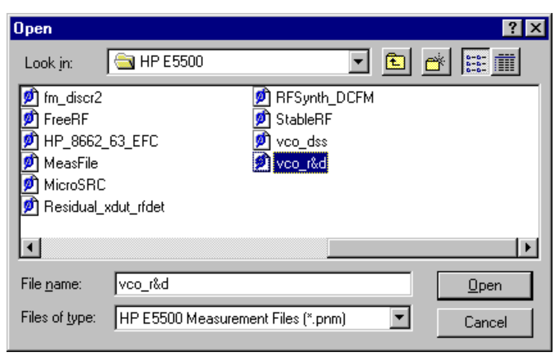

Figure 11-19 Select the Parameters Definition File

4 Click the **Open** button.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 11-6 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 11-20.

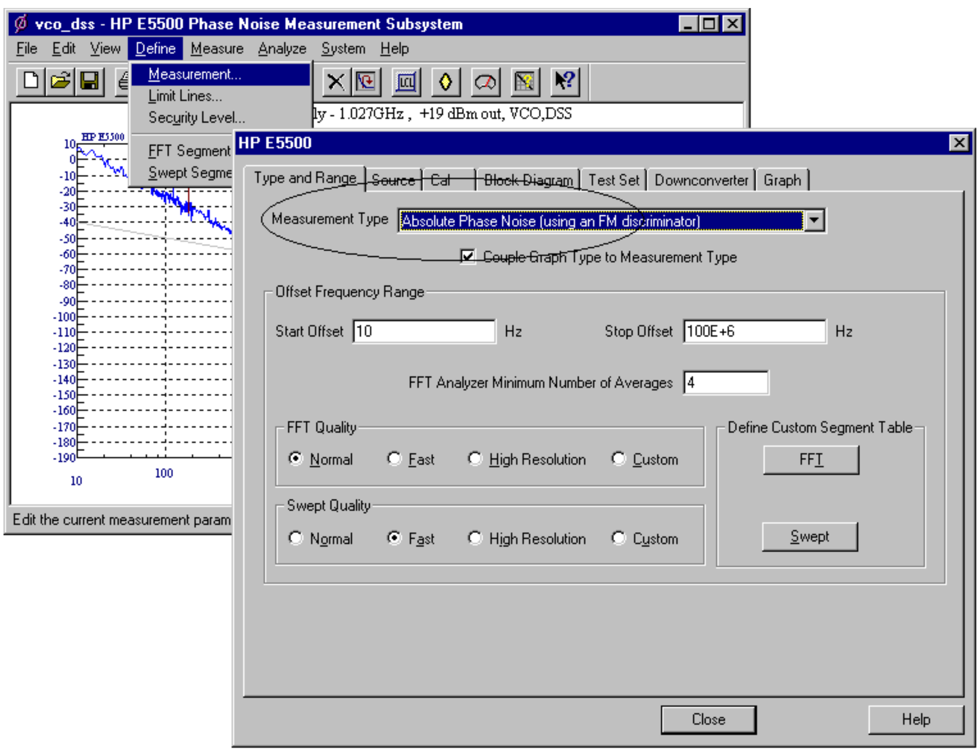

Figure 11-20 Select Measurement Type

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

a Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 Gaze). Enter the same frequency for the detector input frequency. See Figure 11-21.

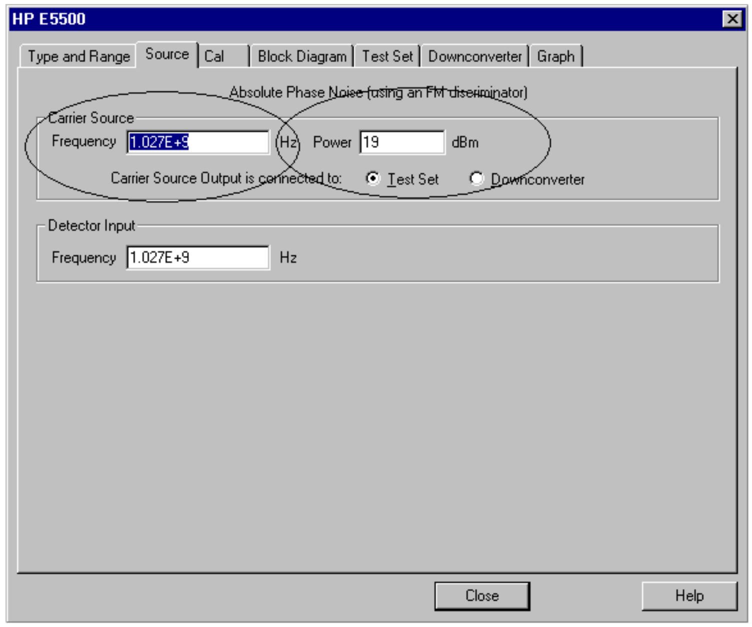

Figure 11-21 Enter Frequencies into Source Tab

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 11-22.

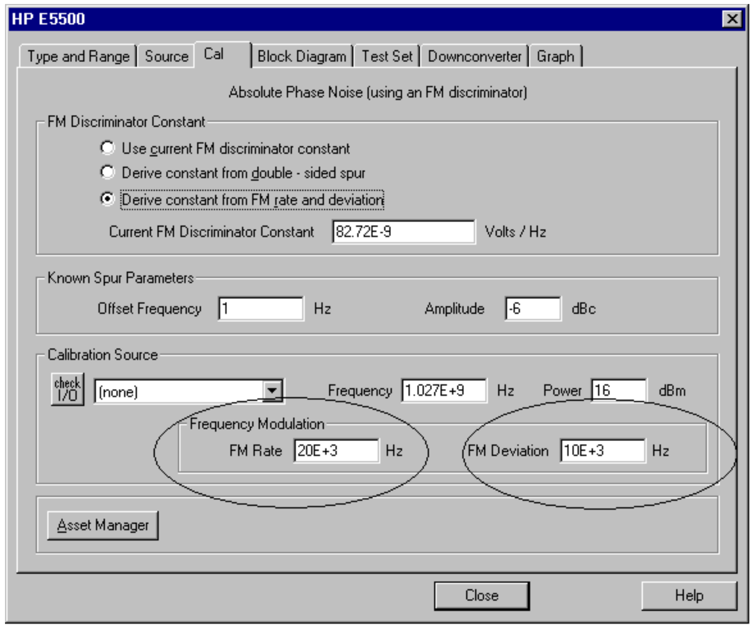

Figure 11-22 Enter Parameters into the Cal Tab

11 Choose the **Block Diagram** tab from the **Define Measurement** window. See Figure 11-23.

a From the **Reference Source** pull-down, select Manual.

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

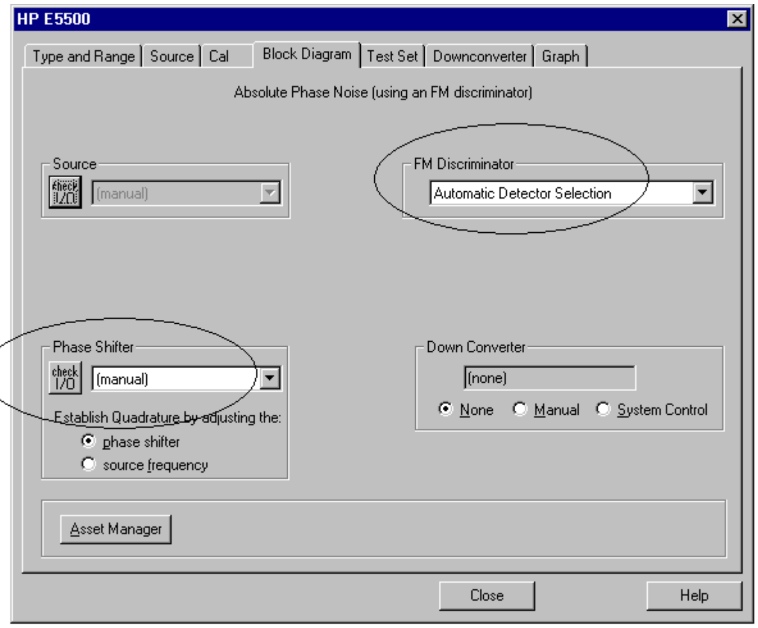

Figure 11-23 Enter Parameters in the Block Diagram Tab

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

13 Enter a graph description of your choice. See Figure 11-24.

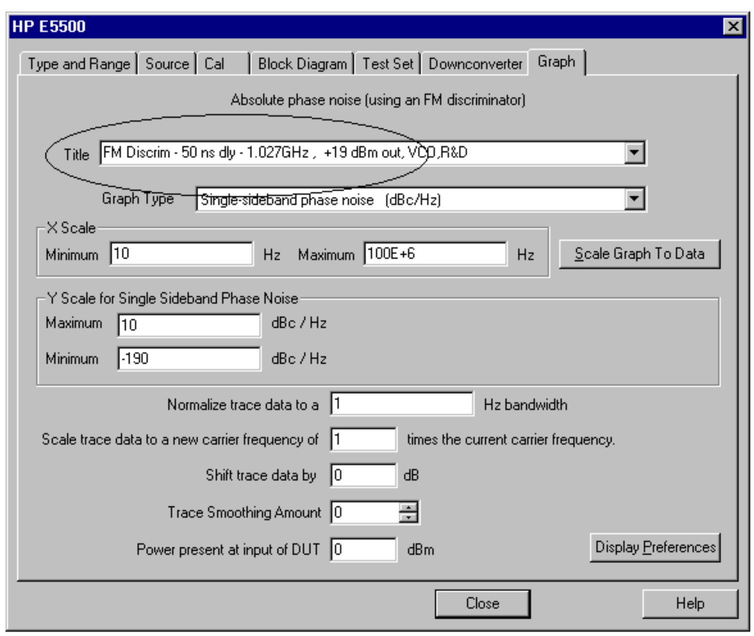

Figure 11-24 Select Graph Description on Graph Tab

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 11-25

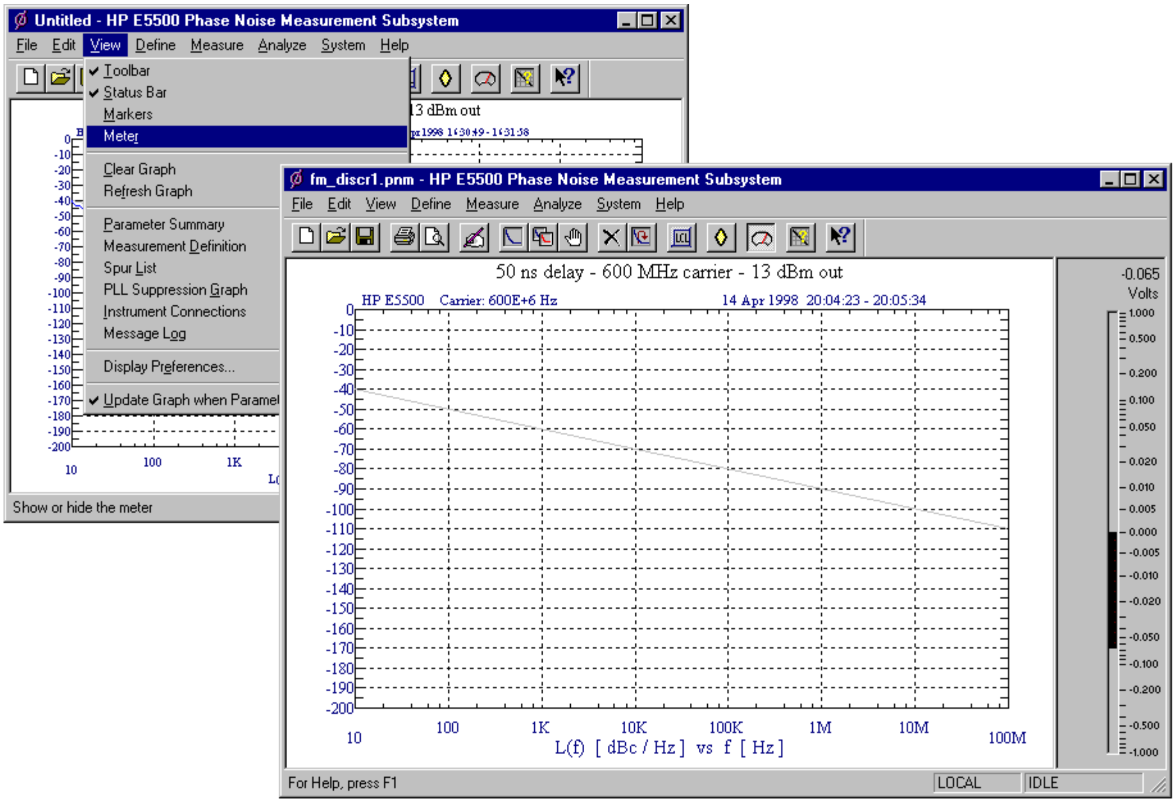

Figure 11-25 Select Meter from the View Menu

2 From the **Measurement** menu, choose **New Measurement.** See Figure 11-26.

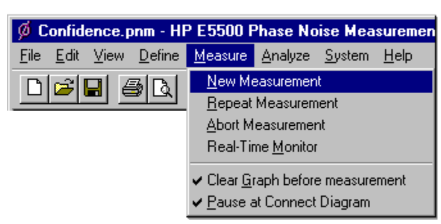

Figure 11-26 Selecting a New Measurement

3 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

4 When the **Connect Diagram** dialog box appears, confirm your connections as shown in Figure 11-27. The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 11-5 Agilent 70420A 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 70422A	0 to +30 dBm
Agilent 70427A	+5 to +15 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

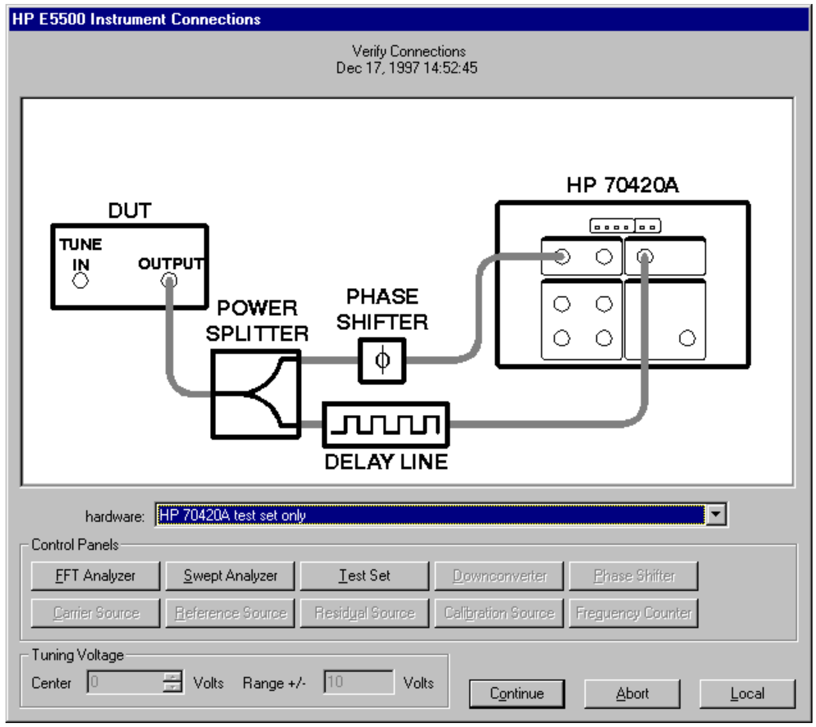

Figure 11-27 Setup Diagram for the FM Discrimination Measurement Example

5 Refer to Figure 11-28 for more information about system interconnections.

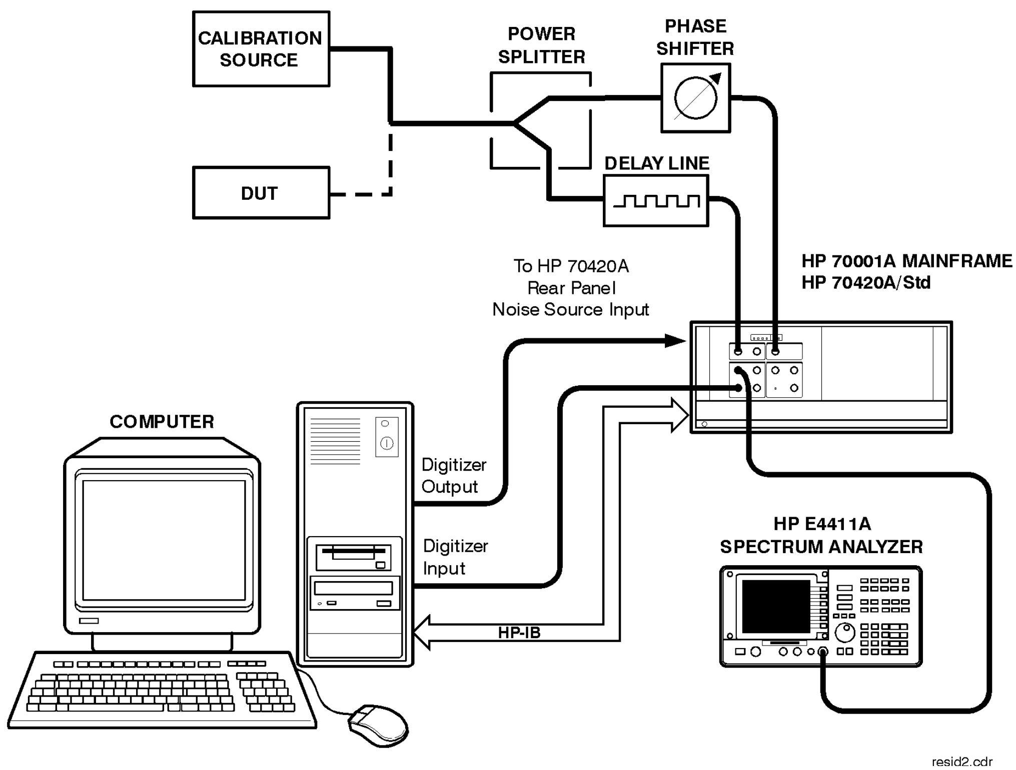

Figure 11-28 System Connect Diagram Example

Making the Measurement

1 Press the **Continue** key 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 11-29 through Figure 11-33.

NOTE: Note that the system must be operating in quadrature during calibration.

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2 First establish quadrature by adjusting the phase shifter until the meter indicates 0 volts, then press Continue. F

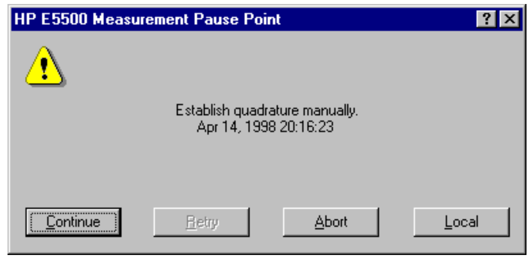

Figure 11-29

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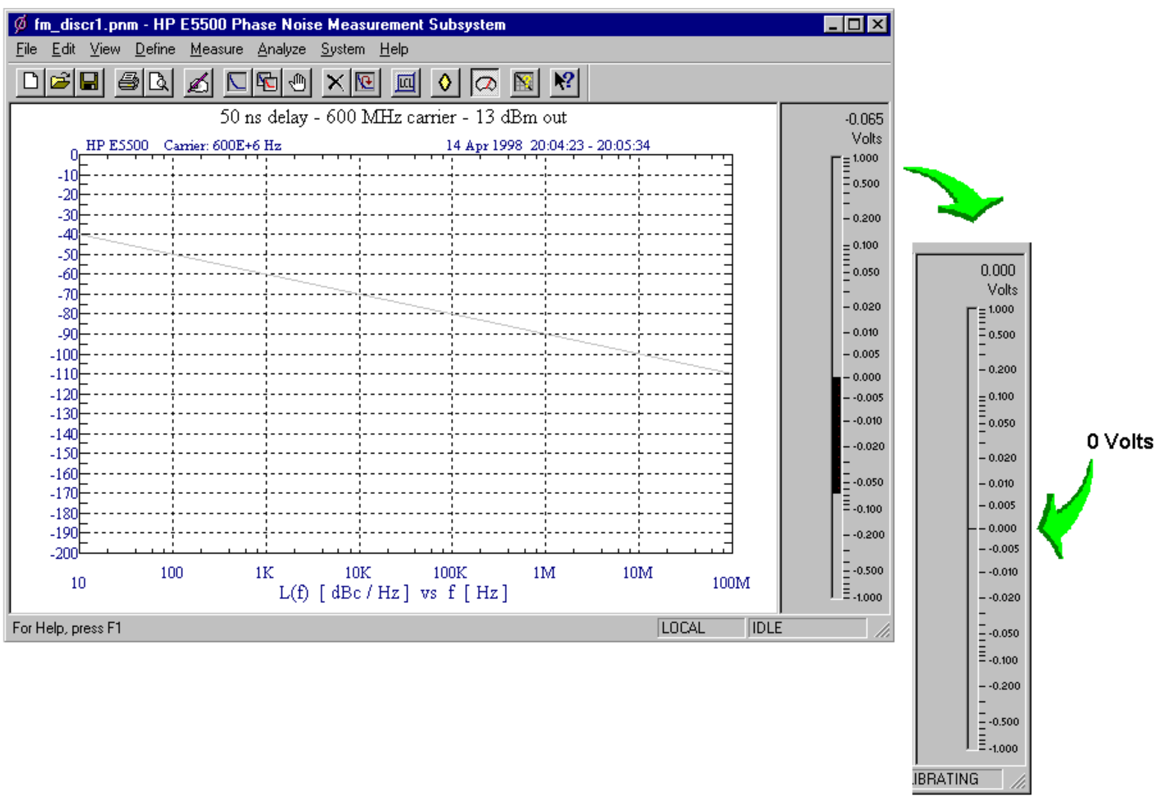


Figure 11-30

3 Next, apply modulation to the carrier signal, then press **Continue**.

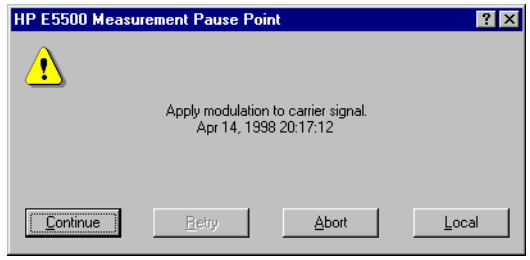


Figure 11-31

4 Remove the modulation from the carrier and connect your DUT.

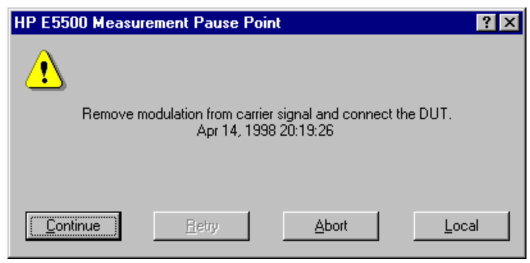


Figure 11-32

5 The system can now run the measurement. at the appropriate point, re-establish quadrature and continue the measurement.

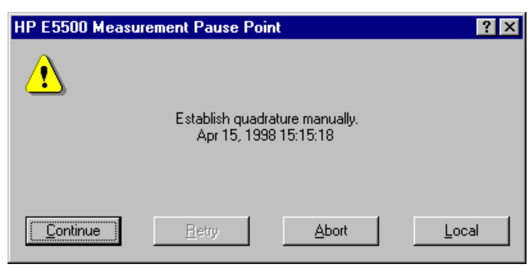


Figure 11-33

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 15, “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 11-34 shows a typical absolute measurement using FM discrimination.

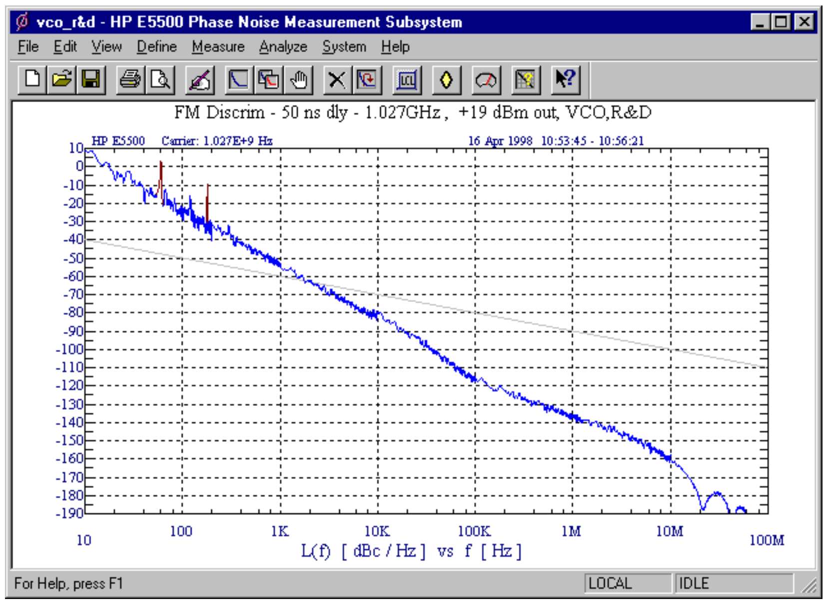


Figure 11-34 Typical Phase Noise Curve Using Rate and Deviation Calibration

Table 11-6 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	
	• Frequency	• 1.027 E + 9 Hz
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.

Table 11-6 Parameter Data for the Rate and Deviation Calibration Example

Step	Parameters	Data
6	**Dowconverter Tab**	The downconverter parameters do not apply to this measurement example.
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:	• 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

12

AM Noise Measurement Fundamentals

AM-Noise Measurement Theory of Operation

Basic Noise Measurement

The Agilent 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

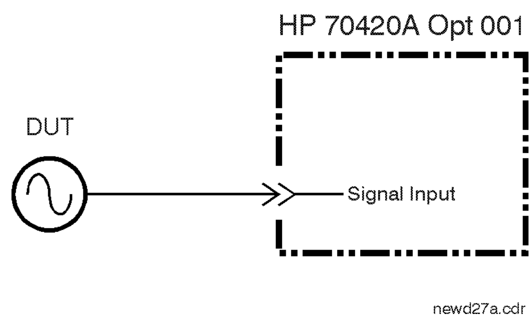


Figure 12-1 AM Noise System Block Diagram using an E5500 Opt 001

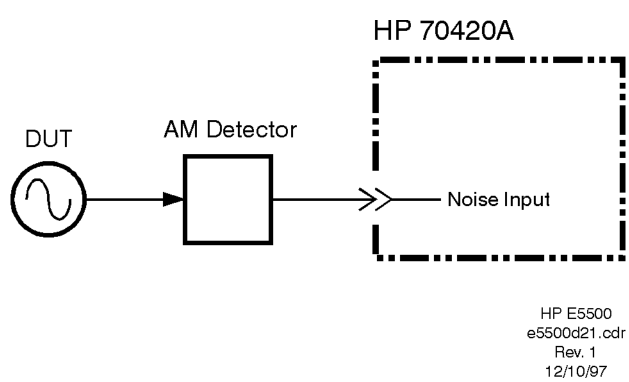


Figure 12-2 AM Noise System Block Diagram using an External Detector

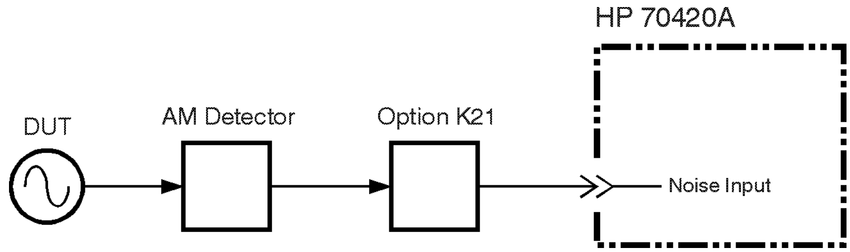


Figure 12-3 AM Noise System Block Diagram using an Agilent 70429A Opt K21

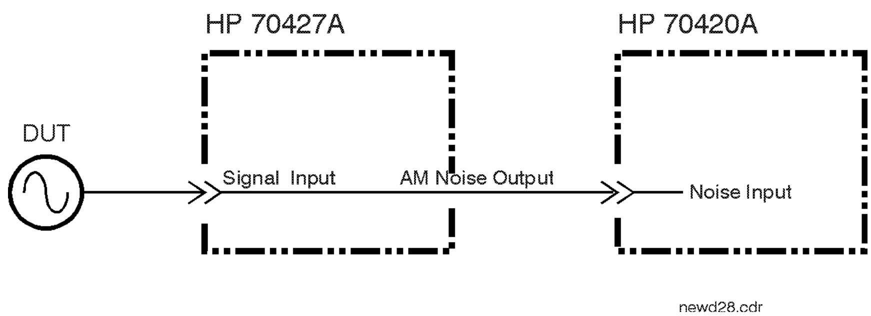


Figure 12-4 AM Noise System Block Diagram using an Agilent 70427A Downconverter

AM Detector

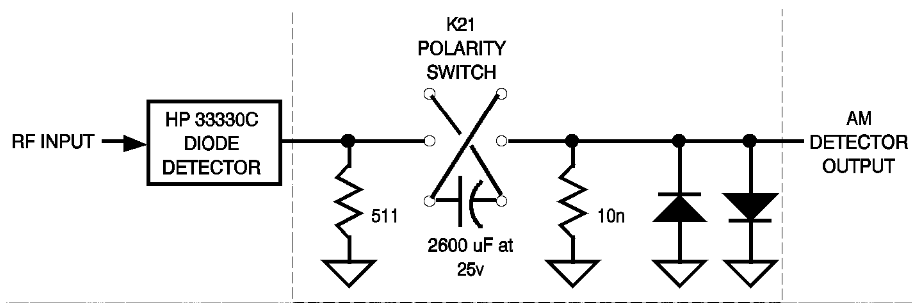


Figure 12-5 AM Detector Schematic

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

- 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 Agilent 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 Agilent 70429A Option K21, 70420A Option 001, or 70427A 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 12-1 shows carrier frequencies with corresponding offset frequencies.

Table 12-1 Maximum Carrier Offset Frequency

Carrier Frequency	Offset Frequency
≥250 kHz	100 MHz
≥50 MHz	20 MHz
≥5 MHz	2 MHz
≥500 kHz	200 kHz
≥50 kHz	20 kHz

- The ac load on the detector is 50 ohms, 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.
- The Agilent 70420A 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 Agilent 70429A Option K21 is

designed specifically for this purpose or the internal DC blocking filter in either the Agilent 70420A or Agilent 70427A may be used.

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 Agilent 70420A Option 001 and Agilent 70427A, along with the Agilent 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 12-6 and Figure 12-7, Connect the circuit and tighten all connections. If the Agilent 70420A Option 001 or Agilent 70427A is available, use one of the connection diagrams described in "AM Noise Measurement Block Diagrams" on page 12-3.

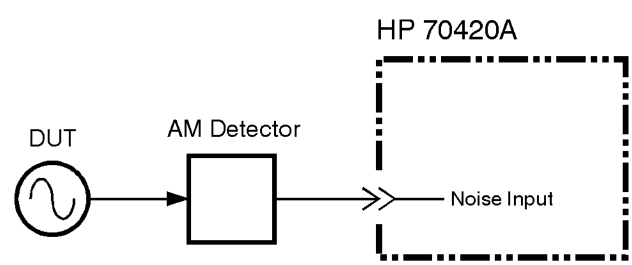


Figure 12-6 User Entry of Phase Detector Constant AM Noise Measurement Setup Method 1, Example 1

2 Measure the power which will be applied to the AM detector (see Figure 12-7). It must be between 0 and +23 dBm.

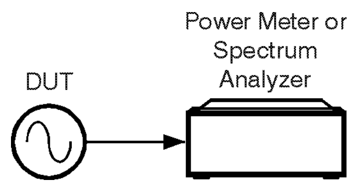


Figure 12-7 AM Noise Calibration Setup

3 Locate the drive level on the AM sensitivity graph (Figure 12-8), 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.

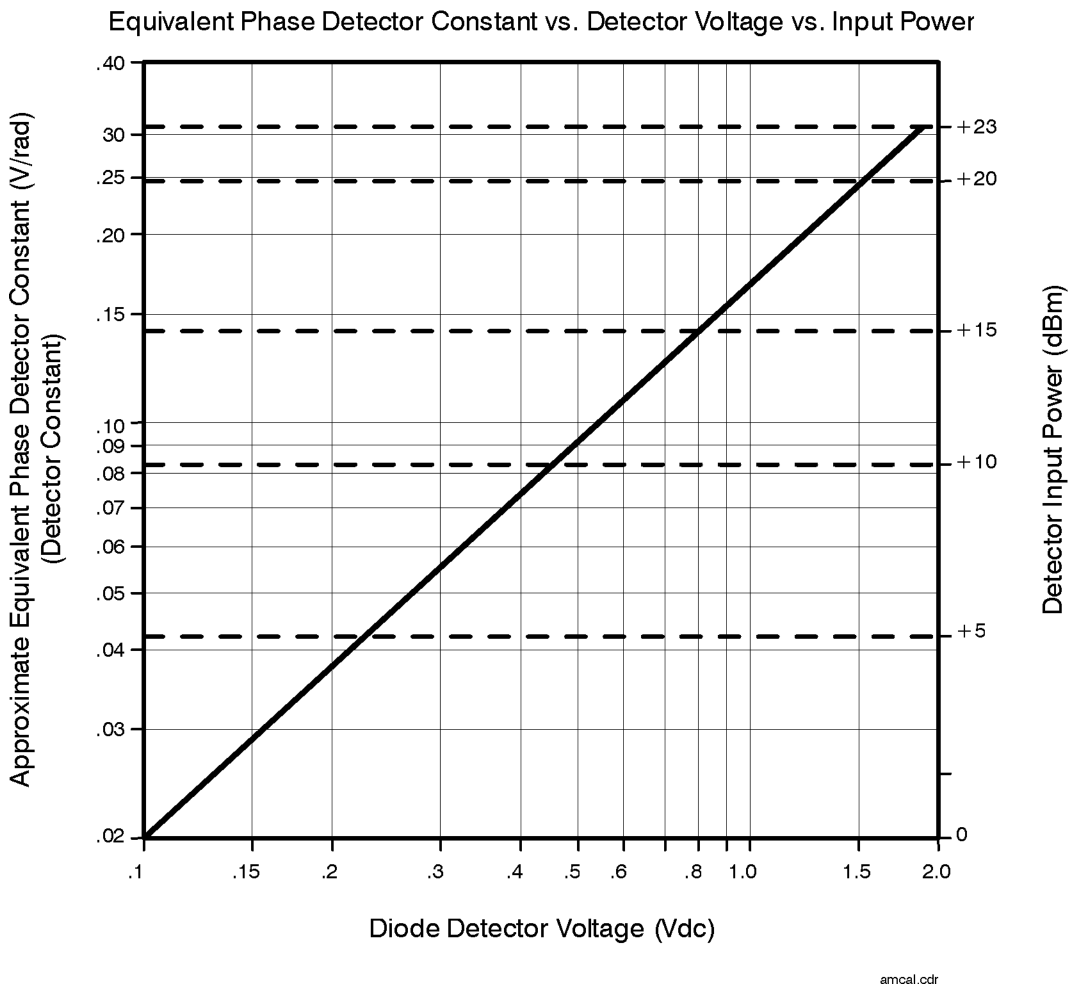


Figure 12-8 AM Detector Sensitivity Graph

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 12-9 and Figure 12-10, connect circuit and tighten all connections. If the Agilent 70420A Option 001 or Agilent 70427A is available, use one of the connection diagrams described in "AM Noise Measurement Block Diagrams" on page 12-3.

2 Measure the power which will be applied to the AM detector. It must be between 0 and +23 dBm.

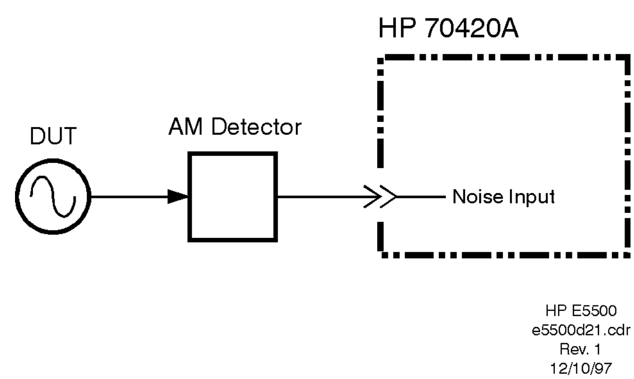


Figure 12-9 User Entry of Phase Detector Constant AM Noise Measurement Setup Method 1, Example 2

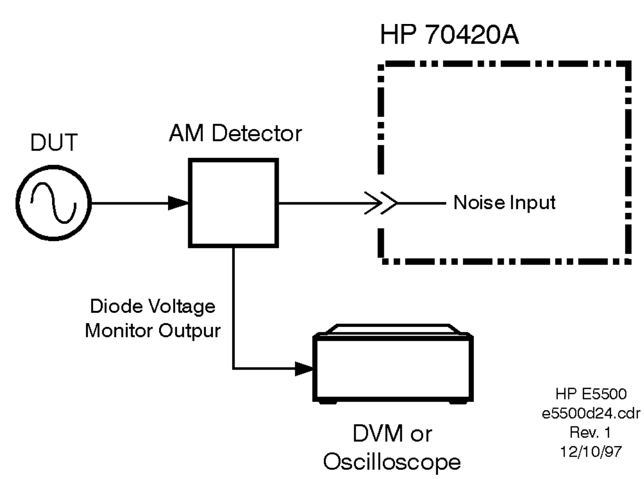


Figure 12-10 Modulation Sideband Calibration Setup

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 12-8). 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 12-11, and tighten all connections. If the Agilent 70420A Option 001 or Agilent 70427A is available, use one of the connection diagrams described in “AM Noise Measurement Block Diagrams” on page 12-3.

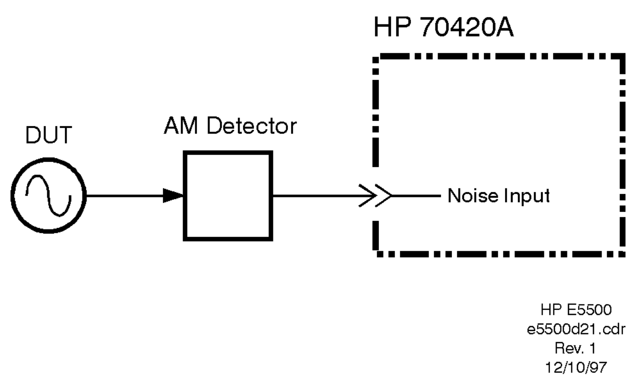


Figure 12-11 Double-sided Spur AM Noise Measurement Setup Method 1, Example 1

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 12-12). 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:

$$\frac{C}{sb} = 20\log\left(\frac{percentAM}{100}\right) = 6dB$$

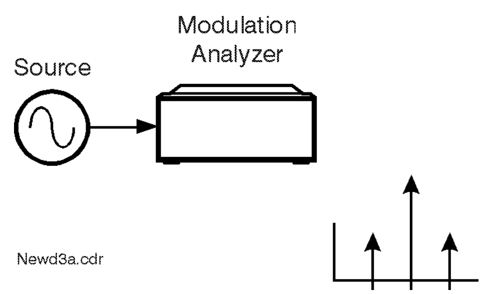


Figure 12-12 Measuring the Carrier-to-Sideband Ratio

4 Reconnect the AM detector and enter the carrier-to-sideband ratio and modulation frequency.

5 Measure the AM detector calibration constant (Figure 12-13).

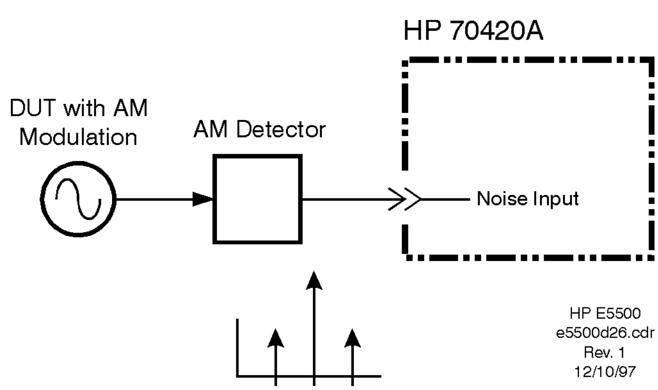


Figure 12-13 Measuring the Calibration Constant

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 12-14, and tighten all connections. If the Agilent 70420A Option 001 or Agilent 70427A is available, use one of the connection diagrams described in "AM Noise Measurement Block Diagrams" on page 12-3.

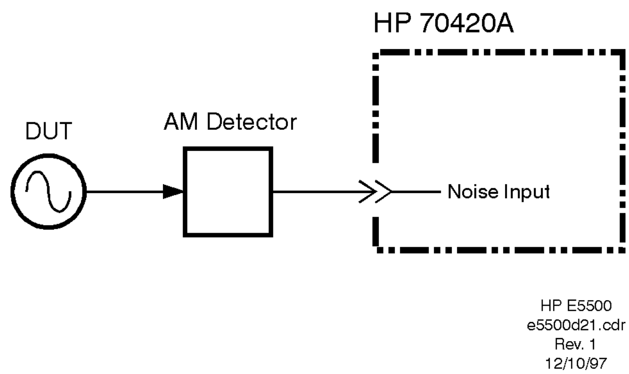


Figure 12-14 Double-sided Spur AM Noise Measurement Setup Method 1, Example 2

2 Measure the power which will be applied to the AM detector (Figure 12-15). It must be between 0 and +23 dBm.

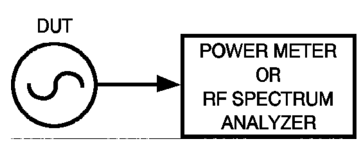


Figure 12-15 Measuring Power at the AM Detector

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 12-16.

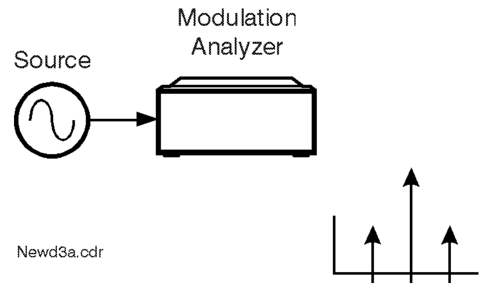


Figure 12-16 Measuring Carrier-to-Sideband Ratio

4 Enter the carrier-to-sideband ratio and offset frequency, then measure the calibration constant. See Figure 12-17.

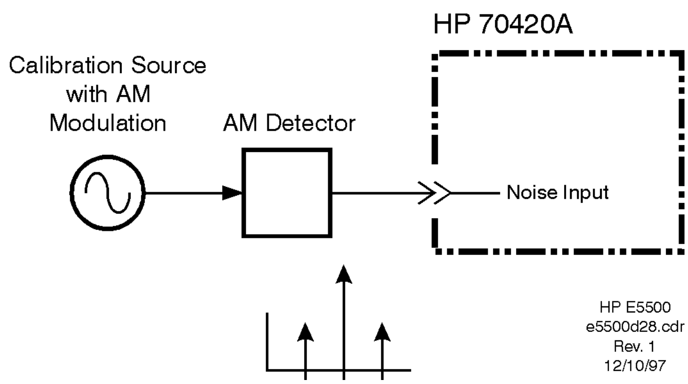


Figure 12-17 Measuring the Calibration Constant

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 12-18, and tighten all connections. If the Agilent 70420A Option 001 or Agilent 70427A is available, use one of the connection diagrams described in “AM Noise Measurement Block Diagrams” on page 12-3.

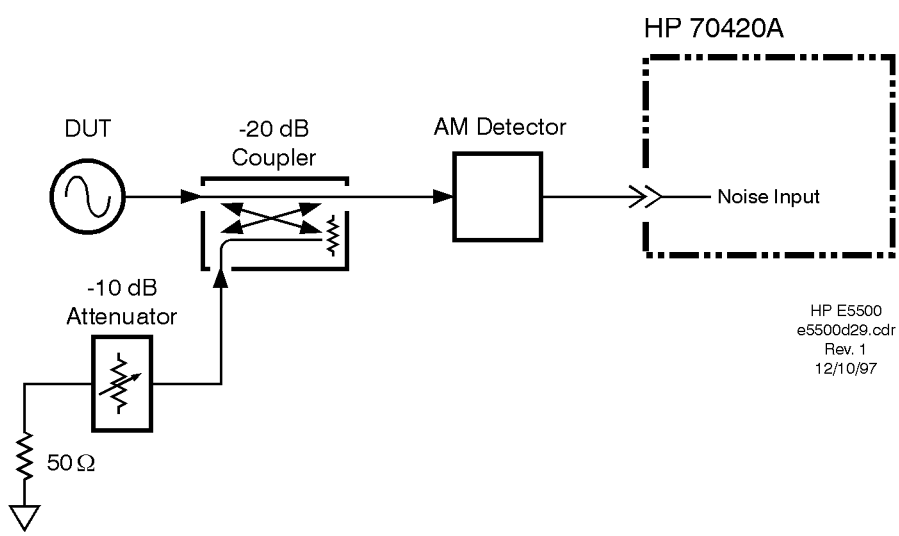


Figure 12-18AM Noise Measurement Setup Using Single-Sided-Spur

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 12-19. The spur should be adjusted such that it is between –30 and –60 dBc, with a carrier offset of 10 Hz to 20 MHz.

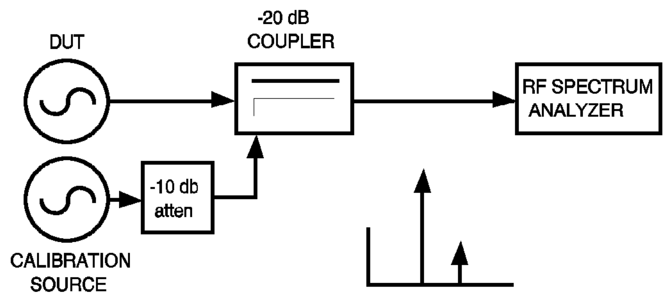


Figure 12-19 Measuring Relative Spur Level

4 Reconnect the AM detector and measure the detector sensitivity. See Figure 12-20.

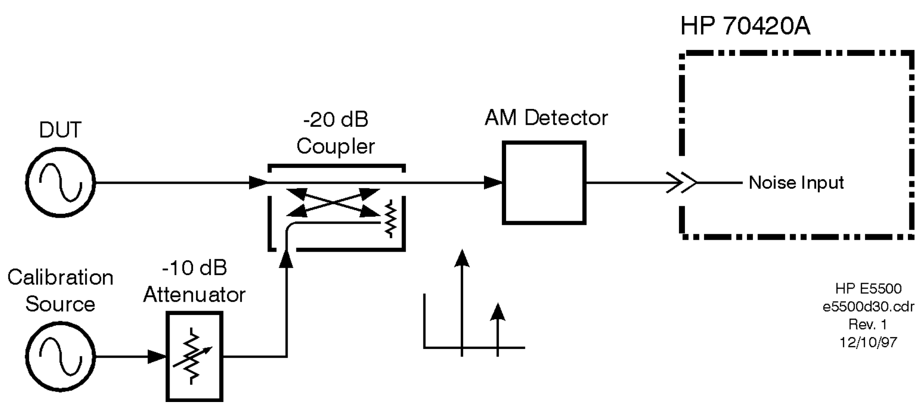


Figure 12-20 Measuring Detector Sensitivity

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.

13

AM Noise Measurement Examples

AM Noise using an Agilent 70420A Option 001

This example demonstrates the AM noise measurement of an Agilent 8662A Signal Generator using the AM detector in the Agilent 70420A Option 001 Phase Noise test set. For more information about various calibration techniques, refer to Chapter 12, “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 Agilent 70420A test set’s hardware components, the input signal **must not** be applied to the signal input connector until the input attenuator has been correctly set for the desired configuration, as show in Table 13-2. Apply the input signal when the connection diagram appears.

The equipment shown in Table 13-1 is required for this example in addition to the phase noise test system and your unit-under-test (UUT).

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour before making the noise measurement.

Table 13-1 Required Equipment for the AM Noise using the Agilent 70420A Option 001 Measurement Example

Equipment	Quantity	Comments
Agilent 8644B	1	
Coax Cables		And adequate adapters to connect the UUT and reference source to the test set.

Figure 13-1 shows the configuration used for an AM noise measurement.

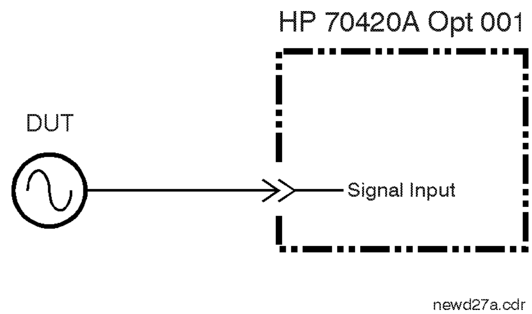


Figure 13-1 AM Noise Measurement Configuration

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 13-2.

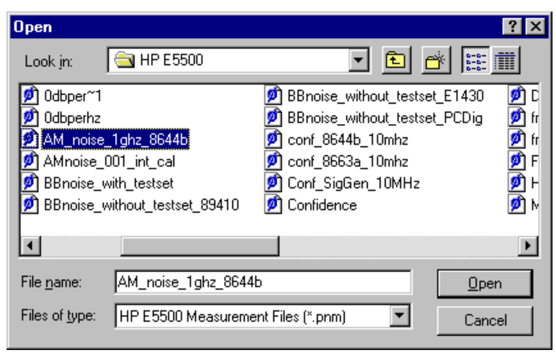


Figure 13-2 Select the Parameters Definition File

4. Choose the **OK** button. The appropriate measurement definition parameters for this example have been pre-stored in this file. (Table 13-3 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.

The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 13-3 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 **AM Noise**. See Figure 13-3.

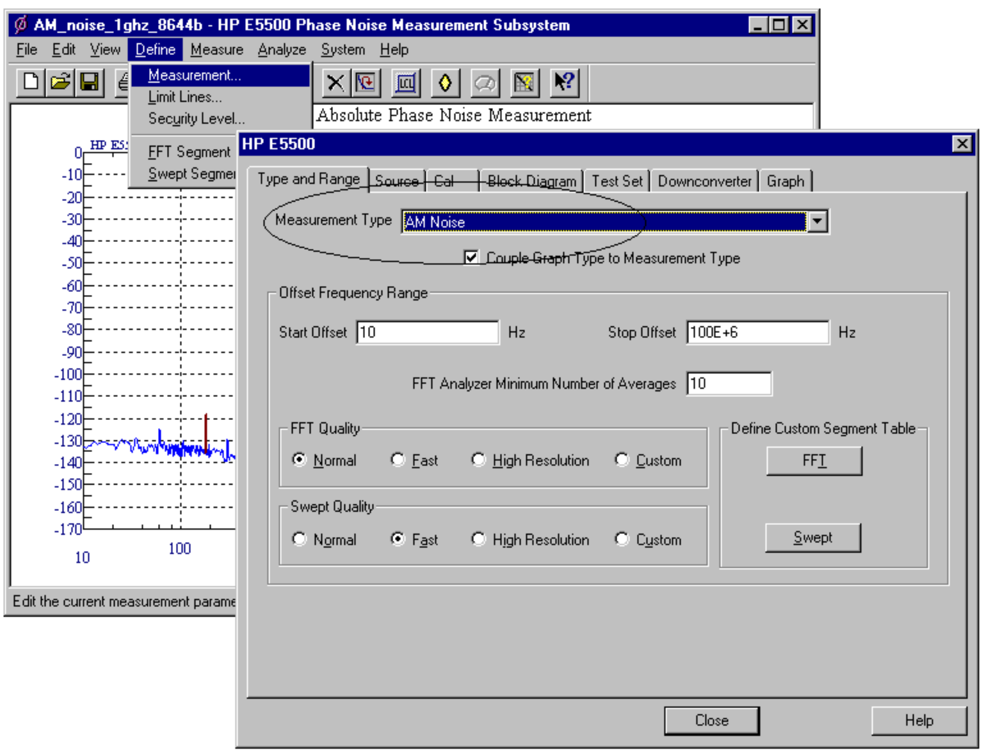


Figure 13-3 Navigate to AM Noise

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

8 Enter the carrier (center) frequency of your UUT. Enter the same frequency for the detector input frequency. See Figure 13-4.

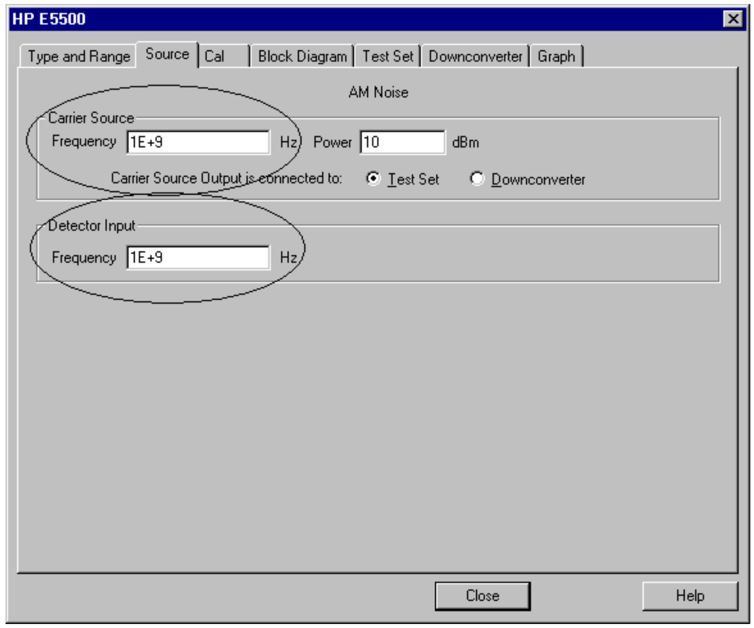


Figure 13-4 Enter Frequencies in Source Tab

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

10 Select **Use automatic internal self-calibration** as the calibration method. See Figure 13-5. For more information about various calibration techniques, refer to Chapter 12, “AM Noise Measurement Fundamentals”.

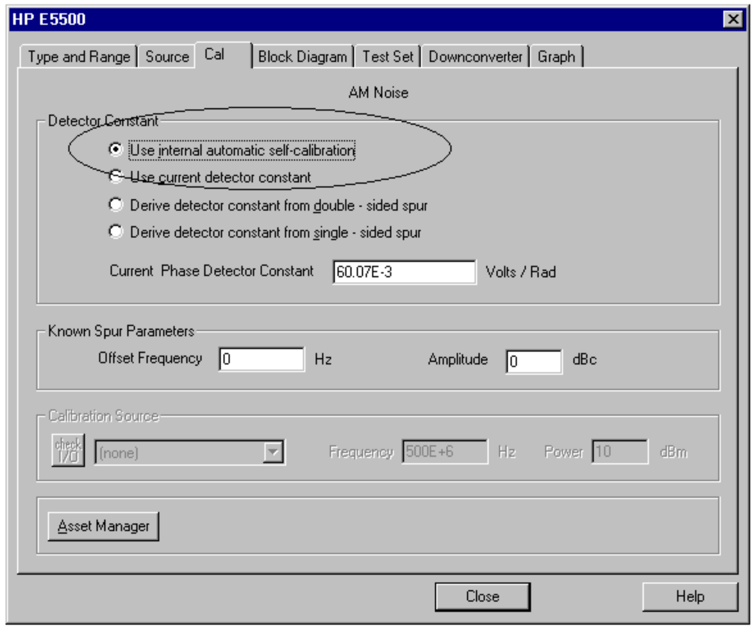


Figure 13-5 Enter Parameters into the Cal Tab

11 Choose the **Block Diagram** tab from the **Define Measurement** window.

12 From the **Phase Detector** pull-down, select **AM Detector**. See Figure 13-6.

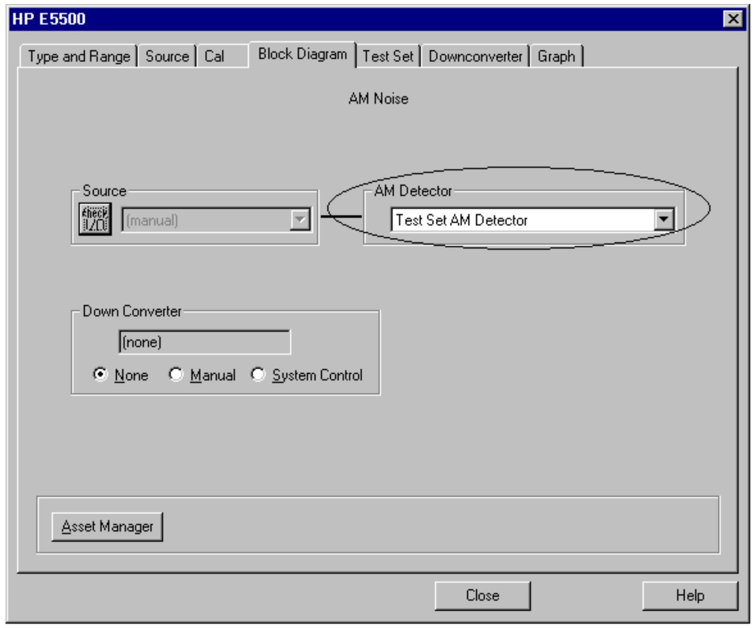


Figure 13-6 Select Parameters in the Block Diagram Tab

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

14 Enter a graph description of your choice. See Figure 13-7

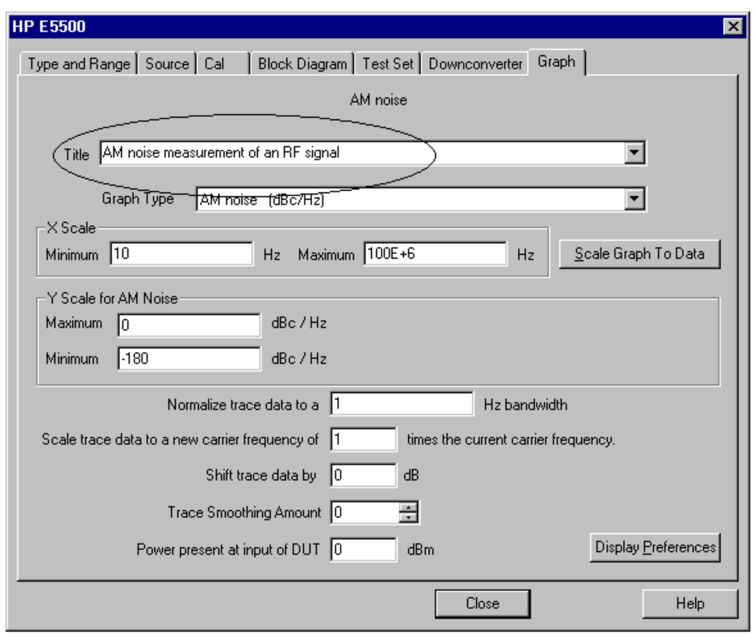


Figure 13-7 Select Graph Description on Graph Tab

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

Beginning the Measurement

1 From the **Measurement** menu, choose **New Measurement See** Figure 13-8.

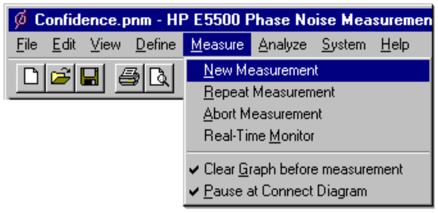


Figure 13-8 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

3 When the **Connect Diagram** dialog box appears, click on the hardware down arrow and select your hardware configuration from the pull-down list. See Figure 13-9

Confirm your connections as shown in the connect diagram. At this time connect your UUT and reference sources to the test set. The input attenuator (Option 001 only) has now been correctly configured based on your measurement definition.

CAUTION: The Agilent 70420A test set's signal input is subject to the following limits and characteristics:

Table 13-2 Agilent 70420A 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 70422A	+5 to +15 dBm
Agilent 70427A	0 to +30 dBm
CAUTION: To prevent damage to the Agilent 70420A test set's hardware components, the input signal must not be applied to the test set's signal input connector until the input attenuator (Option 001) has been correctly set by the phase noise software, which will occur at the connection diagram.	
Characteristics	
Input Impedance	50 ohm Nominal
AM Noise	dc coupled to 50 ohm load

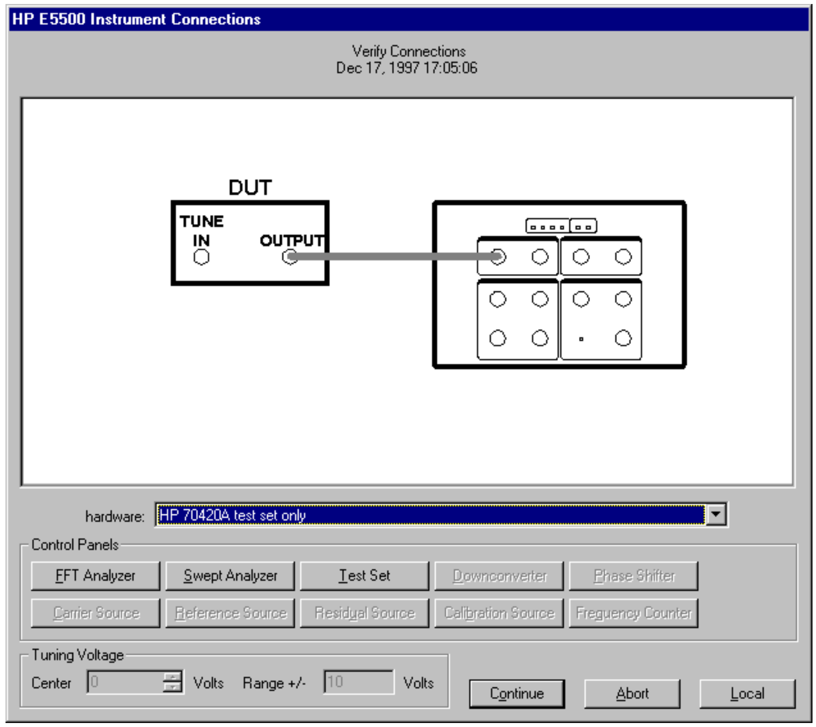


Figure 13-9 Connect Diagram for the AM Noise Measurement

4 Refer to Figure 13-10 for more information about system interconnections.

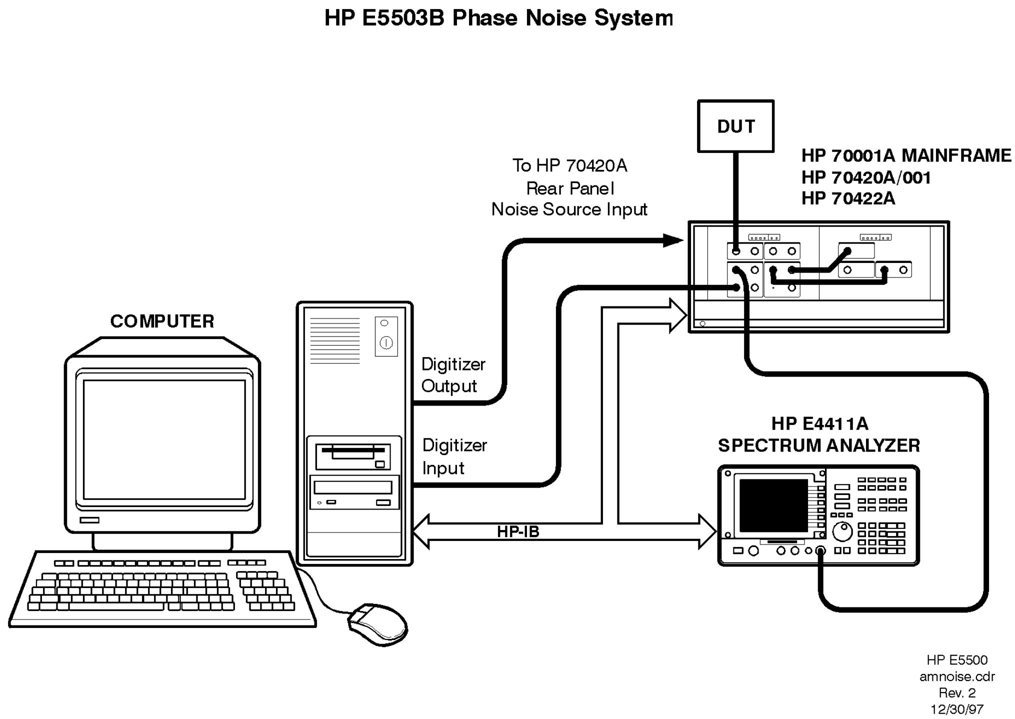


Figure 13-10 Connect Diagram Example

Making the Measurement

Press the **Continue** key when you are ready to make the measurement.

For more information about various calibration techniques, refer to Chapter 12, “AM Noise Measurement Fundamentals”.

The system is now ready to make the measurement. The measurement results will be updated on the computer screen after each frequency segment has been measured.

When the Measurement is Complete

When the measurement is complete, refer to Chapter 15, “Evaluating Your Measurement Results” for help in evaluating your measurement results. Figure 13-11 shows a typical AM noise curve.

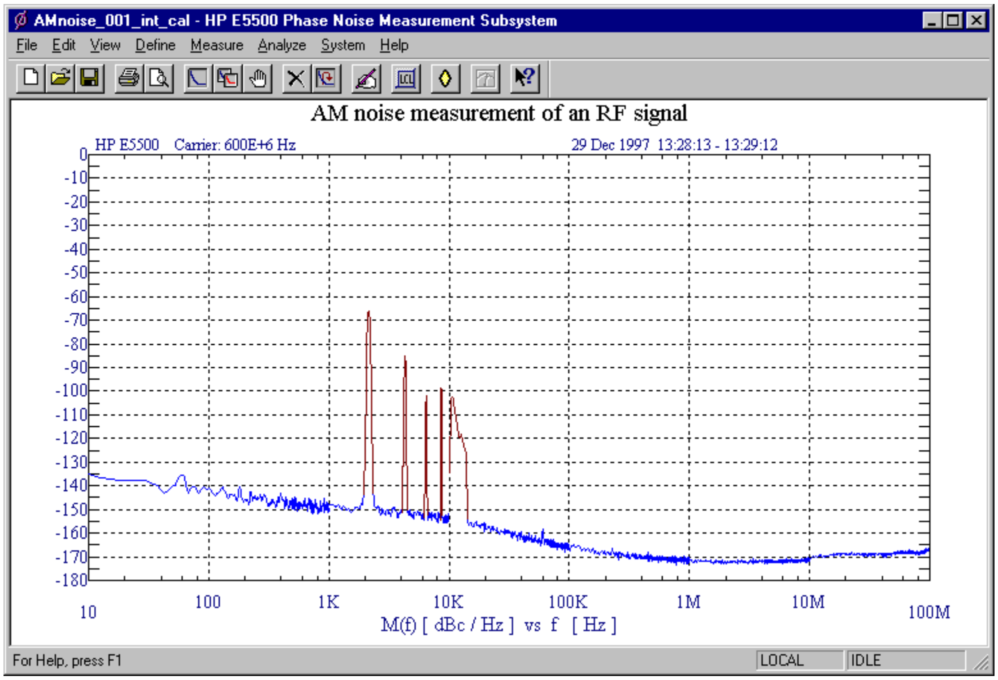


Figure 13-11 Typical AM Noise Curve

Table 13-3 Parameter Data for the AM Noise using an Agilent 70420A 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

Table 13-3 Parameter Data for the AM Noise using an Agilent 70420A Option 001

Step	Parameters	Data
3	**Cal Tab** • Detector Constant • Known Spur Parameters Offset Frequency Amplitude	 • Use internal automatic self-calibration • 1 Hz • -130 dBc
4	**Block Diagram Tab** • Source • AM Detector • Down Converter	 • Manual • TestSet AM Detector • None
5	**Test Set Tab** • Input Attenuation • LNA Low Pass Filter • LNA Gain • Detector Maximum Input Levels Microwave Phase Detector RF Phase Detector AM Detector • Ignore out-of-lock conditions • Pulsed Carrier • DC Block • Analyzer View • PLL Integrator Attenuation	 • Auto checked • Auto checked • Auto Gain • 0 dBm • 0 dBm • 0 dBm • Not checked • Not checked • Not checked • Baseband • 0.00 dBm
6	**Dowconverter Tab**	Does not apply to this measurement example.
7	**Graph Tab** • Title • Graph Type • X Scale Minimum • X Scale Maximum • Y Scale Minimum • Y Scale Maximum • Normalize trace data to a: • Scale trace data to a new carrier frequency of: • Shift trace data DOWN by: • Trace Smoothing Amount • Power present at input of DUT	 • AM Noise Measurement of an RF Signal • AM Noise (dBc/Hz) • 10 Hz • 100E + 6 Hz • 0 dBc/Hz • - 180 dBc/Hz • 1 Hz bandwidth • 1 times the current carrier frequency • 0 dB • 0 • 0 dB

14

Baseband Noise Measurement Examples

Baseband Noise using a Test Set Measurement Example

This measurement example will help you measure the noise voltage of a source.

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour 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_with_testset.pnm."** See Figure 14-1.

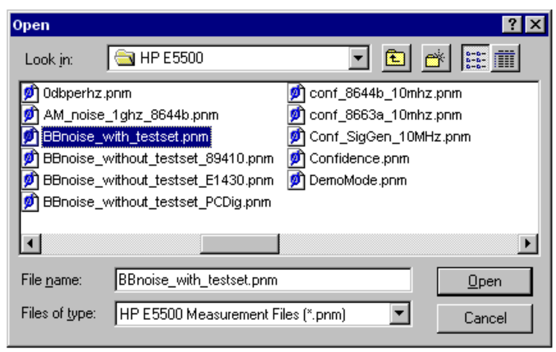


Figure 14-1 Select the Parameters Definition File

4 Choose the OK button. The appropriate measurement definition parameters for this example have been pre-stored in this file. (Table 14-1) 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 14-2.

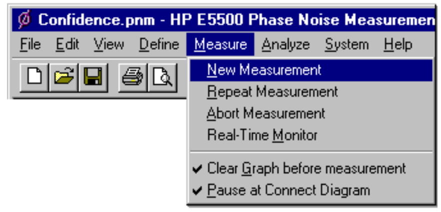


Figure 14-2 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** dialog box appears, click **OK**.

3 When the Connect Diagram appears on the computer's display, click on the hardware down arrow and select "HP 70420A option 001 test set only" from the pull-down list. See Figure 14-3

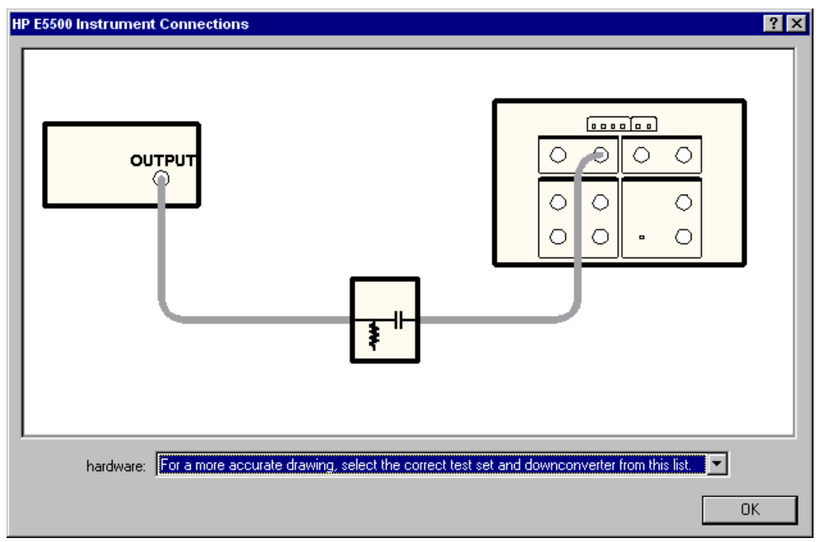


Figure 14-3 Connect Diagram for the Baseband using a Test Set Measurement

Making the Measurement

1 Press the Continue key.

Figure 14-4 shows a typical phase noise curve for a baseband noise measurement using a test set.

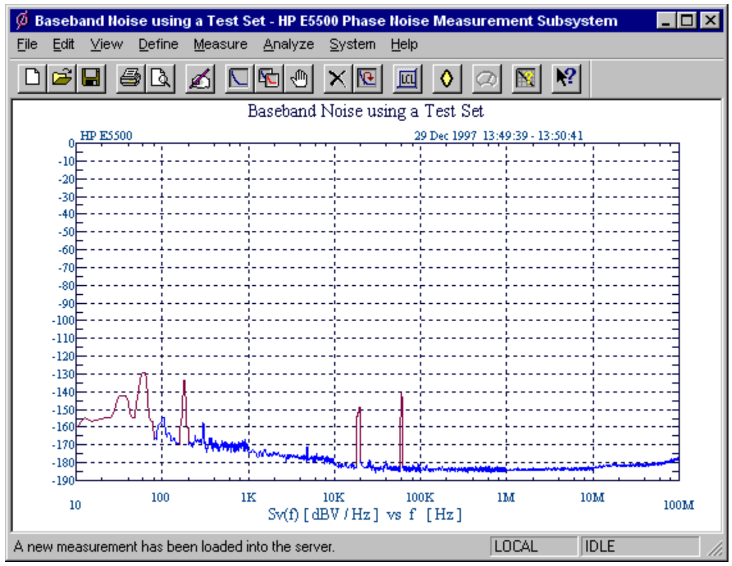


Figure 14-4 Typical Phase Noise Curve for a Baseband using a Test Set Measurement.

Table 14-1 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

Table 14-1 Parameter Data for the Baseband Using a Test Set Measurement

Step	Parameters	Data
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 Agilent 70420A 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 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

Baseband Noise without using a Test Set Measurement Example

This measurement example will help you measure the noise voltage of a source.

NOTE: To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least one hour 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."**

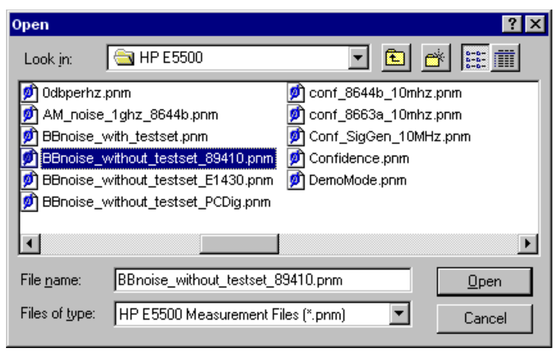


Figure 14-5 Select the Parameters Definition File

4. Choose the OK button. The appropriate measurement definition parameters for this example have been pre-stored in this file. Table 14-2 lists the parameter data that has been entered for this measurement example.

Beginning the Measurement

1 From the **Measurement** menu, choose **New Measurement**.

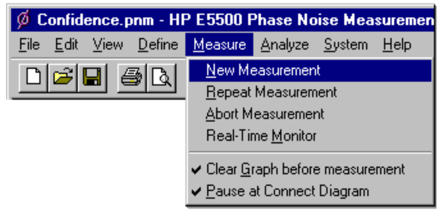


Figure 14-6 Selecting a New Measurement

2 When the **Perform a New Calibration and Measurement?** prompt appears, click **OK**.

Making the Measurement

1 When the Connect Diagram appears on the computer's display, click on the Continue button.

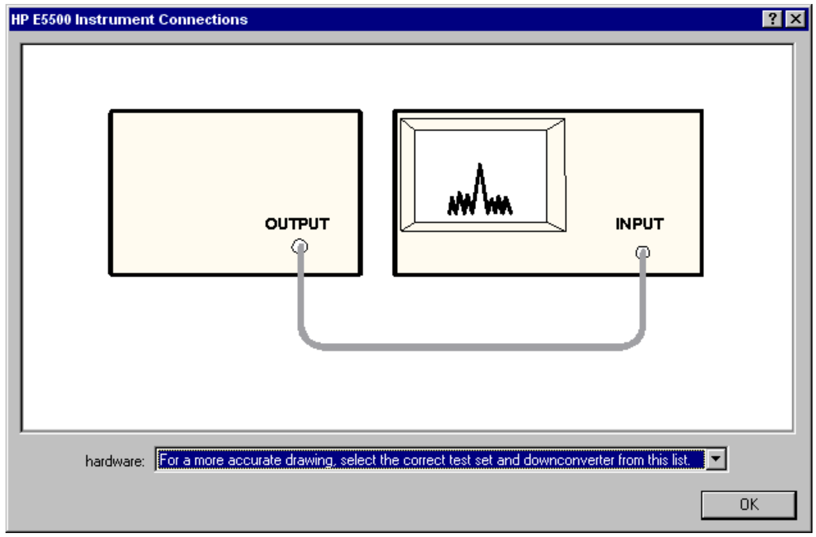


Figure 14-7 Connect Diagram for the Baseband Without Using a Test Set Measurement

Figure 14-8 shows a typical phase noise curve for a baseband noise measurement without using a test set

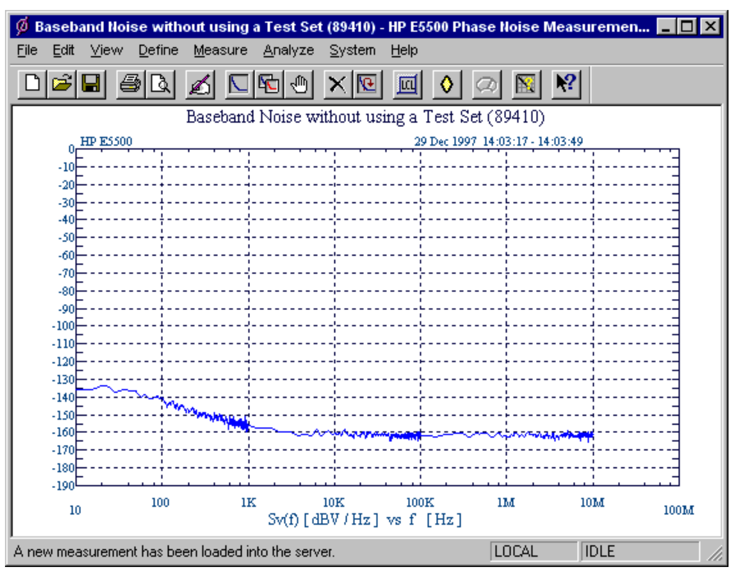


Figure 14-8 Typical Phase Noise Curve for a Baseband Without using a Test Set Measurement.

Table 14-2 Parameter Data for the Baseband without using a Test Set Measurement

Table 14-3

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

15

Evaluating Your Measurement Results

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 unit-under-test (UUT). 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 UUT.

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 15-1 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.

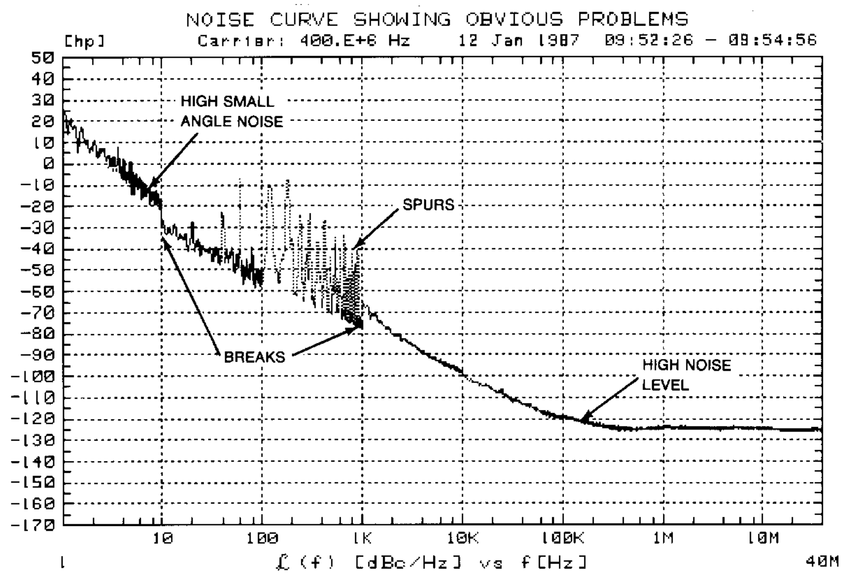


Figure 15-1 Noise Plot Showing Obvious Problems

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 unit-under-test.
- 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 Unit-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 15-2 to determine if the measurement results need to be decreased to reflect the actual noise level of the UUT.

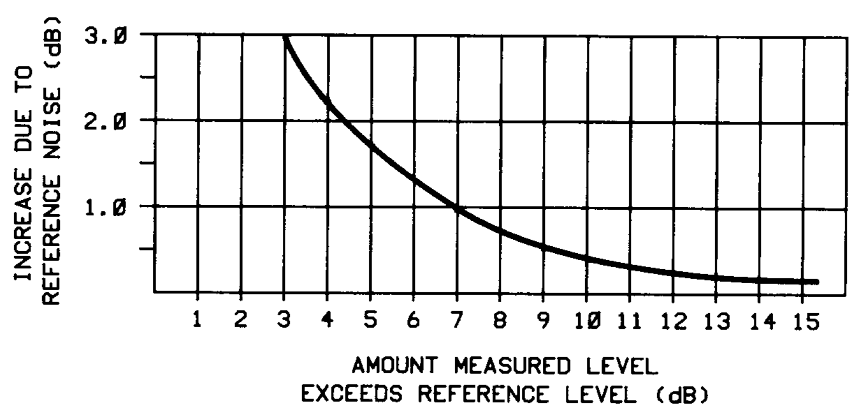


Figure 15-2 Graph Showing How Much to Decrease Measured Noise to Compensate for Added Reference Source Noise

For example, applying the 7 dB difference in noise levels, shown in Figure 15-3 at 10 kHz, to the graph, reveals that the measured results should be decreased by about 1 dB at 10 kHz to reflect the actual noise of the UUT.

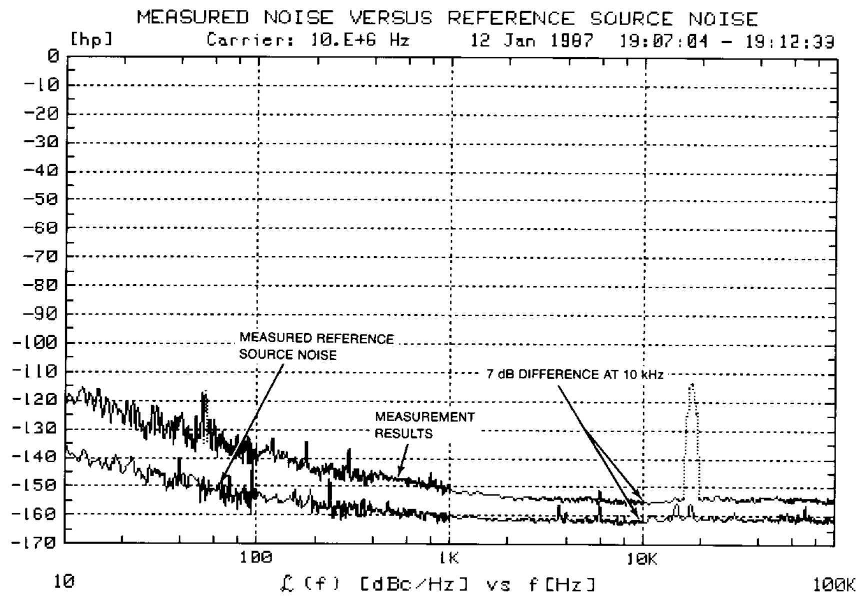


Figure 15-3 Example Comparison of Measurement Results and Reference Source Noise.

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 15-13), 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 15-4.

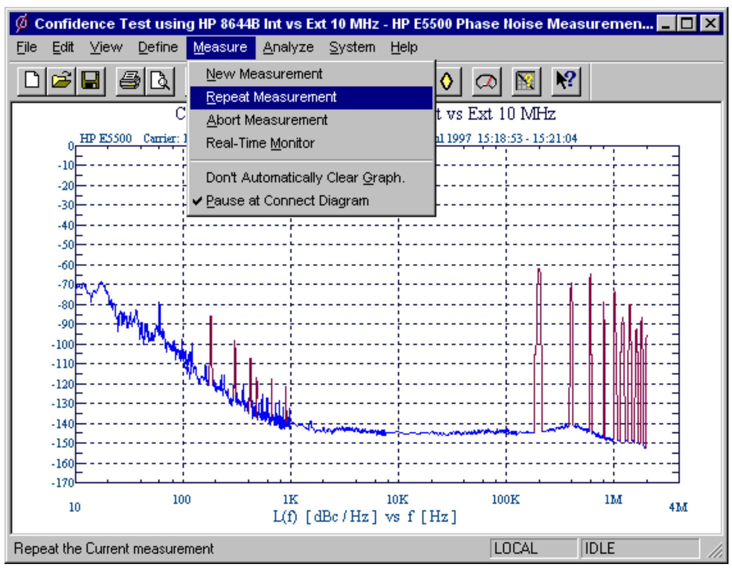


Figure 15-4 Repeating a Measurement

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 unit-under-test or data sheets for components used in the device) can often provide insights into the expected performance of the unit-under-test.

Outputting the Results

To generate a printed hardcopy of your test results, you must have a printer must be connected to the computer.

Using a Printer

To print the phase noise graph along with parameter summary data, click Print on the File menu.

Graph of Results

The Graph of Results functions are accessed from the main graph menu, and are used to display and evaluate the measurement results. This screen is automatically displayed as a measurement is being made. You can also 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 15-8
- "Omit Spurs" on page 15-10
- "Parameter Summary" on page 15-11

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 15-5.

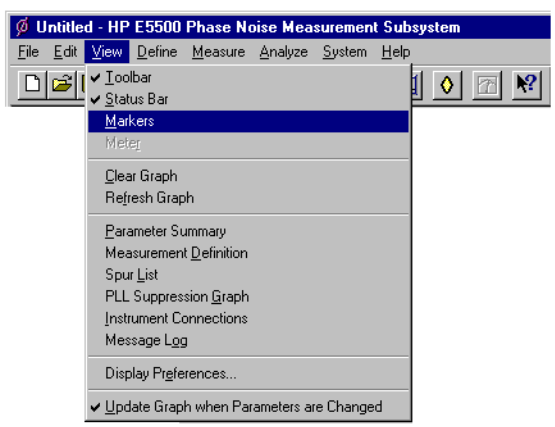


Figure 15-5 Navigate to Marker

2 To remove the highlighted marker, click the **Delete** button. You may add as many as nine markers. See Figure 15-6.

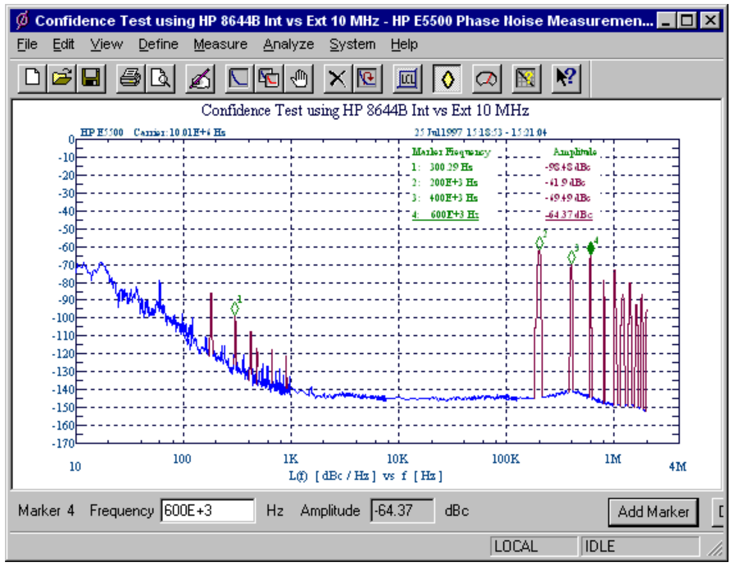


Figure 15-6 Add and Delete Markers

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 15-7.

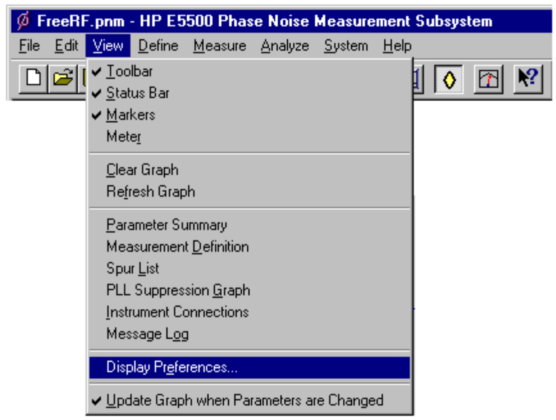


Figure 15-7 Select Display Preferences

2 In the **Display Preferences** dialog box, uncheck **Spurs**. See Figure 15-8. Click OK.

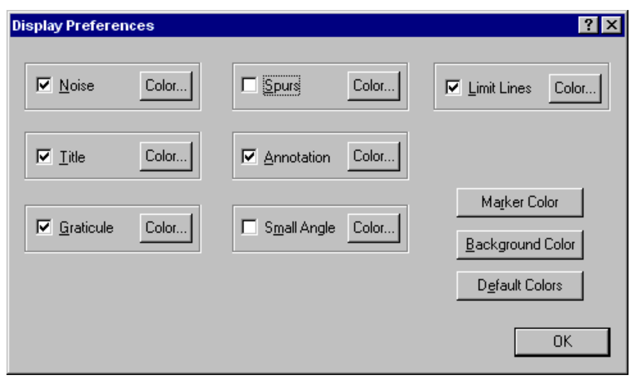


Figure 15-8 Uncheck Spurs

3 The Graph will be displayed without spurs (Figure 15-9). To re-display the spurs, check **Spurs** in the **Display Preferences** dialog box.

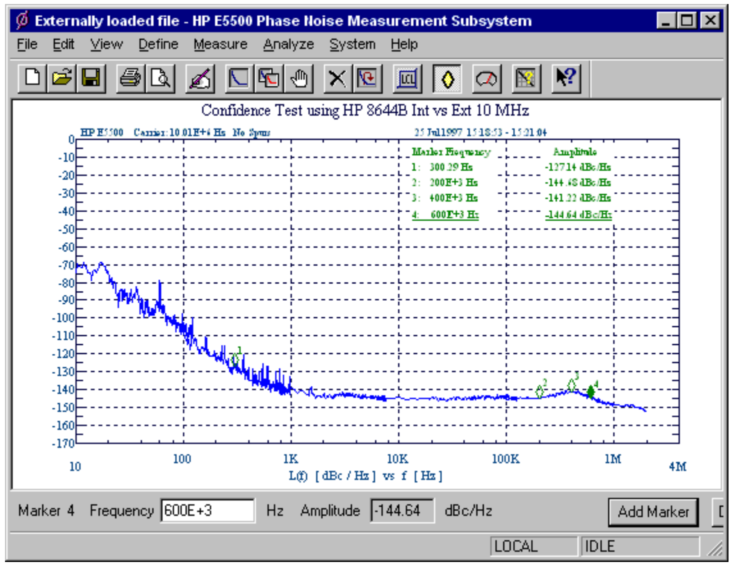


Figure 15-9 Graph Without Spurs

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 15-10).

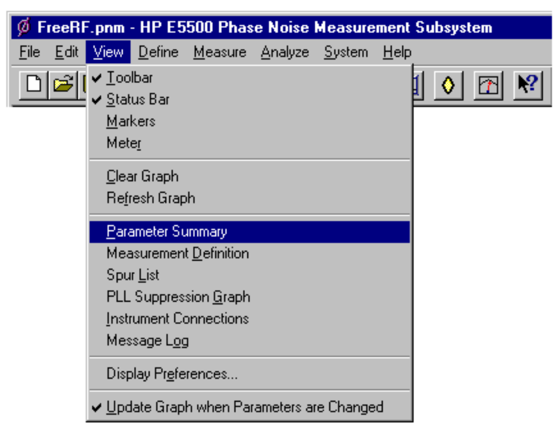


Figure 15-10 Navigate to Parameter Summary

2 The Parameter Summary Notepad dialog box appears (Figure 15-11). The data can be printed or changed using standard Notepad functionality.

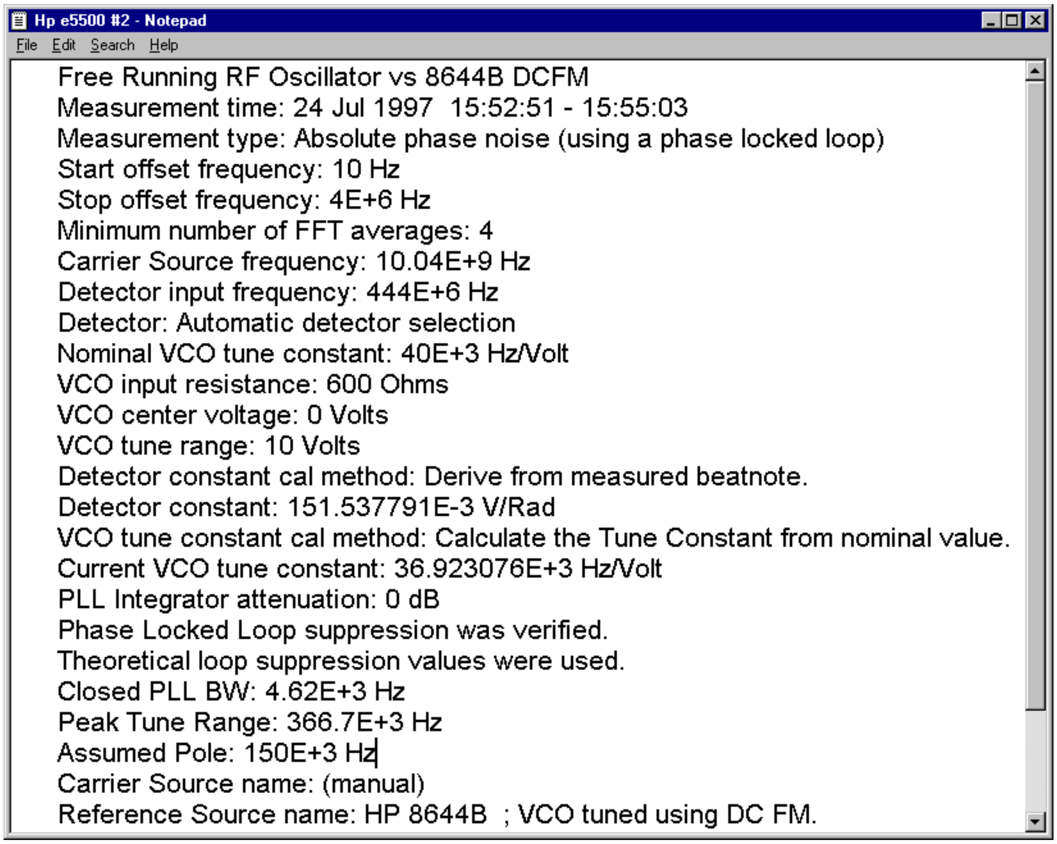


Figure 15-11 Parameter Summary Notepad

Problem Solving

Table 15-1

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 15-2 identifies the circumstances that can cause discontinuity in the graph.

Table 15-2 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 15-2 Potential Causes of Discontinuity in the Graph

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 15-3. 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 15-3 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 unit-under-test wiring, etc. A breadboarded or prototype circuit should be well shielded from external RF fields when phase noise measurements are being made.

Table 15-4 shows actions to take to eliminate spurs.

Table 15-4 Actions to Eliminate Spurs

Spur Sources	Description	Recommended Action
Internal	Potential spur sources within the measurement system include the phase noise system, the unit-under-test, 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 unit-under-test 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 coax 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.
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 15-12. 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.

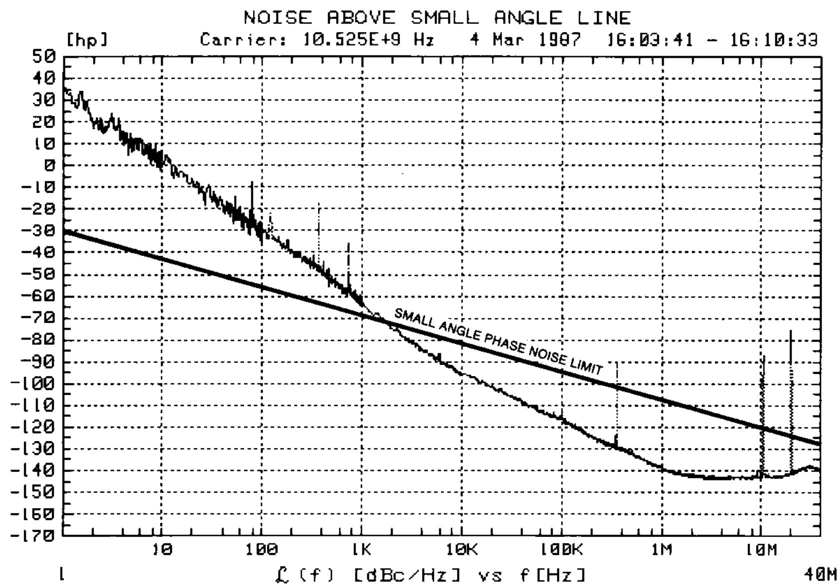


Figure 15-12L(f) Is Only Valid for Noise Levels Below the Small Angle Line

16

Advanced Software Features

Introduction

Advanced Functions allows you to manipulate the test system or to customize a measurement using the extended capabilities provided by the Agilent E5500 phase noise measurement software. These functions are recommended to be used only by those who understand how the measurement and the test system are affected. Refer to the following pages for details:

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 16-1, when it is verified during measurement calibration. The plot appears whether or not an accuracy degradation occurs.

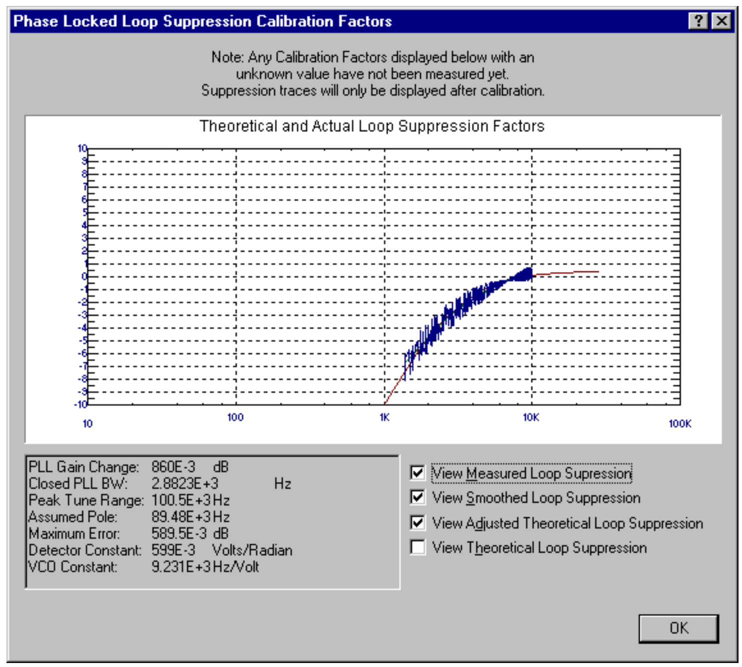


Figure 16-1 PLL Suppression Verification Graph

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 3048A System noise floor exclusive of the reference source. VCO CONSTANT: This 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 troubleshoot 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 Agilent 70420A 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 “Noise Input” port on the rear-panel of the Agilent 70420A test set. For the E550xB systems, the PC digitizer used as the FFT analyzer also provides a companion D/A output to be used for this purpose. When an Agilent 89410A vector signal analyzer is the system FFT analyzer, the Agilent 89410As companion source output is used. For the E550xA systems, the Agilent E1441A VXI arbitrary source is used as the stimulus signal for the Agilent E1430A VXI digitizer and is connected per Figure 16-2.

The sync output from the Agilent E1441A MUST Connect to both the Ext trigger inputs - use a BNC “T”.

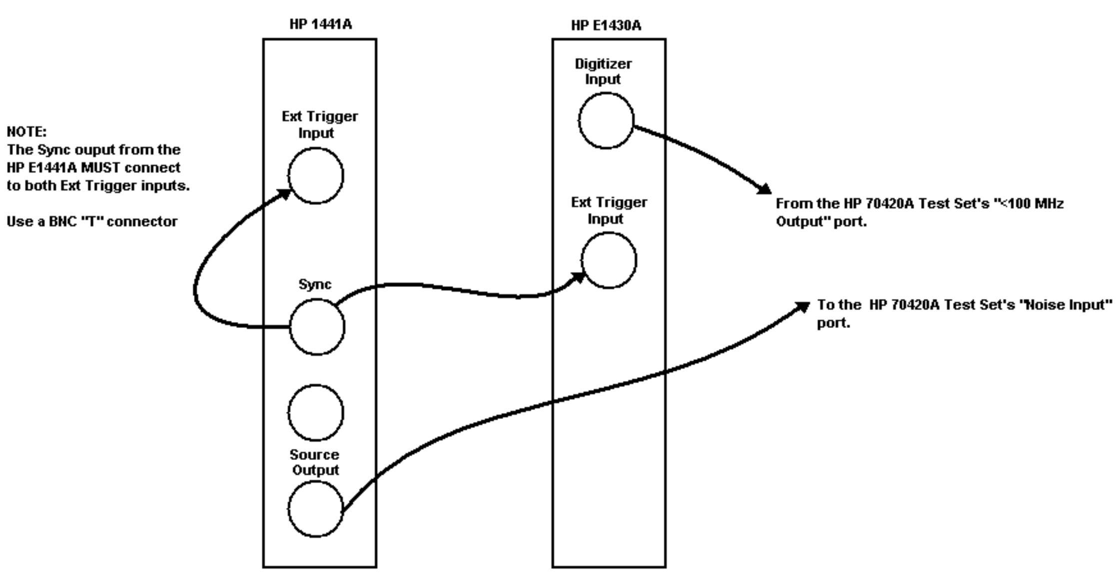


Figure 16-2 Using the E1441A as a Stimulus Response for the E1430A

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 16-3) is provided.

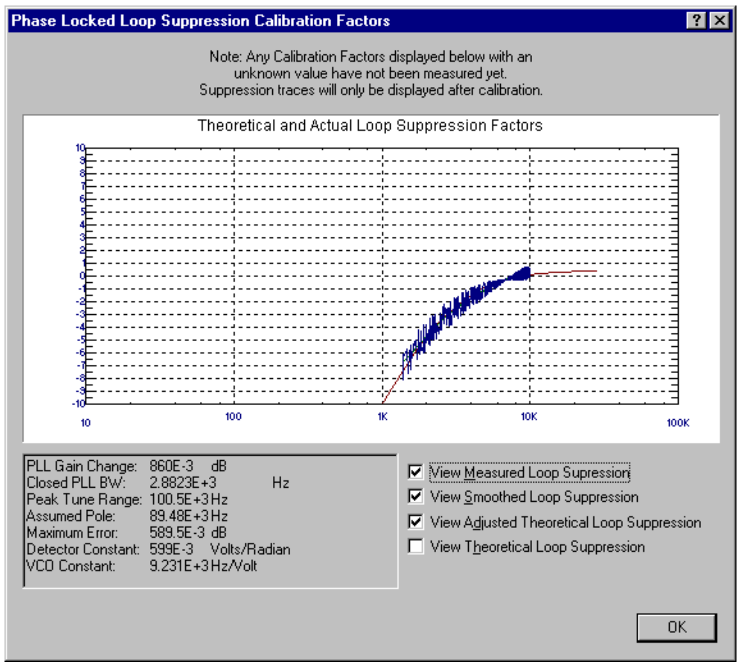


Figure 16-3 Default PLL Suppression Verification Graph

There are four different curves available for the this graph:

1. “Measured” loop suppression curve (Figure 16-4) - this is the result of the loop suppression measurement performed by the E5500 system;
2. “Smoothed” measured suppression curve (Figure 16-5) - this is a curve-fit representation of the measured results, it is used to compare with the “theoretical” loop suppression;
3. “Theoretical” suppression curve (Figure 16-6) - 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).

4 “Adjusted” theoretical suppression curve (Figure 16-7 through Figure 16-9) - 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.

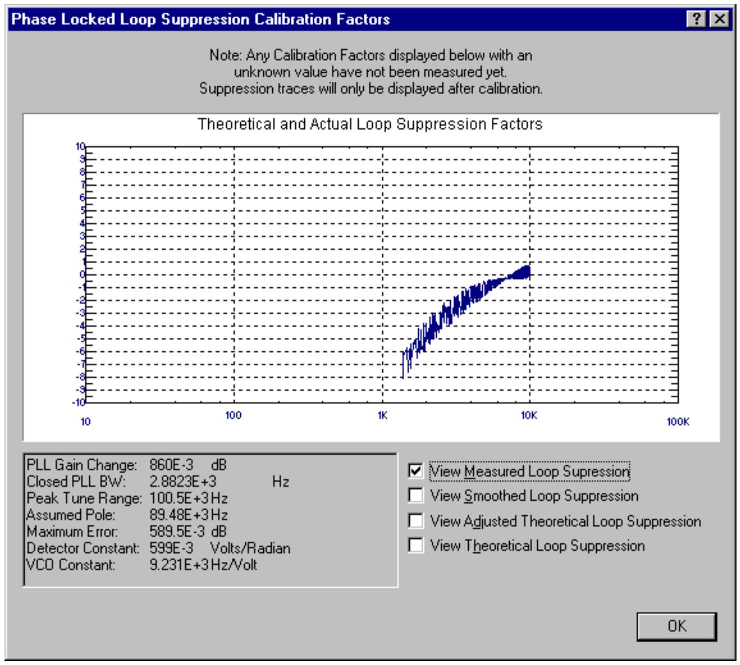


Figure 16-4 Measured Loop Suppression Curve

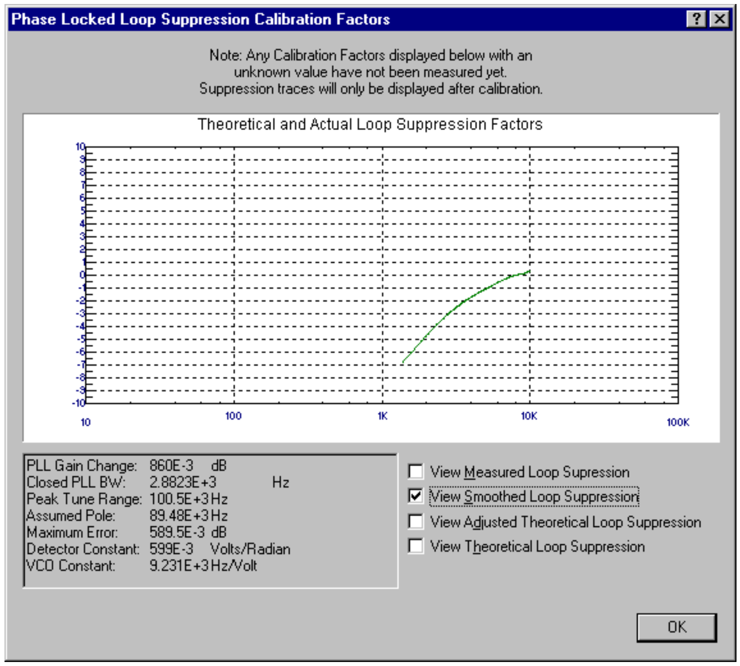


Figure 16-5 Smoothed Loop Suppression Curve

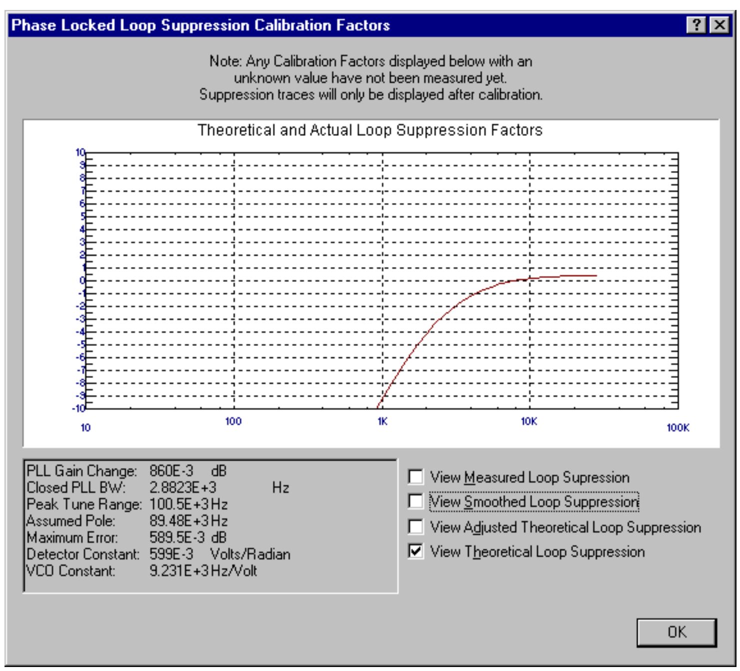


Figure 16-6 Theoretical Loop Suppression Curve

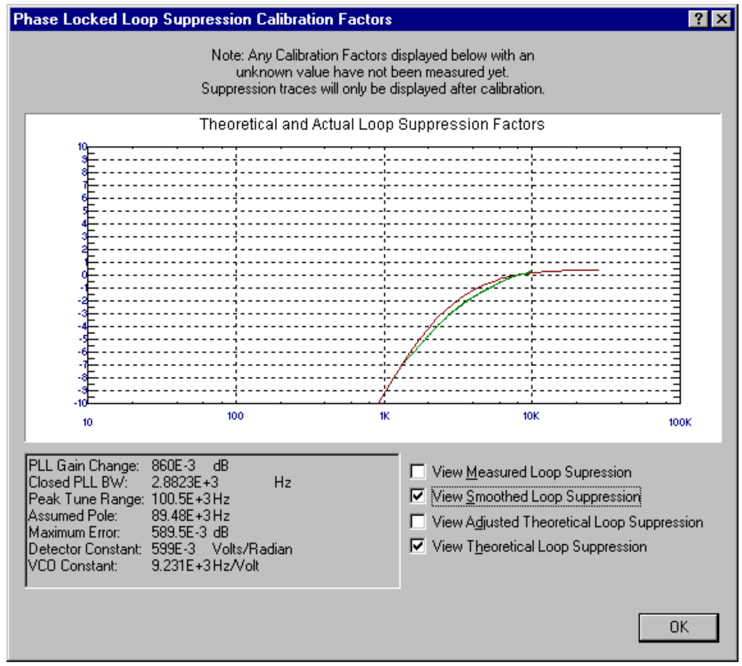


Figure 16-7 Smoothed vs Theoretical Loop Suppression Curve

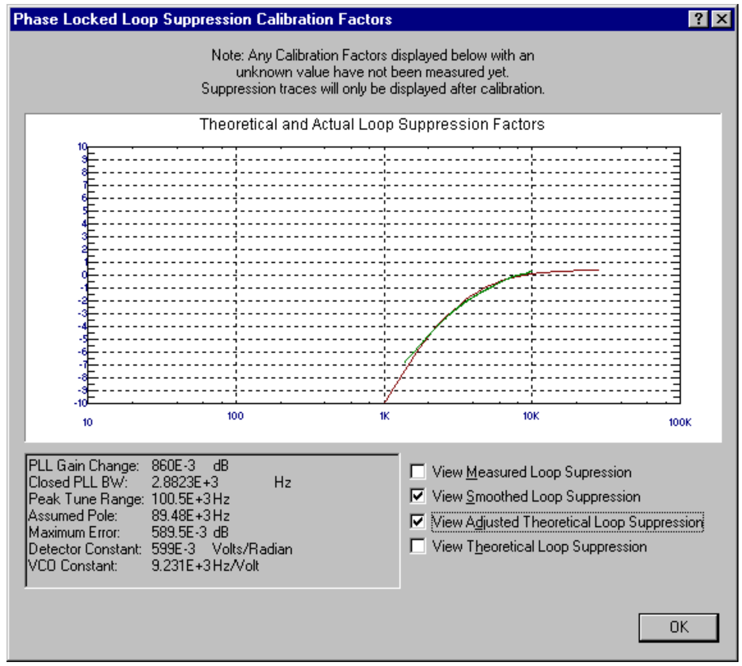


Figure 16-8 Smoothed vs Adjusted Theoretical Loop Suppression Curve

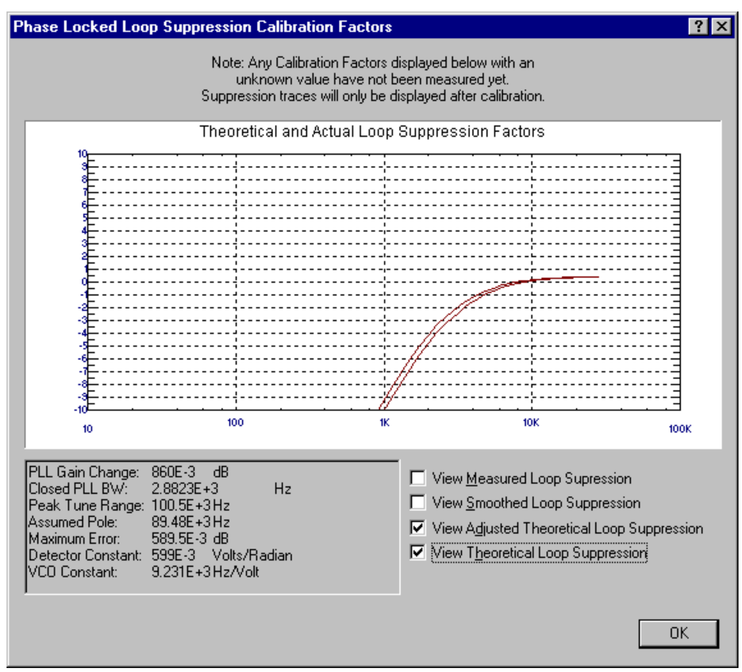


Figure 16-9 Adjusted Theoretical vs Theoretical Loop Suppression Curve

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 spec. degradation is determined by taking the larger of Maximum Error and magnitude of PLL Gain Change and then subtracting 1 dB.

Supporting an Embedded VXI PC:

A.02.00 also allows the use of an embedded VXI PC running Microsoft® Windows® 2000. In this case, the VXI interface to the VXI assets will be “VXI direct” (select within the Asset Manager Configuration). The VISA I/O libraries must also support the embedded PC’s GPIB card.

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 16-10.

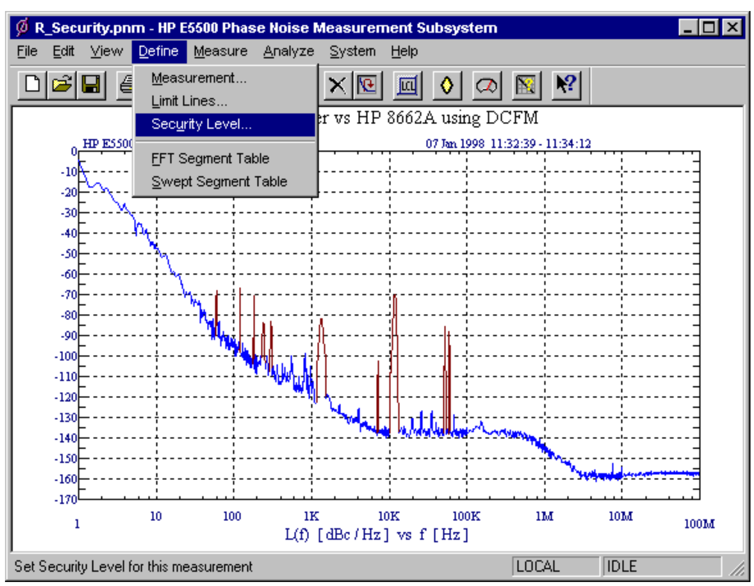


Figure 16-10 Navigate to Security Level

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 16-11 and Figure 16-12.

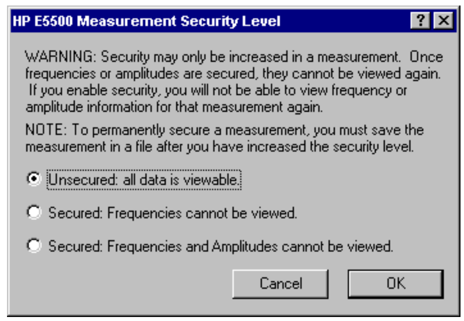


Figure 16-11 Choosing Levels of Security

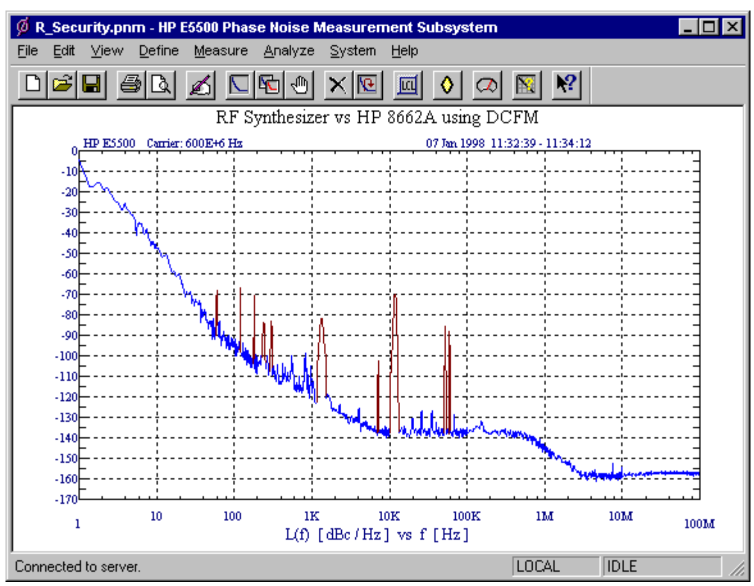


Figure 16-12 Unsecured: All Data is Viewable

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 16-13 through Figure 16-15.

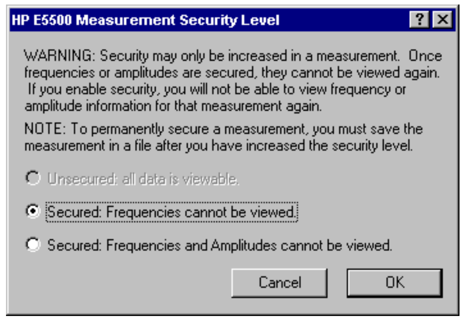


Figure 16-13 Choosing Levels of Security

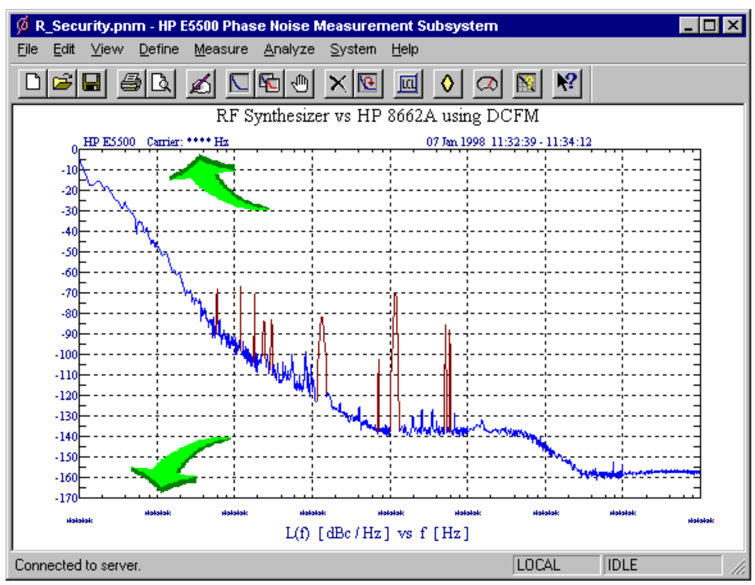


Figure 16-14 Secured:Frequencies Cannot be Found-1

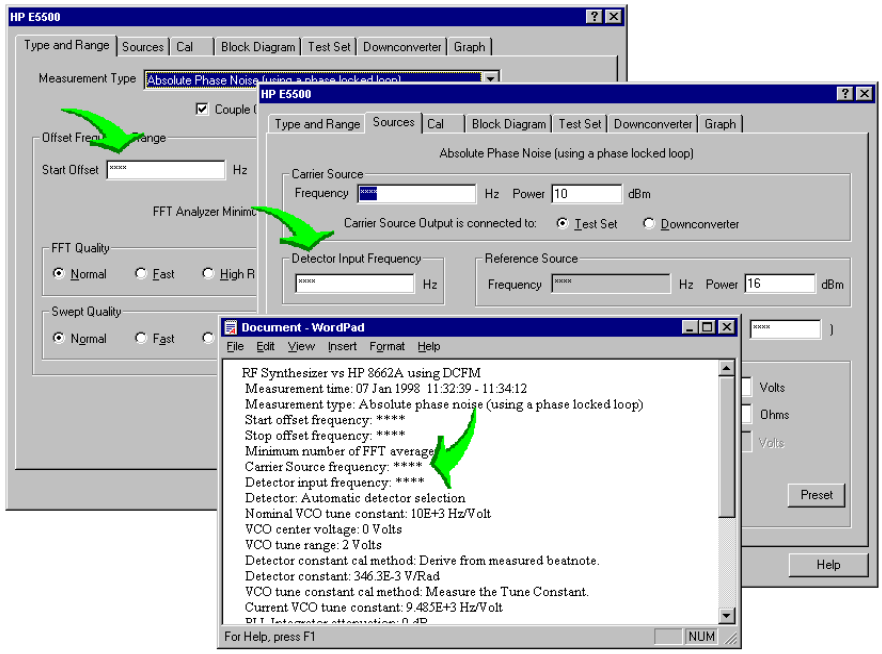


Figure 16-15 Secured:Frequencies Cannot be Found-2

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 16-16 and Figure 16-17.

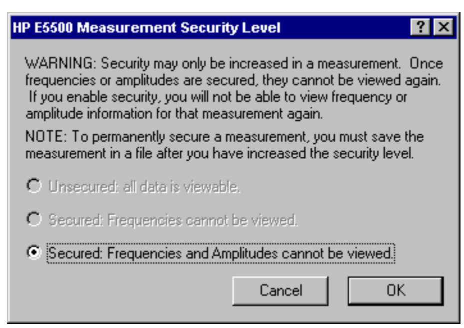


Figure 16-16 Choosing Levels of Security

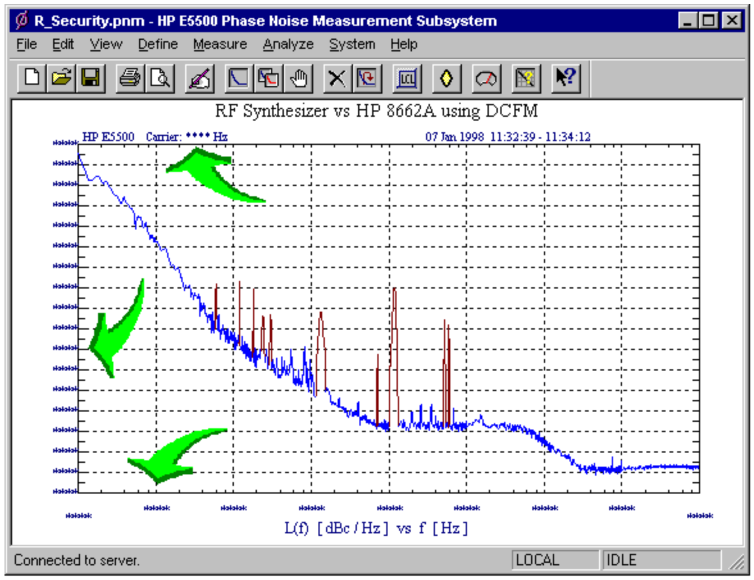


Figure 16-17 Secured: Frequencies and Amplitudes Cannot be Viewed

17

Reference Graphs and Tables

Approximate System Phase 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 17-1 illustrates the approximate noise floor of the Agilent 70420A 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.

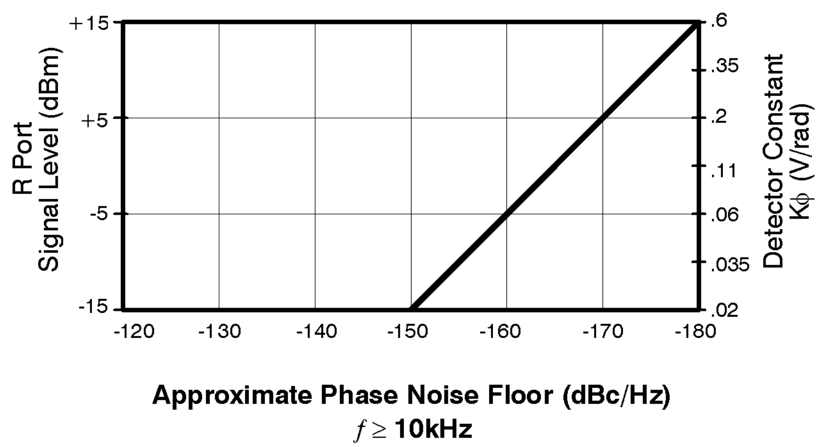


Figure 17-1

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 show in Figure 17-2, below the line the 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.

$$S_\phi(f) = 2\,(L(f)) \text{ or } S_\phi(f)_{dB} = L(f)_{dBc} + 3\text{ dB}$$

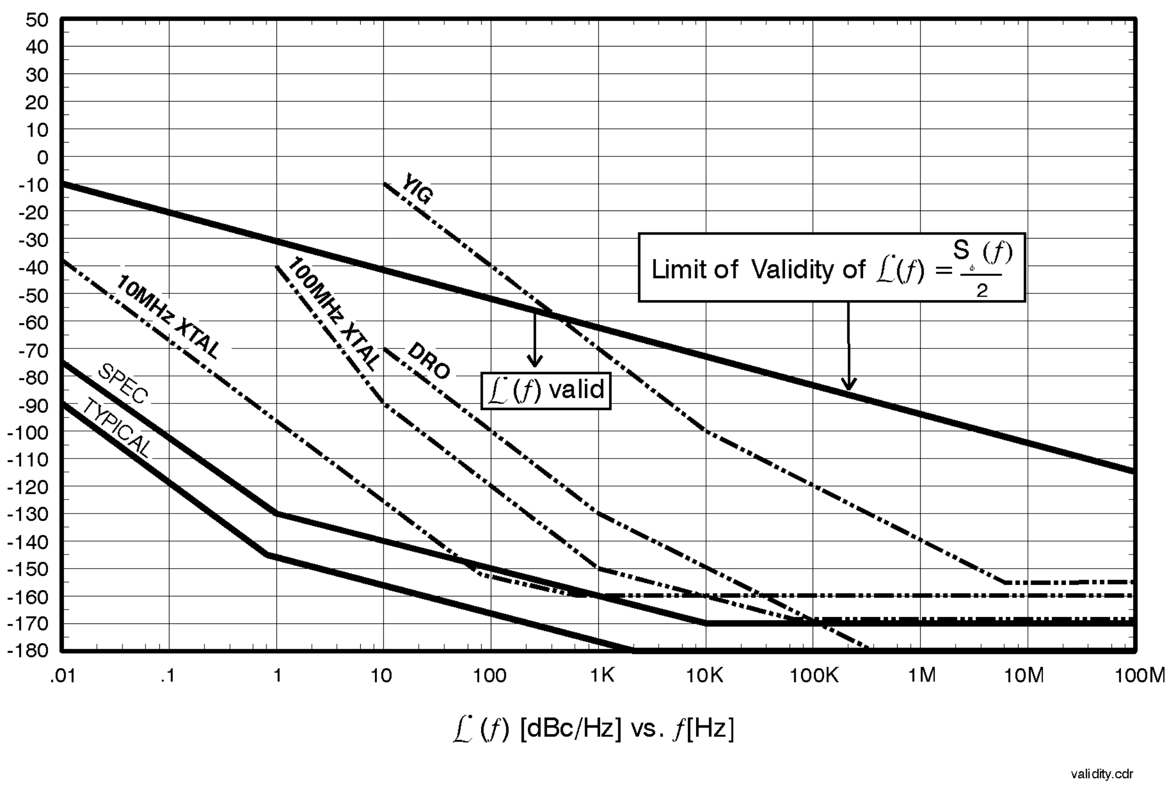


Figure 17-2

Phase Noise Level of Various Agilent Sources

The graph in Figure 17-3 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.

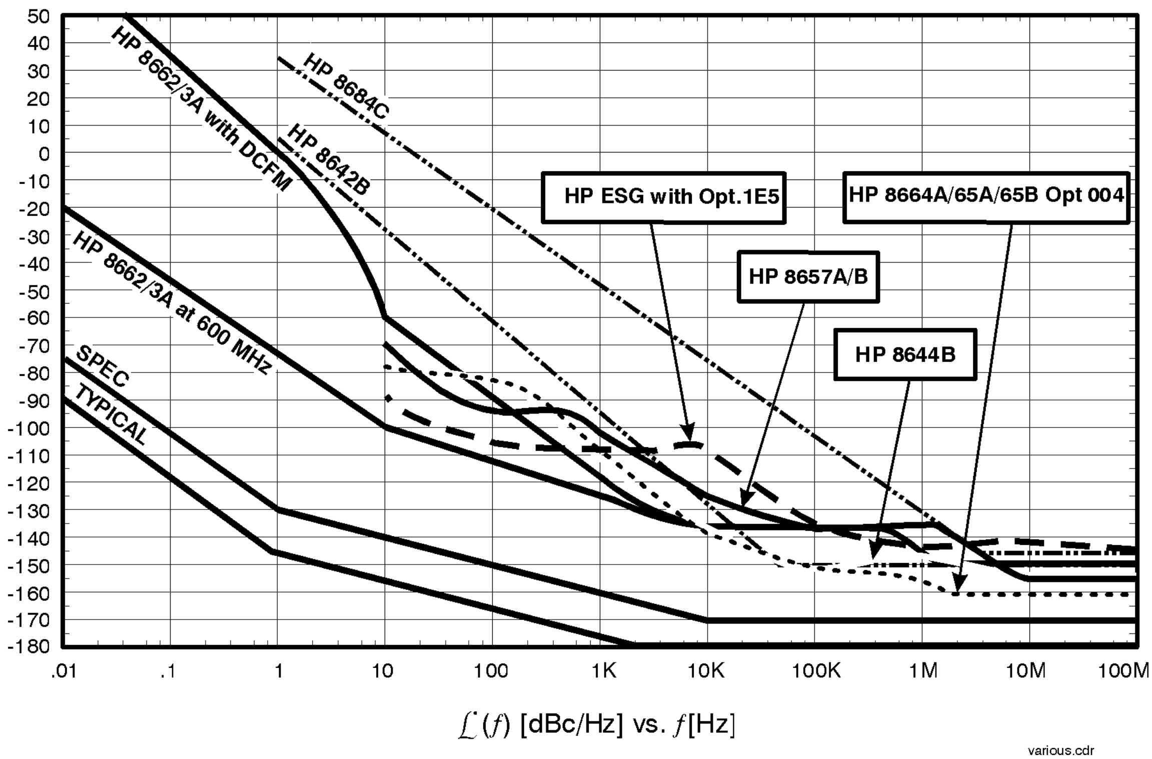


Figure 17-3

Increase in Measured Noise as Ref Source Approaches UUT Noise

The graph shown in Figure 17-4 demonstrates that as the noise level of the reference source approaches the noise level of the UUT, 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 UUT.

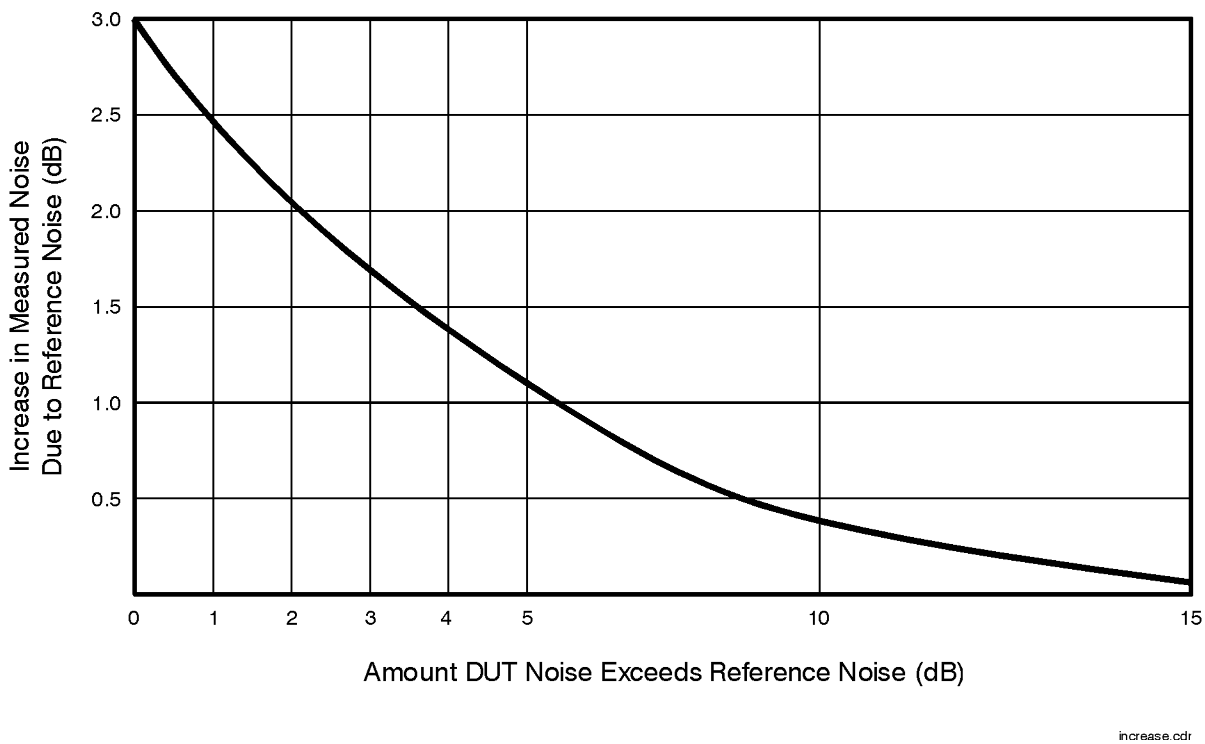


Figure 17-4

Approximate Sensitivity of Delay Line Discriminator

The dependence of a frequency discriminator's sensitivity on the offset frequency is obvious in the graph shown in Figure 17-5. 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.

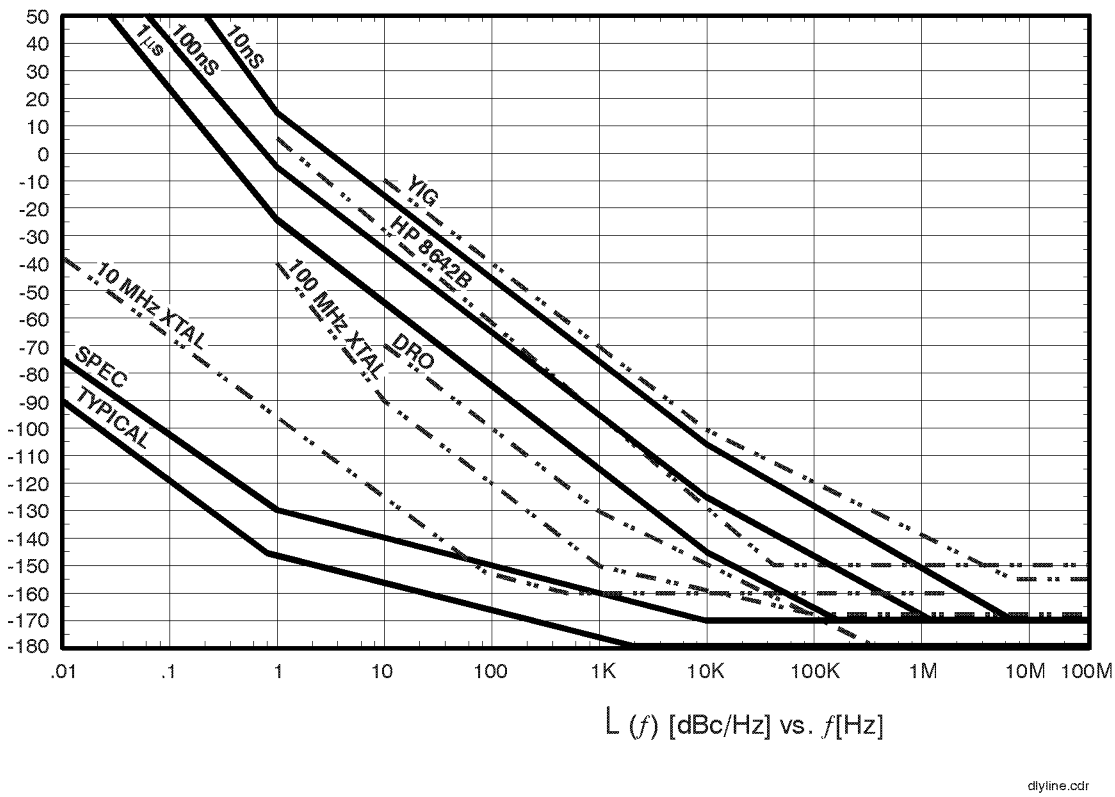


Figure 17-5

AM Calibration

The AM detector sensitivity graph shown in Figure 17-6 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.

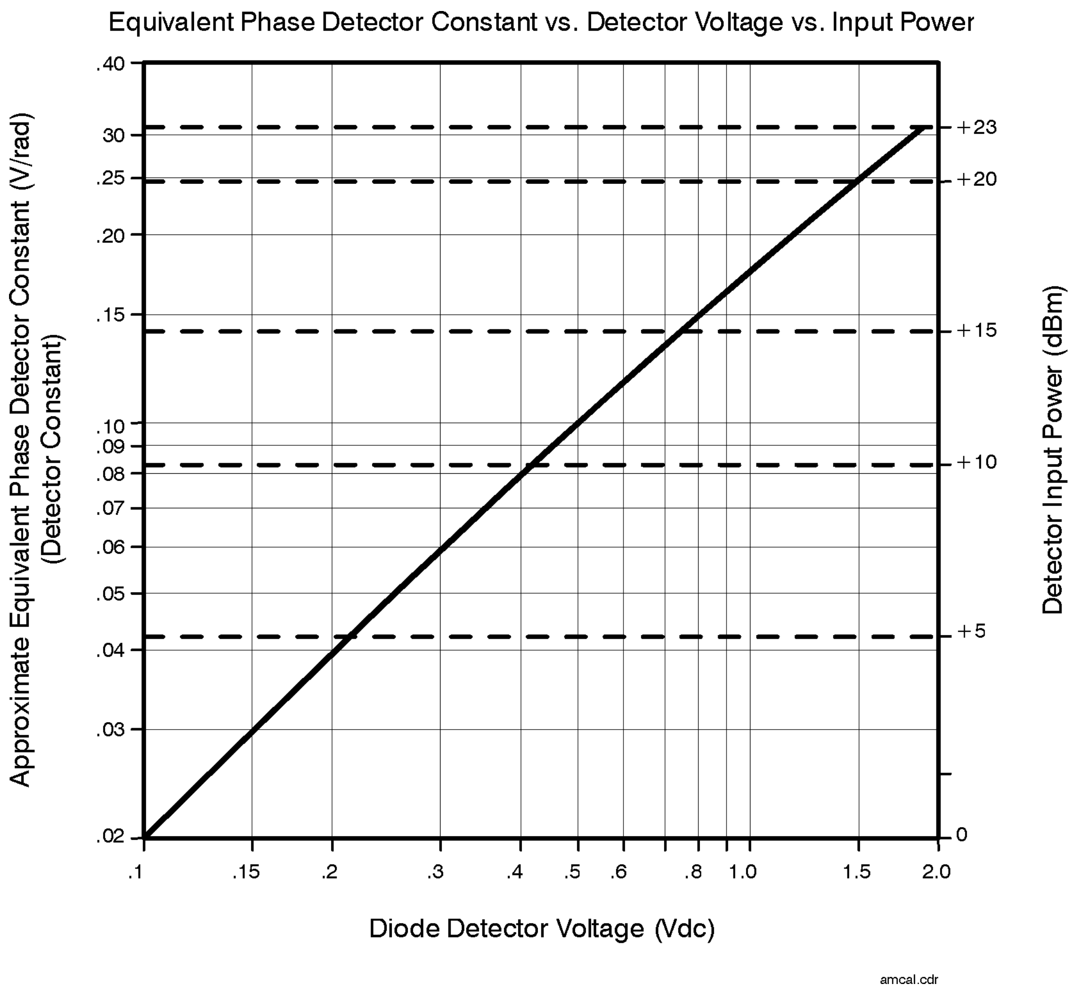


Figure 17-6

Voltage Controlled Source Tuning Requirements

Peak Tuning Range (PTR) ≈ Tune Range of VCO x VCO Tune Constant.

Min. PTR =.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 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 17-7.

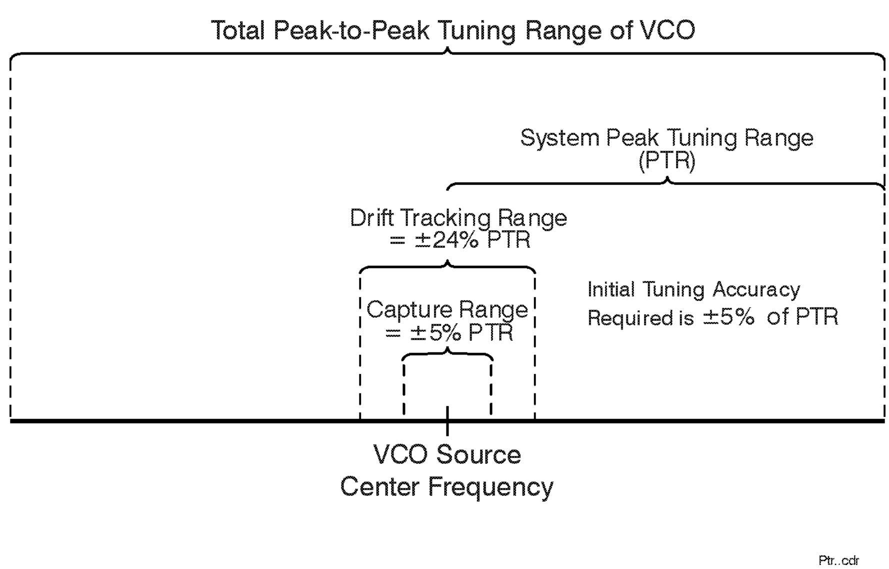


Figure 17-7

Tune Range of VCO vs. Center Voltage

The graph shown in Figure 17-8 outlines the minimum to maximum Tune Range of VCO which 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.

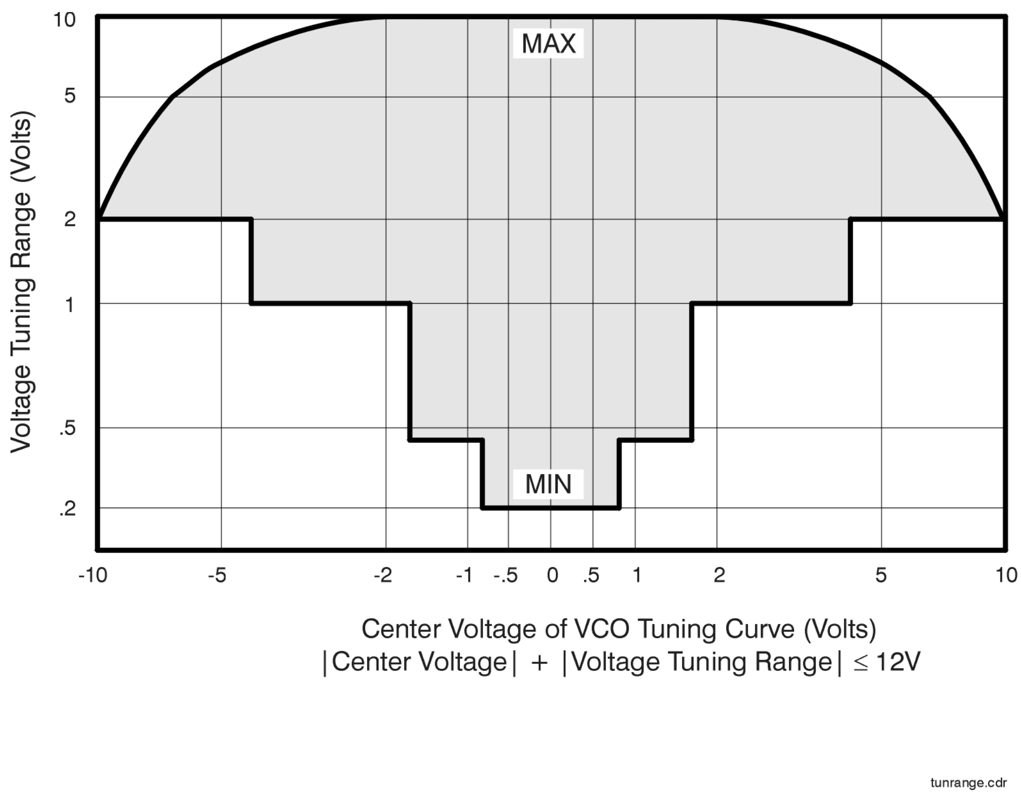


Figure 17-8

Peak Tuning Range Required Due to Noise Level

The graph shown in Figure 17-9 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.

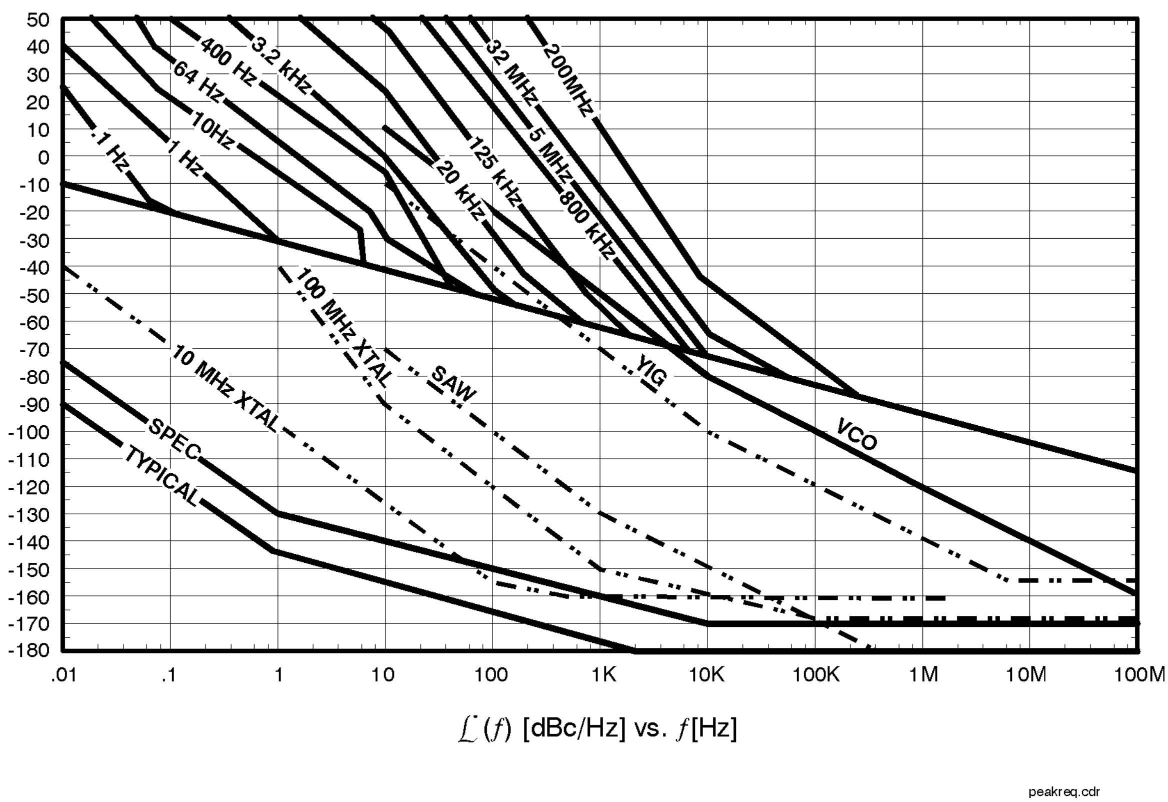


Figure 17-9

Phase Lock Loop Bandwidth vs. Peak Tuning Range

The graph shown in Figure 17-10 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.

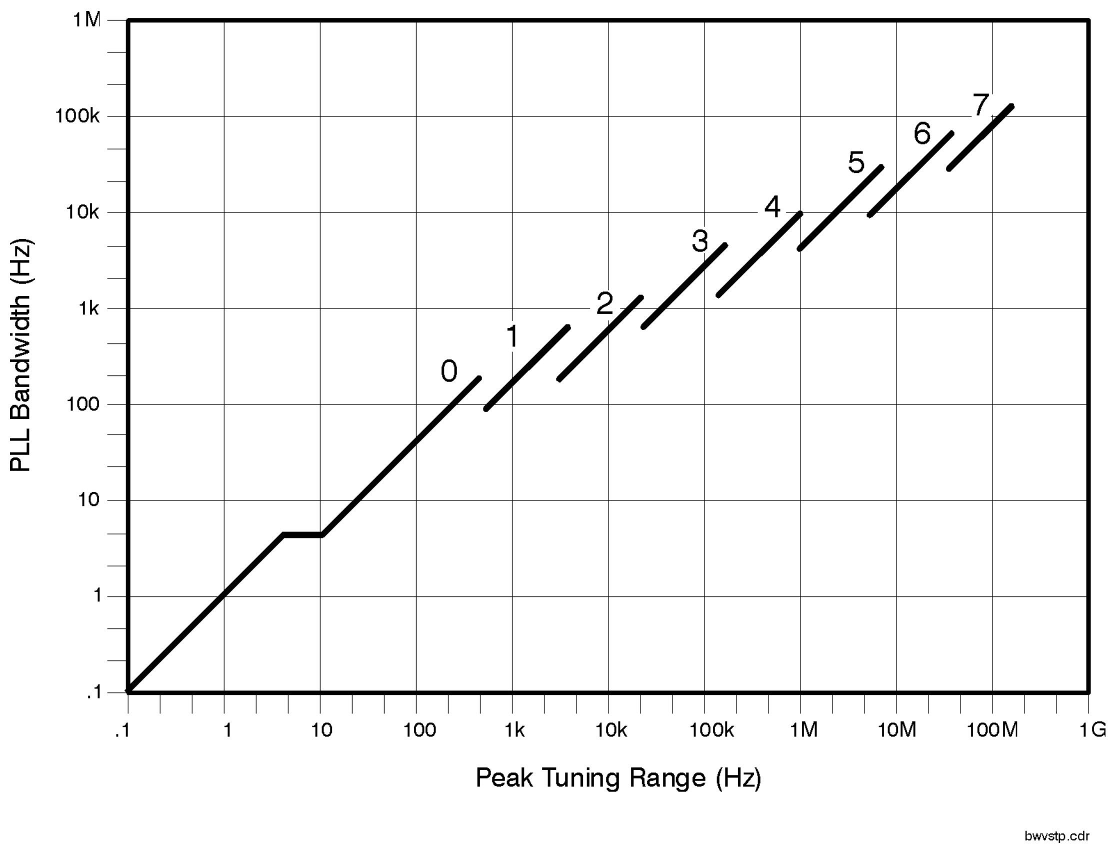


Figure 17-10

Noise Floor Limits Due to Peak Tuning Range

The graph shown in Figure 17-11 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.)

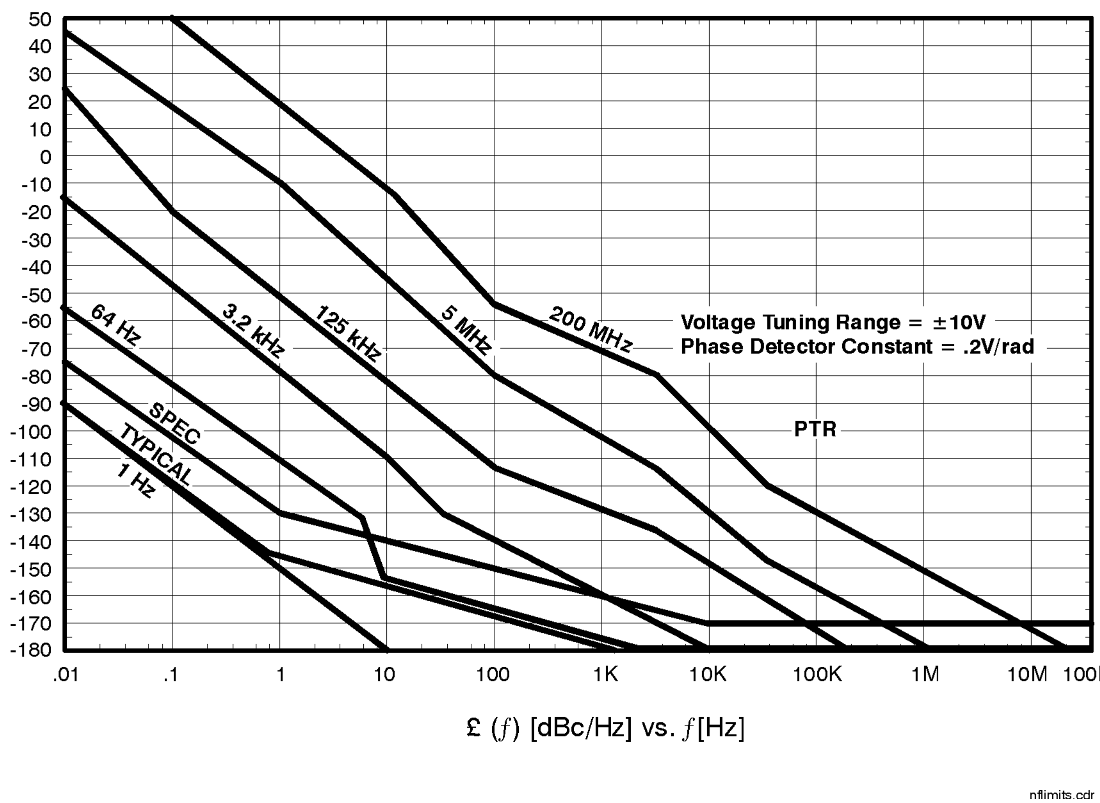


Figure 17-11

Tuning Characteristics of Various VCO Source Options

Table 17-1 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	υ_0	$5\,E-9 \times \upsilon_0$	0	10	1E + 6	Measure
DCFM		FM Deviation	0	10	1 k (8662)	Calculate
					600 (8663)	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[1] (*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 vs. Center Voltage" on page 17-10	1 E + 6	Measure

[1] **Caution: Exceeding 5 volts maximum may damage equipment.**

Agilent 8643A Frequency Limits

Table 17-2 Agilent 8643A Frequency Limits

Note: Special Function 120 must be enabled for DCFM

[1] Minimum Recommended PTR (Peak Tune Range)
PTR =FM Deviation x VTR

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 17-16).

[2] The Agilent 8643A defaults to Mode 2 operation.

[3] Wideband FM: Use Special Function 125 (refer to "How to Access Special Functions" on page 17-16).

Agilent 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 the following table.
- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 17-3. The Agilent 8643A defaults to Mode 2 operation.

Table 17-3 Operating Characteristics for Agilent 8643A Modes 1, 2, and 3

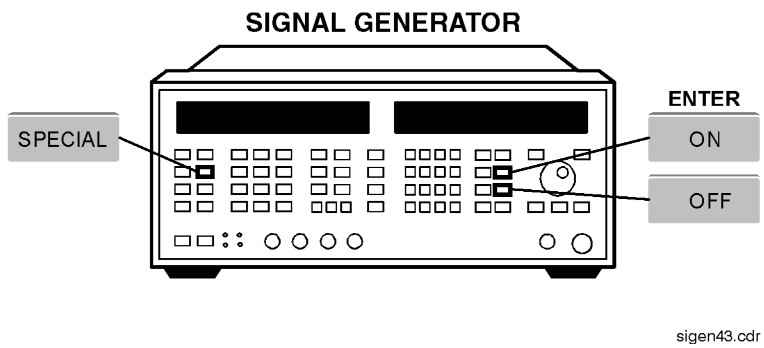
Characteristic	Synthesis Mode	
	Mode 1	Mode 2
RF Frequency Switching Time	90 ms	200 ms
FM Deviation at 1 GHz	10 MHz	1 MHz
Phase Noise (20 kHz offset at 1 GHz)	-120 dBc	-130 dBc

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).



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 (Agilent 8643A only)

Mode 1 operation can be selected using this special function, which allows you to turn on wide FM deviation. The Agilent 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.

Agilent 8644B Frequency Limits

Table 17-4 Agilent 8644B Frequency Limits

Note: Special Function 120 must be enabled for 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	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 17-18).

Agilent 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 17-5.
- 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 17-5 Operating Characteristics for Agilent 8644B Modes 1, 2, and 3

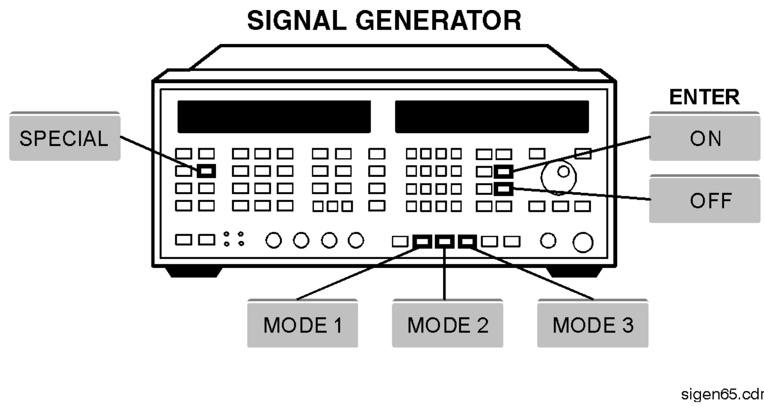
Characteristic	Synthesis Mode		
	Mode 1	**Mode 2**	**Mode 3**
RF Frequency Switching Time	90 ms	200 ms	350 ms
FM Deviation at 1 GHz	10 MHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-120 dBc	-130 dBc	-136 dBc

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).



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.

Agilent 8664A Frequency Limits

Table 17-6 Agilent 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 freq - 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 17-20).

Agilent 8664A Mode Keys

- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 17-7.
- 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 17-7 Operating Characteristics for Agilent 8664A Modes 2 and 3

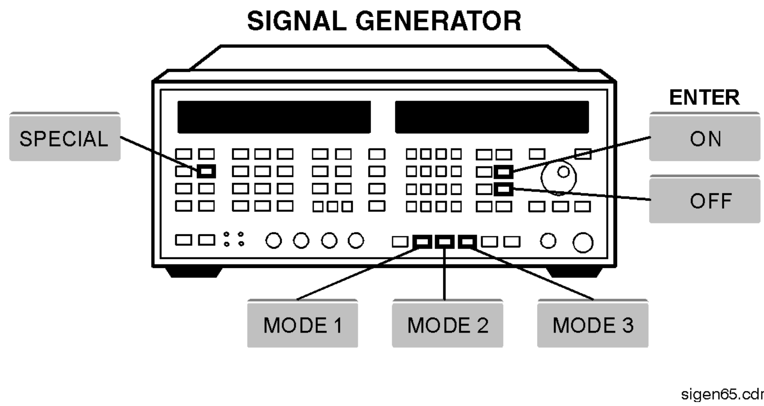
Characteristic	**Synthesis Mode**	
	Mode 2	**Mode 3**
RF Frequency Switching Time	200 ms	350 ms
FM Deviation at 1 GHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-130 dBc	-136 dBc

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).



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.

Agilent 8665A Frequency Limits

Table 17-8 Agilent 8665A Frequency Limits

Note: Special Function 120 must be enabled for 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
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 freq - 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 17-22).

Agilent 8665A Mode Keys

- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 17-9.
- 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 17-9 Operating Characteristics for Agilent 8665A Modes 2 and 3

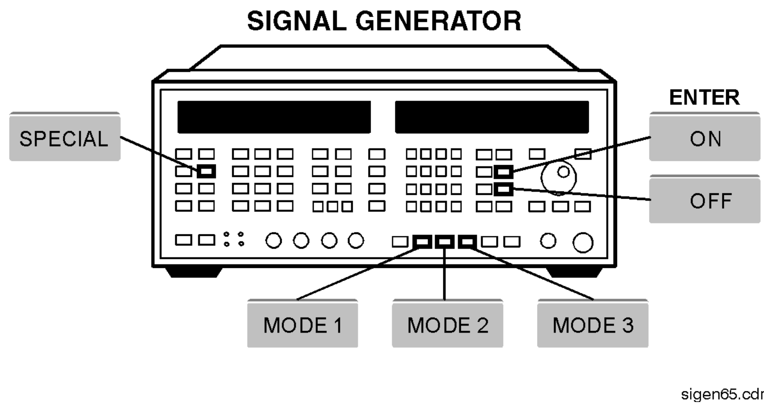
Characteristic	Synthesis Mode	
	Mode 2	Mode 3
RF Frequency Switching Time	200 ms	350 ms
FM Deviation at 1 GHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-130 dBc	-136 dBc

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).



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 Agilent 8643A/8644B User’s Guide for specific details.

Agilent 8665B Frequency Limits

Table 17-10 Agilent 8665B Frequency Limits

Note: Special Function 120 must be enabled for 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
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 freq - 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 17-24).

Agilent 8665B Mode Keys

- The **[Mode 2]** key provides a median range of FM deviation and RF output switching time, as shown in Table 17-11.
- 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 17-11 Operating Characteristics for Agilent 8665B Modes 2 and 3

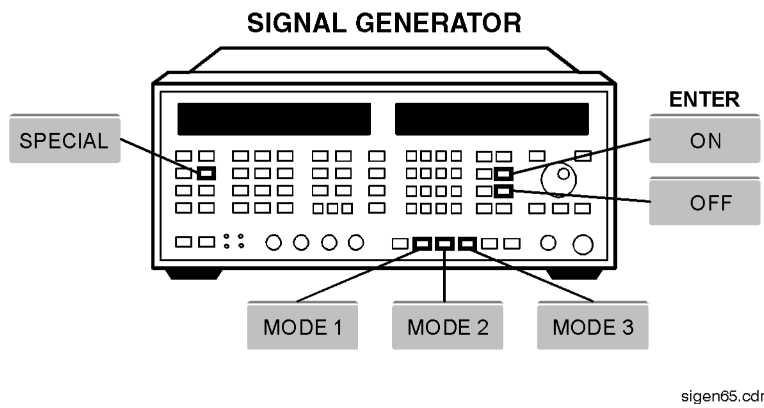
Characteristic	Synthesis Mode	
	Mode 2	Mode 3
RF Frequency Switching Time	200 ms	350 ms
FM Deviation at 1 GHz	1 MHz	100 kHz
Phase Noise (20 kHz offset at 1 GHz)	-130 dBc	-136 dBc

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).



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.

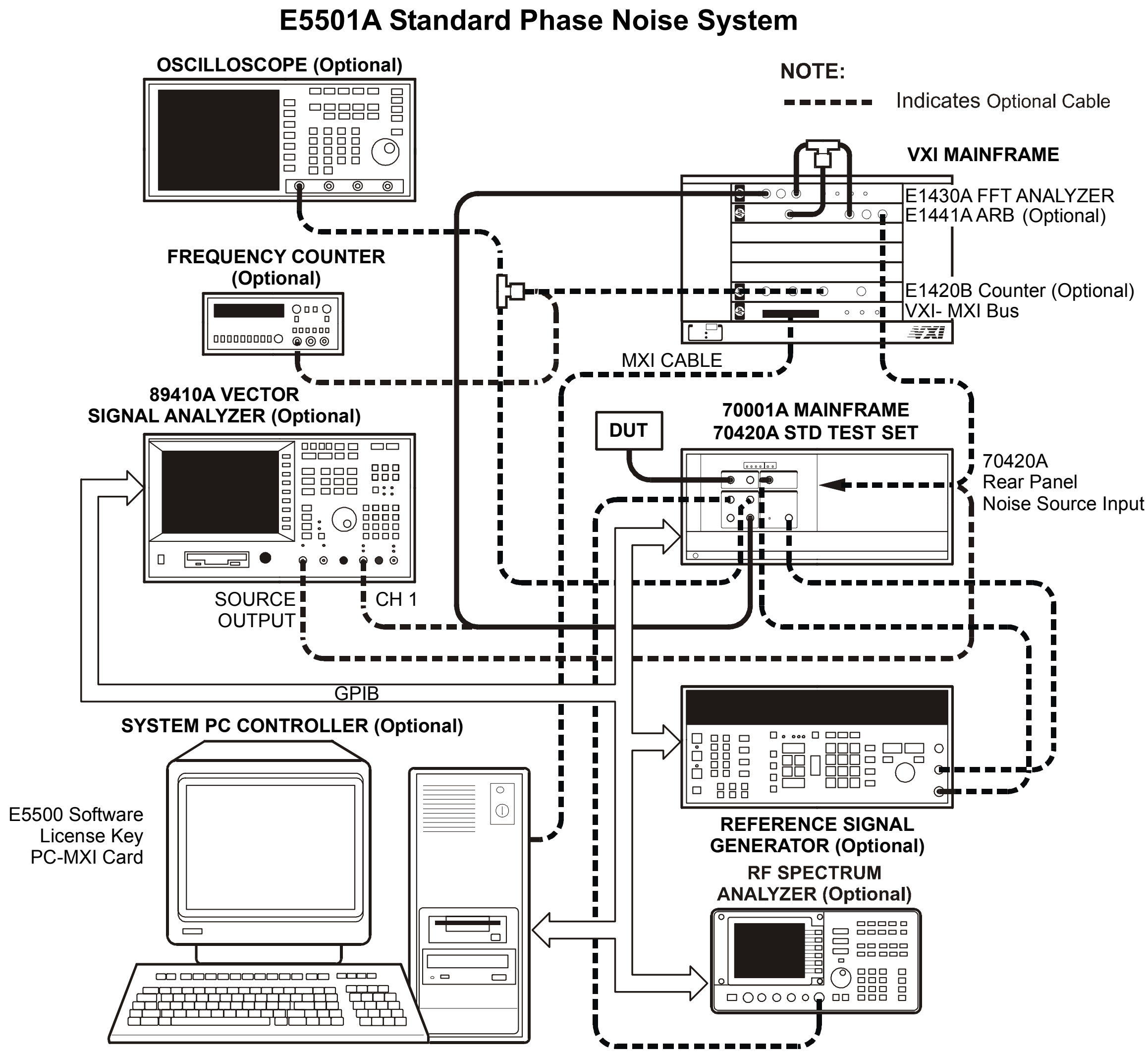
124: FM Dly Equalizer

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 Agilent 8643A/8644B User’s Guide for specific details.

18

Connect Diagrams



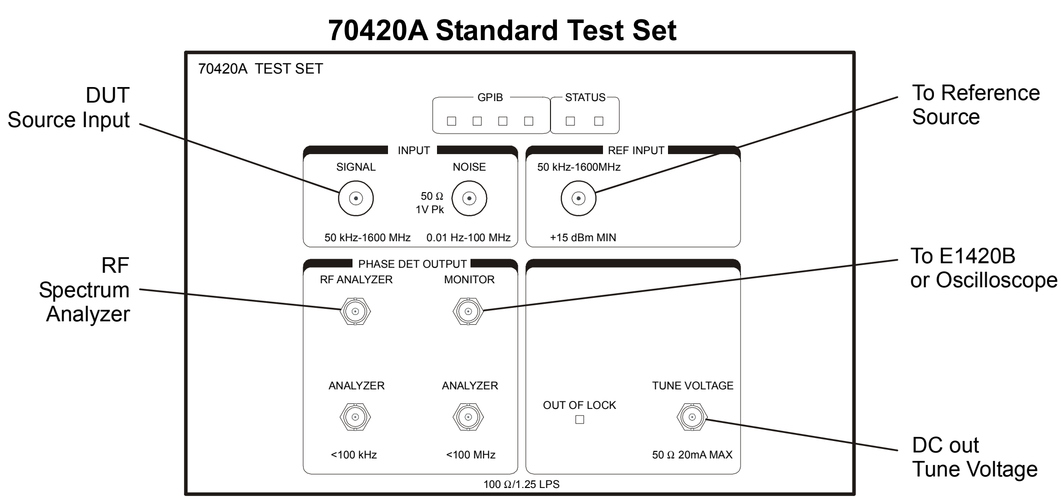
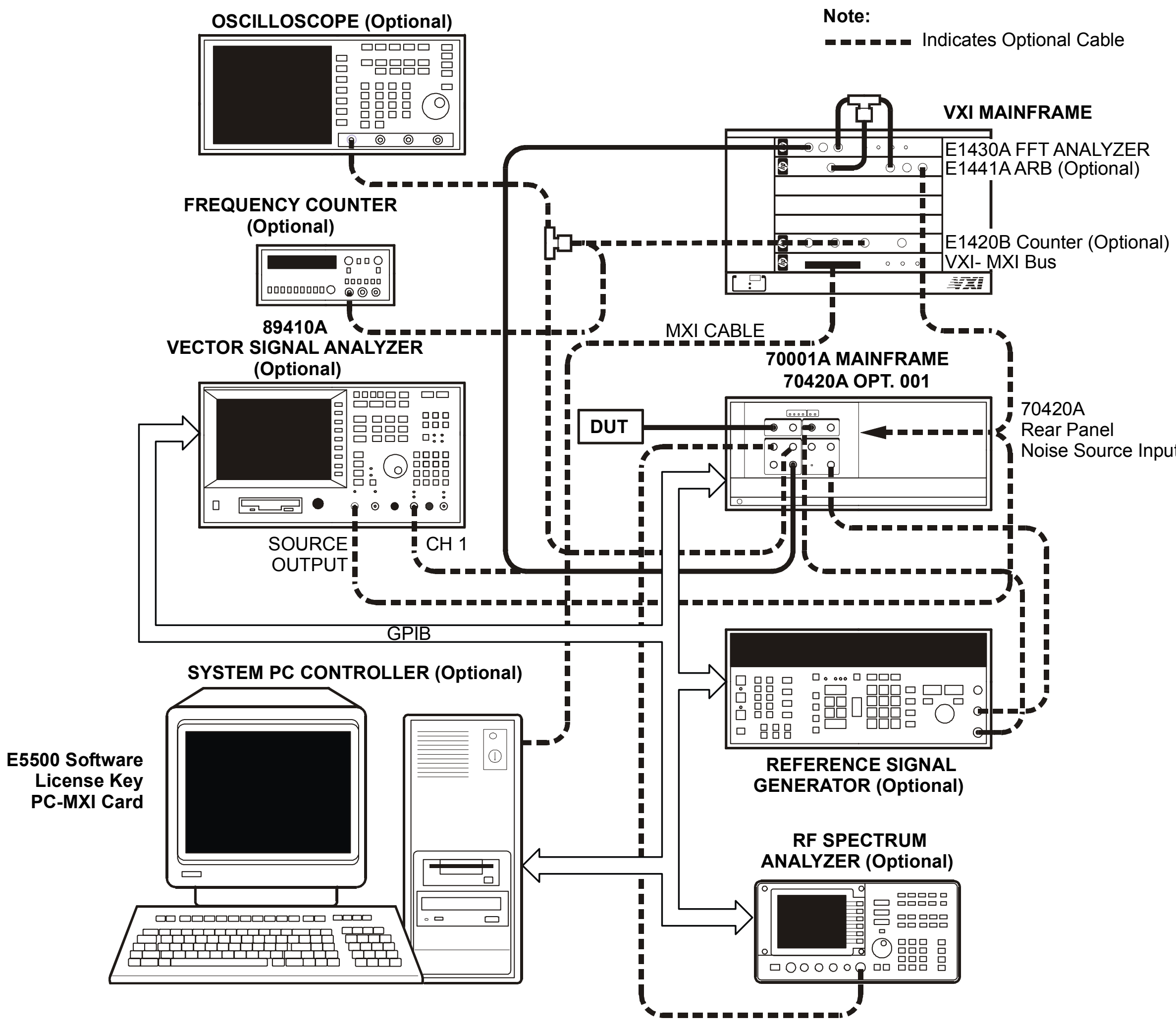


Figure 18-1 E5501A Standard Connect Diagram

E5501A Opt 001 Phase Noise System



70420A Opt. 001 Test Set

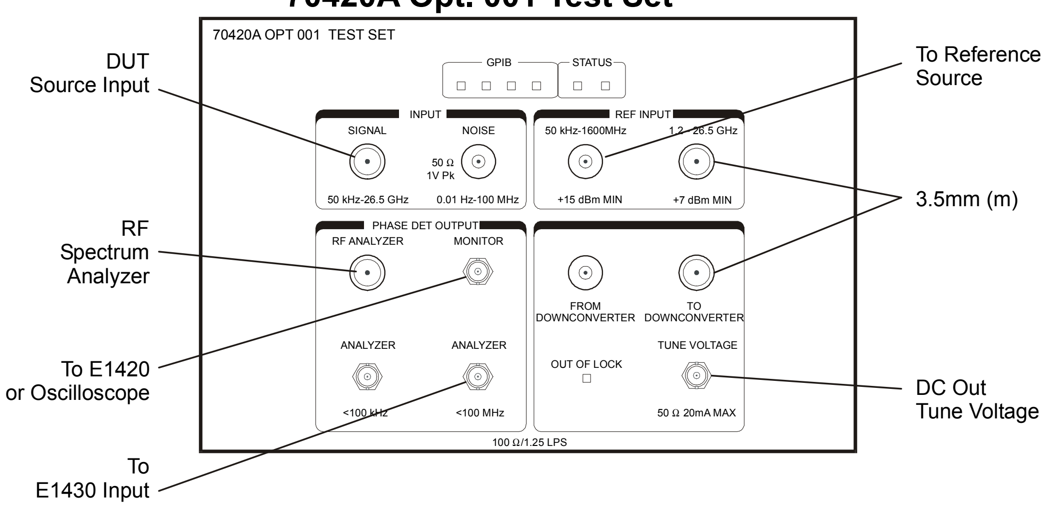
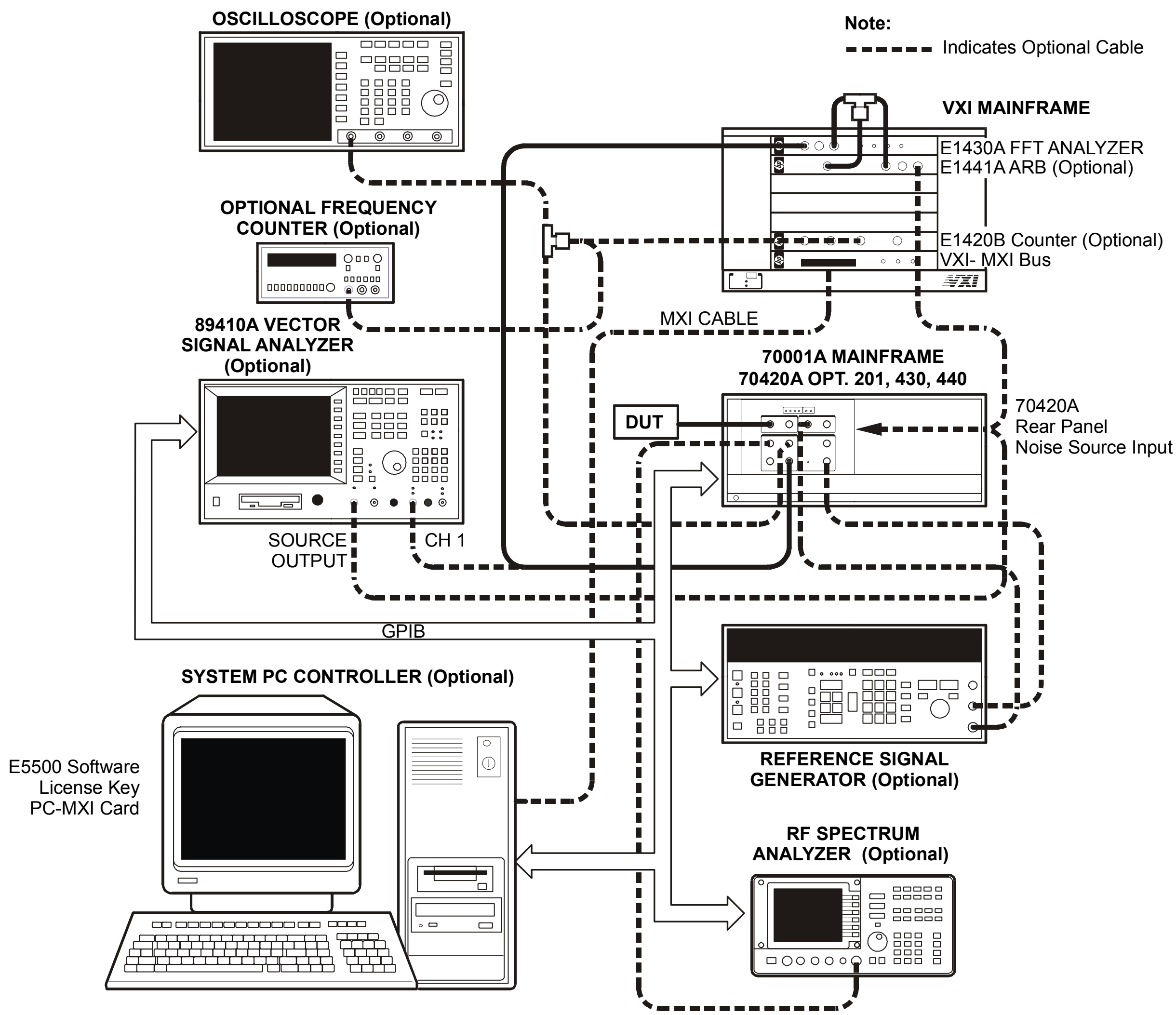


Figure 18-2 E5501A Opt. 001 Connect Diagram

E5501A Opt. 201, 430, 440 Phase Noise System



70420A Opt. 201 Test Set

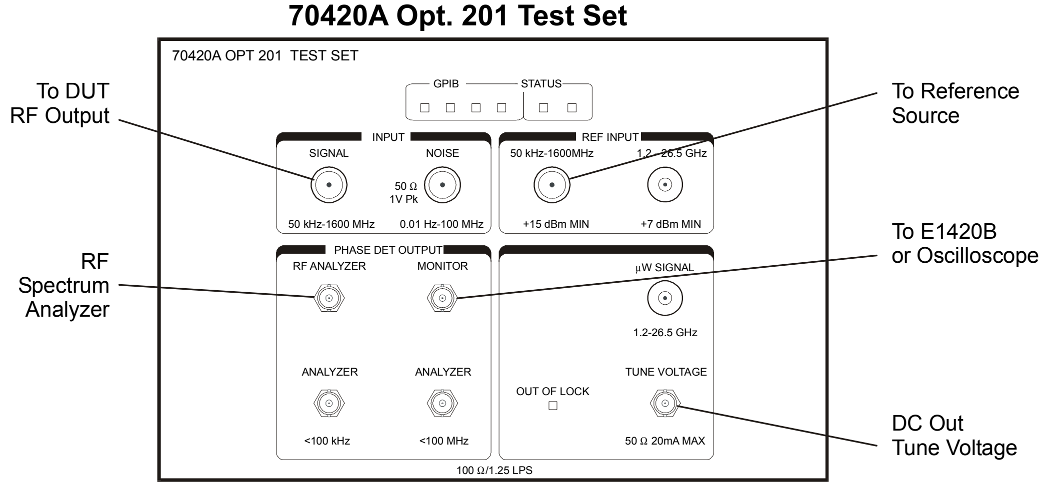
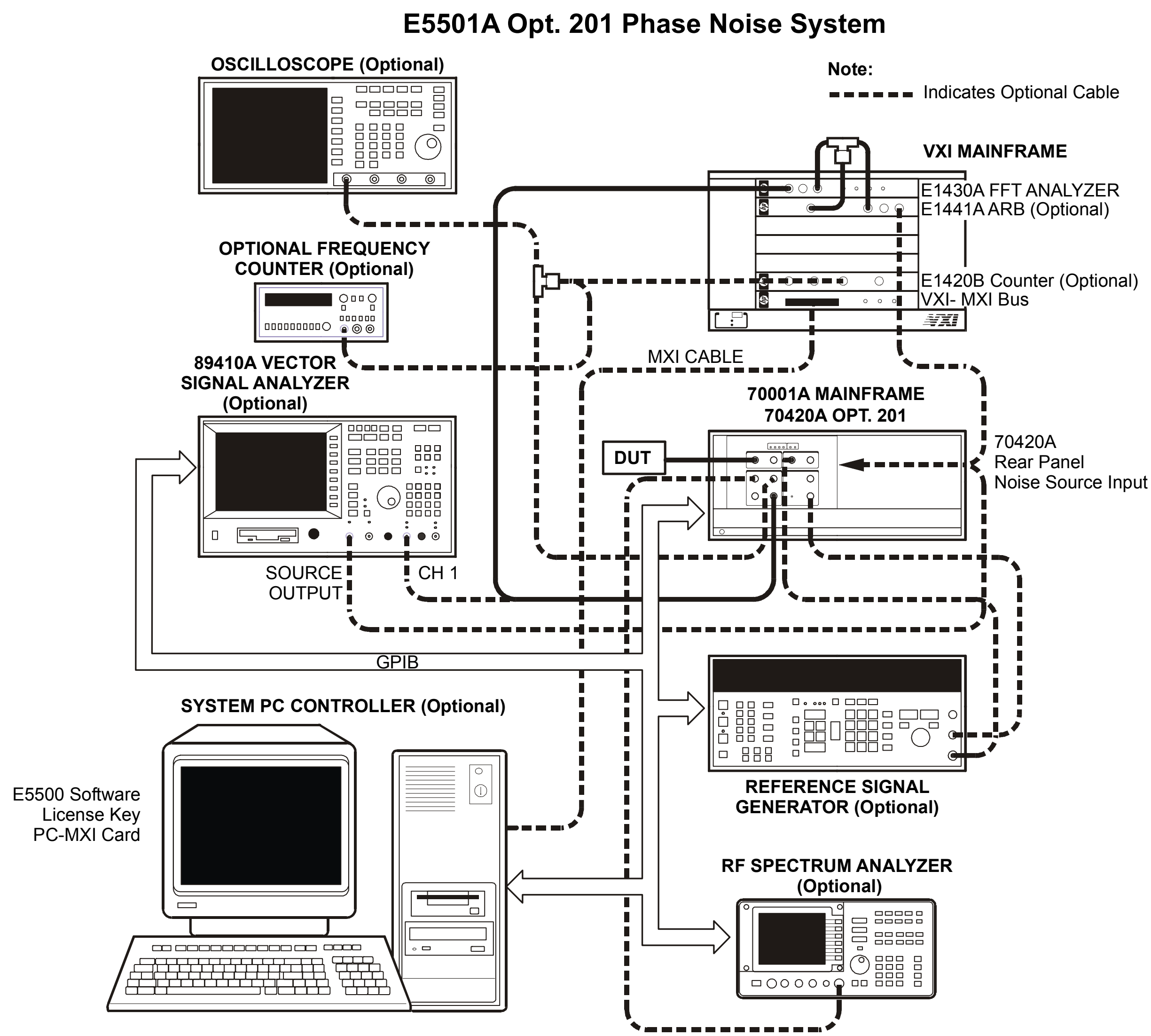


Figure 18-3 E5501A Opt. 201, 430, 440 Connect Diagram



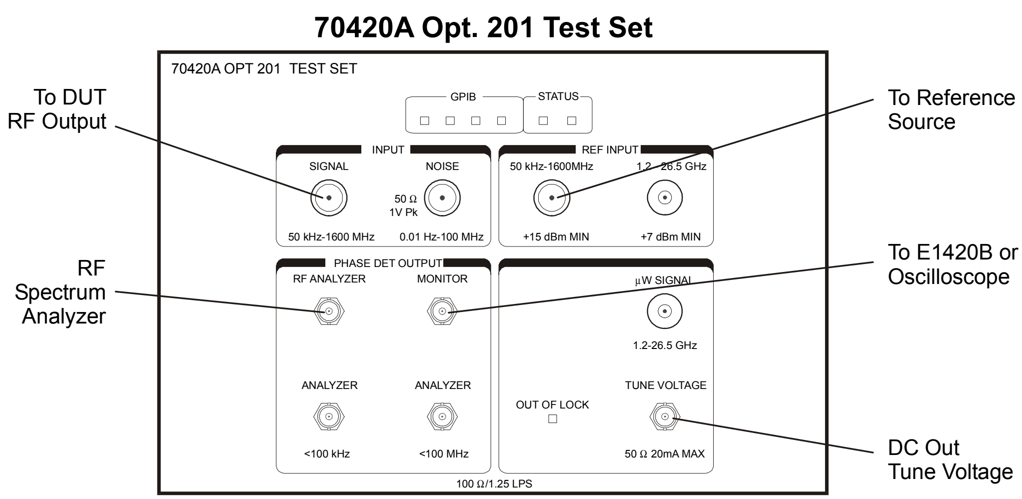


Figure 18-4 E5501A Opt. 201 Connect Diagram

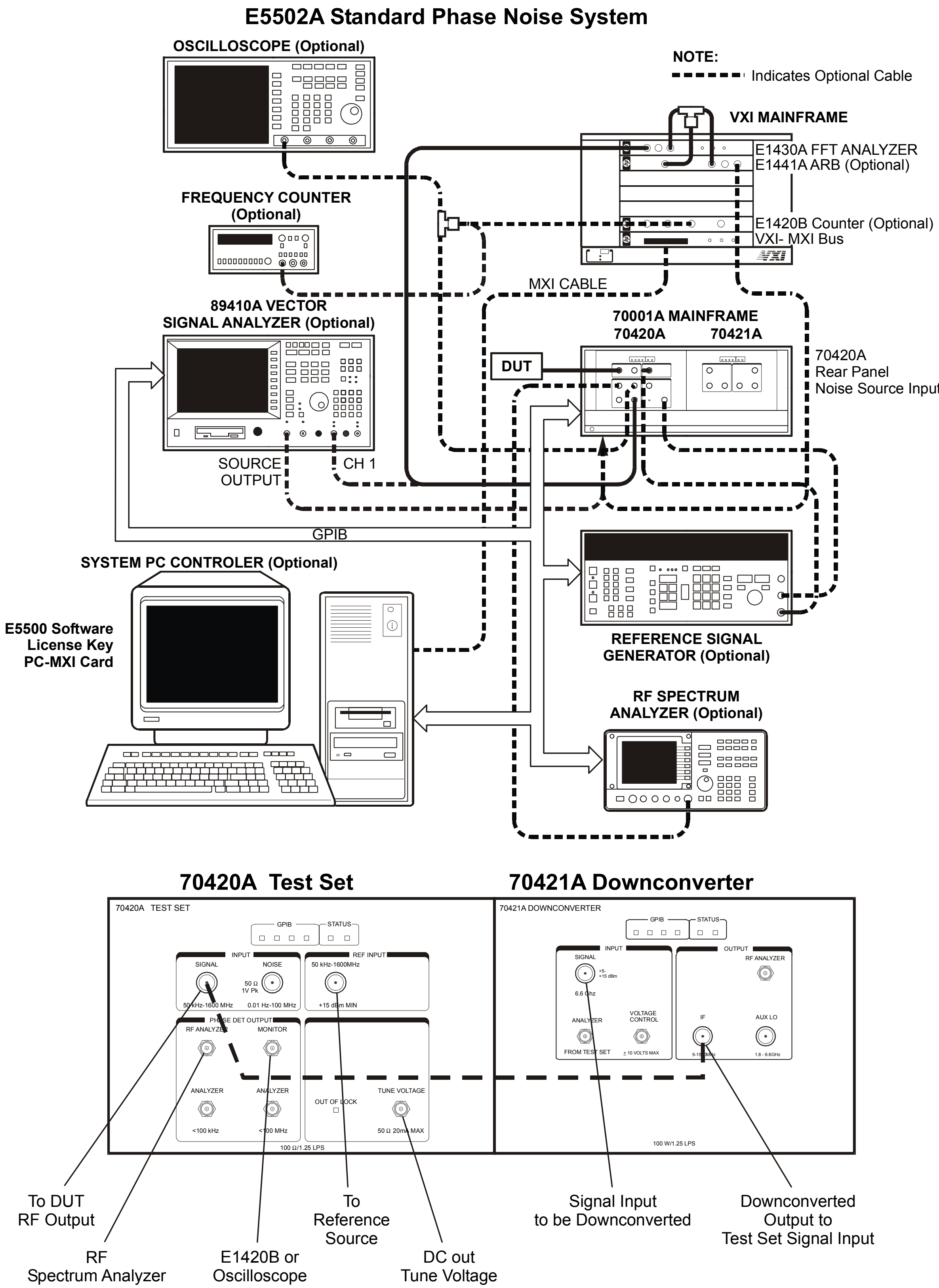


Figure 18-5 E5502A Standard Connect Diagram

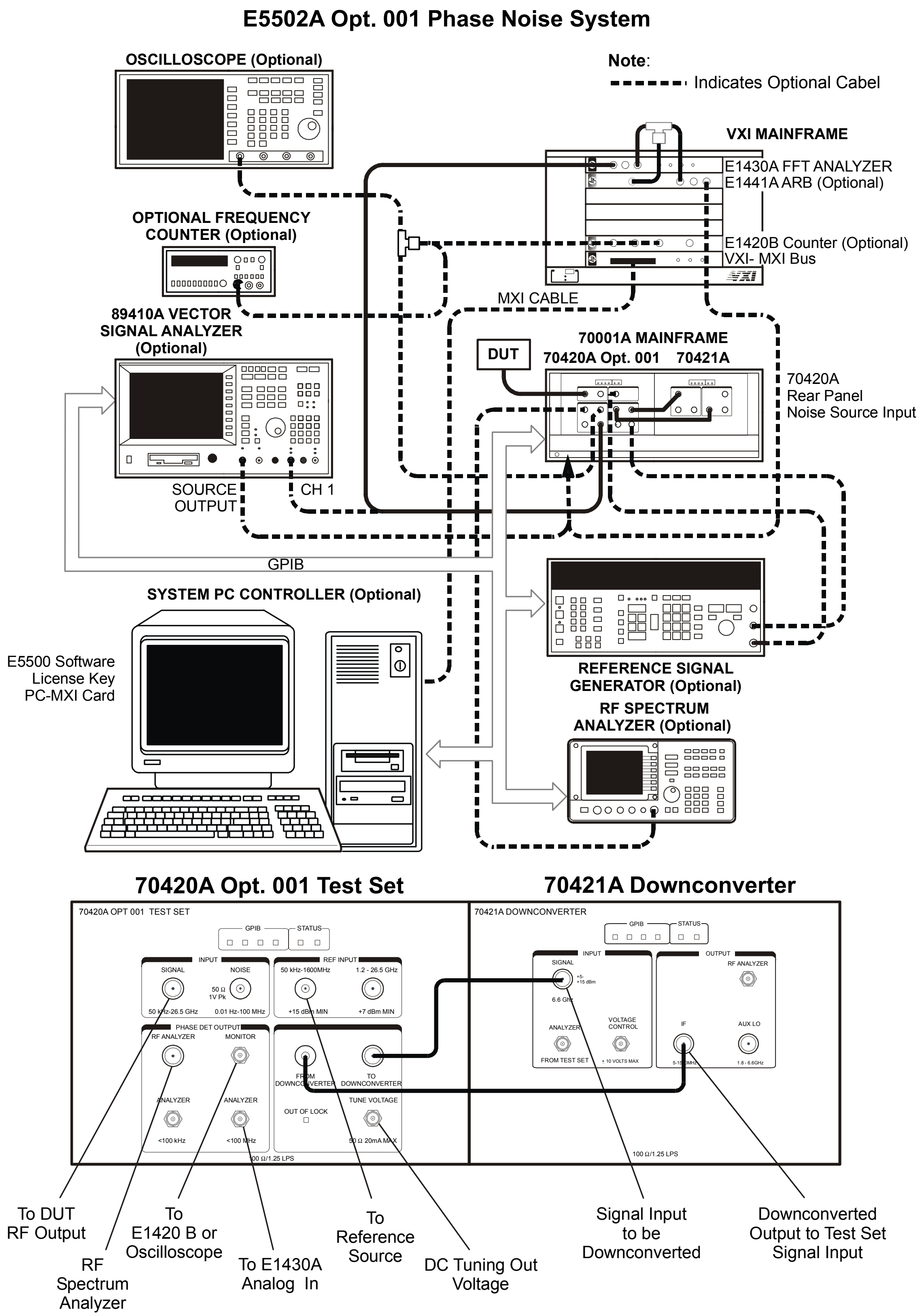


Figure 18-6 E5502A Opt. 001 Connect Diagram

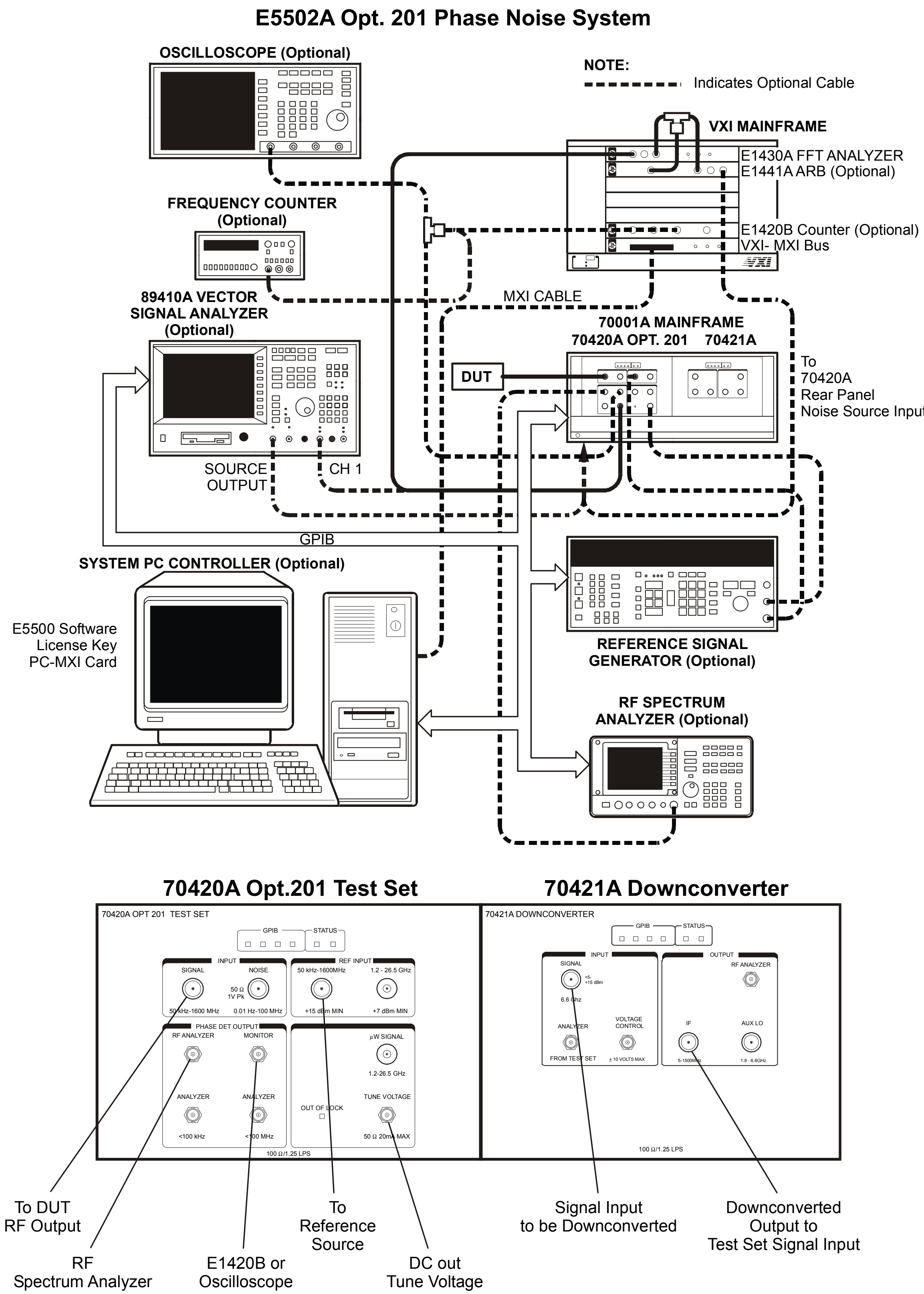


Figure 18-7 E5502A Opt. 201 Connect Diagram

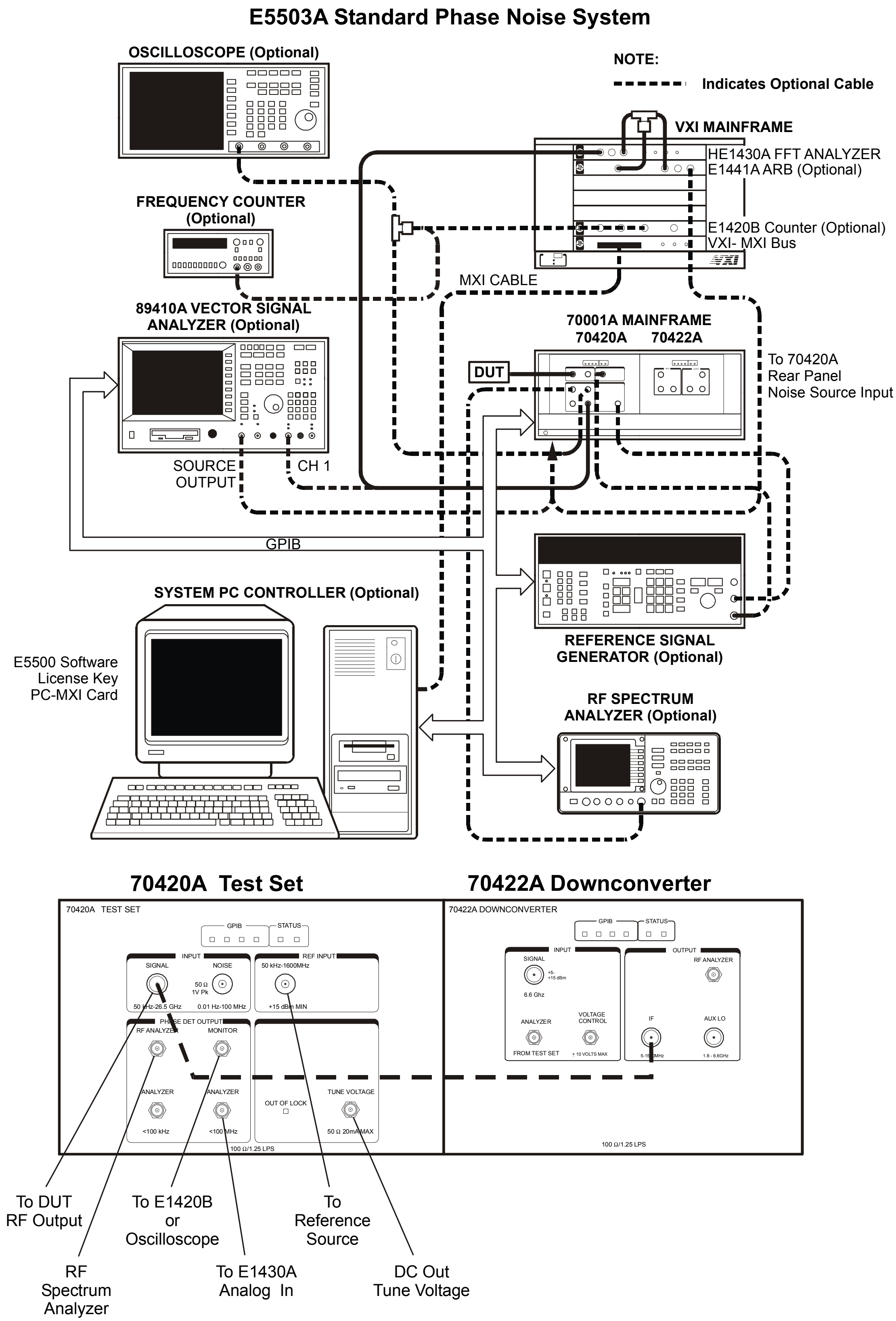


Figure 18-8 E5503A Standard Connect Diagram

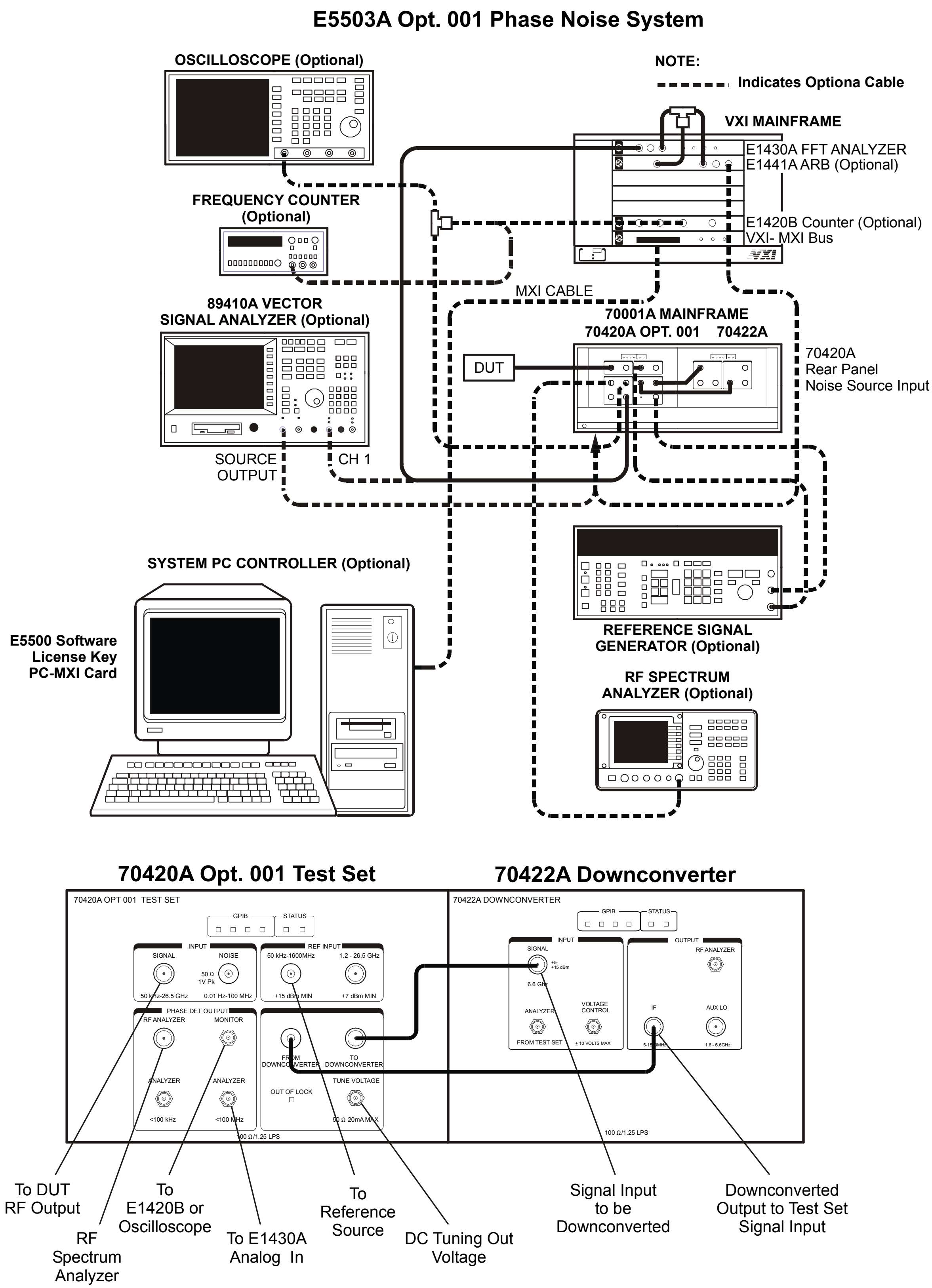


Figure 18-9 E5503A Opt. 001 Connect Diagram

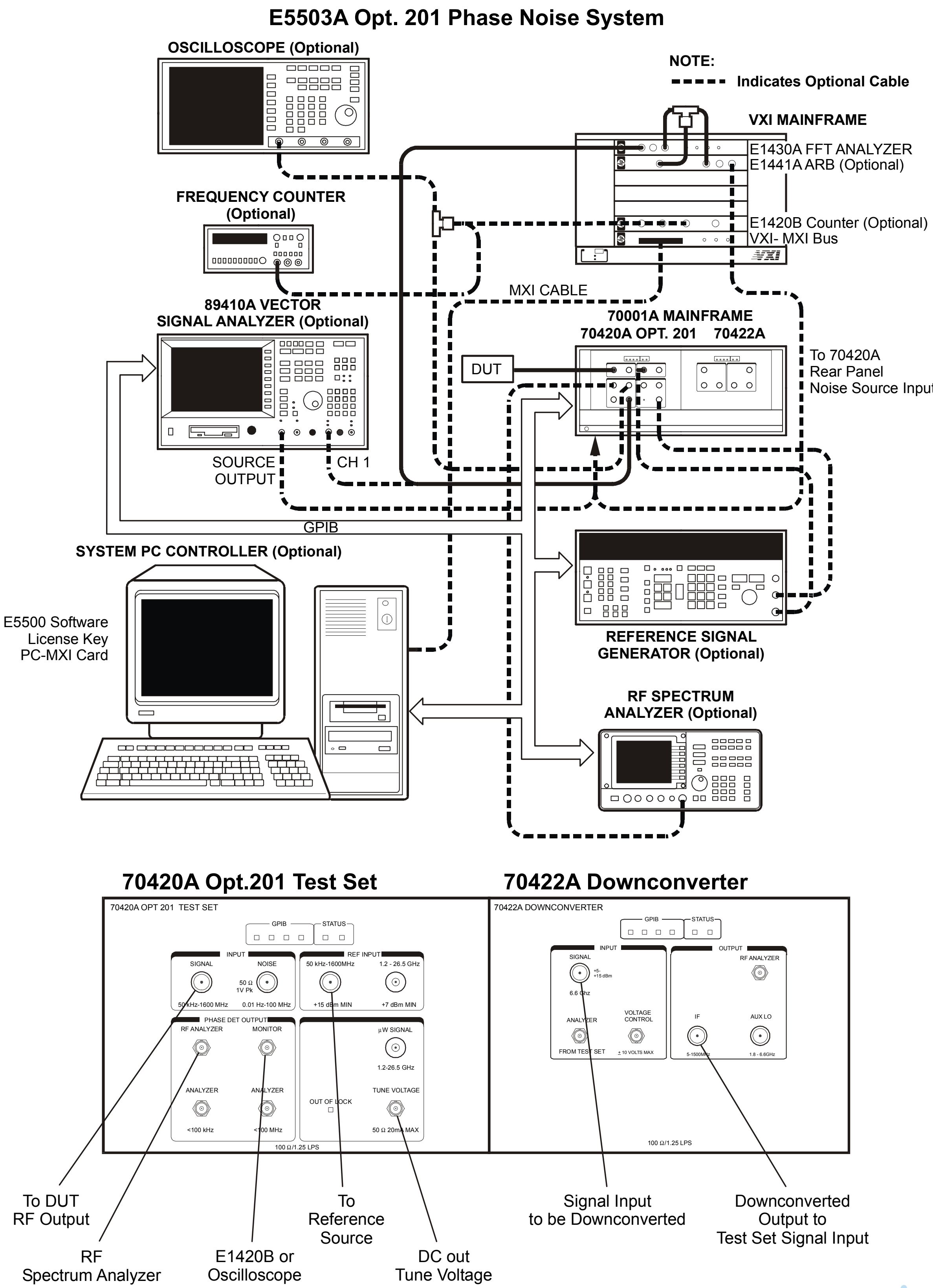


Figure 18-10E5503A Opt. 201 Connect Diagram

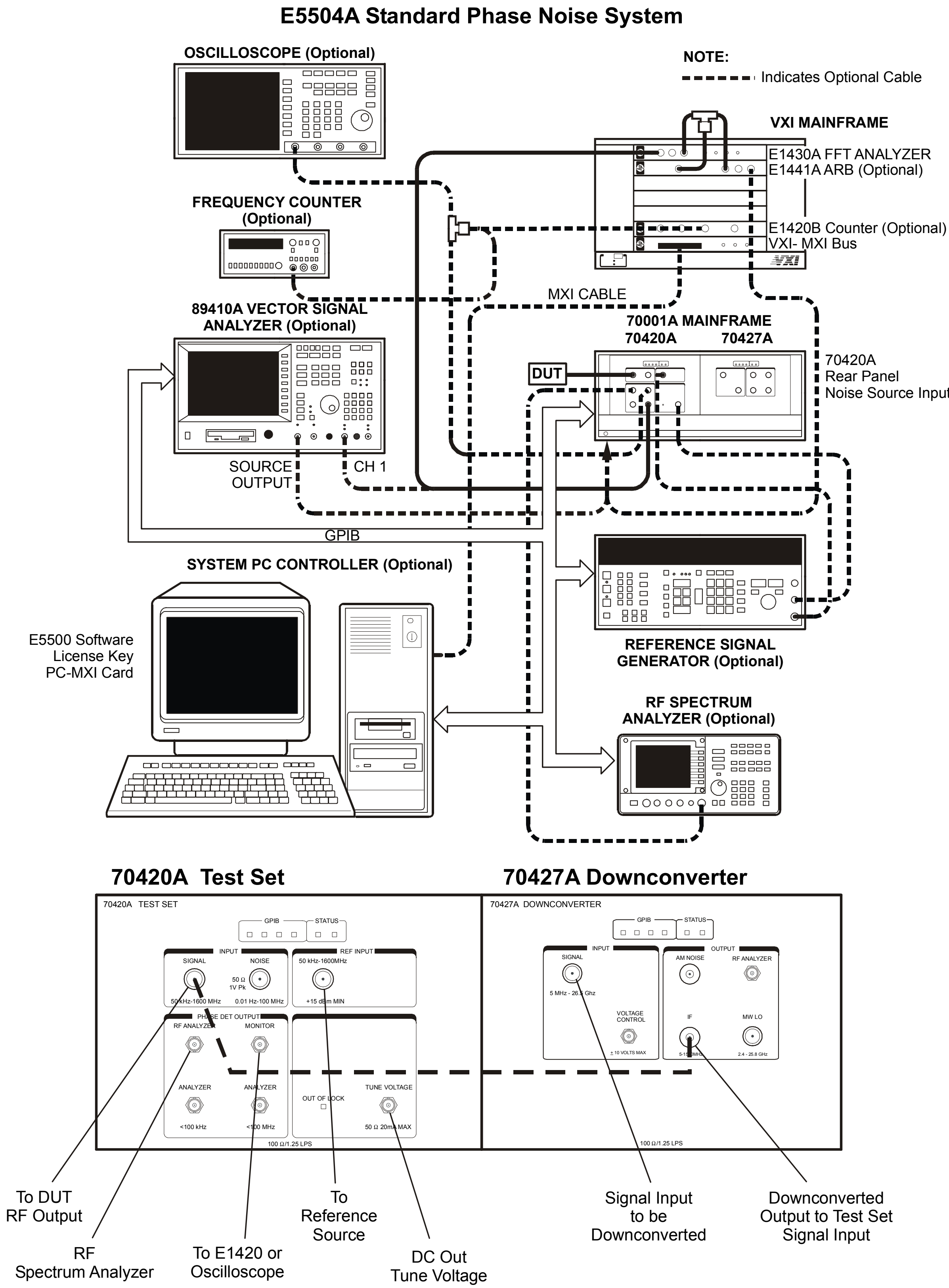


Figure 18-11 E5504A Standard Connect Diagram

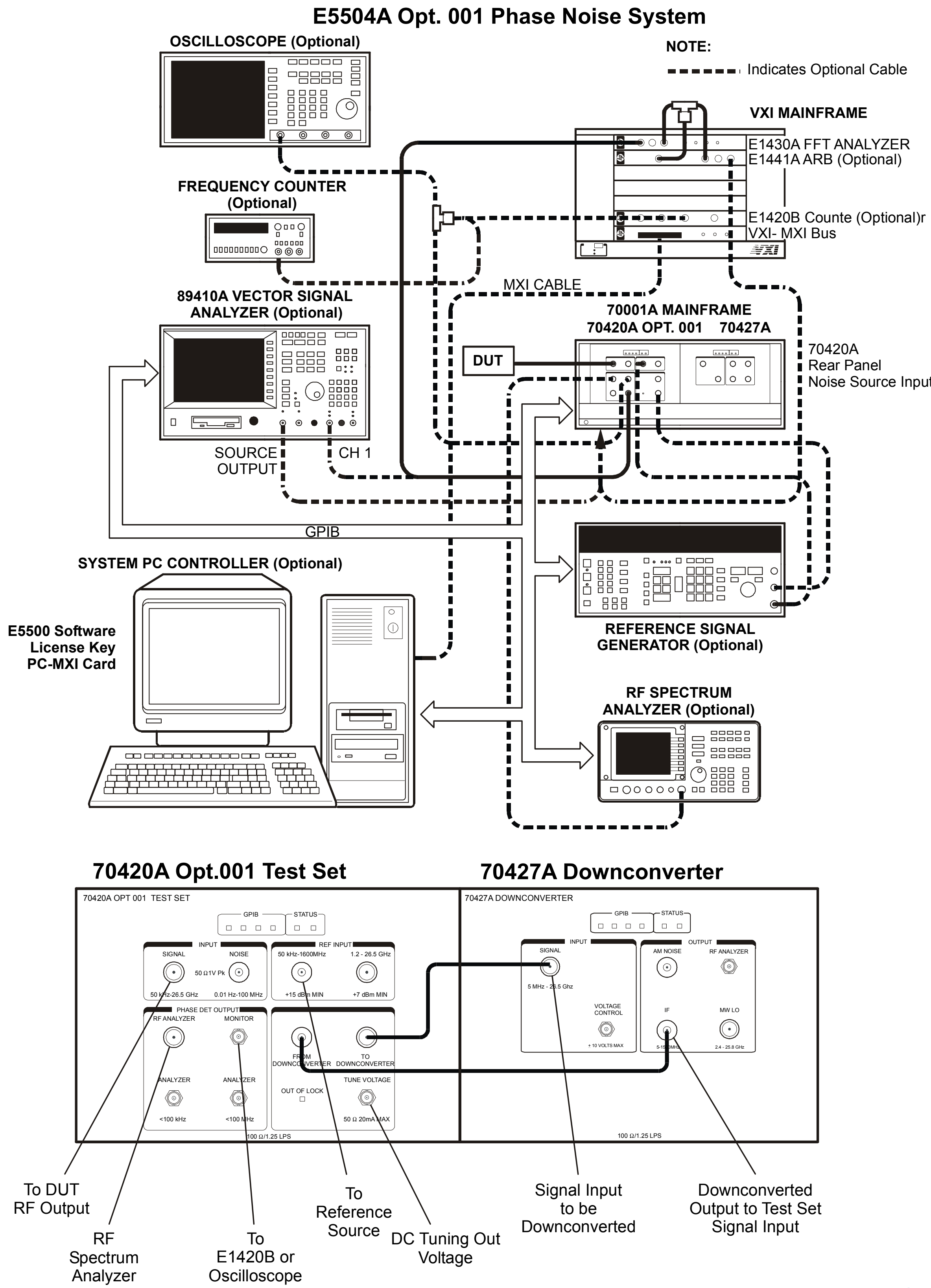


Figure 18-12 E5504A Opt. 001 Connect Diagram

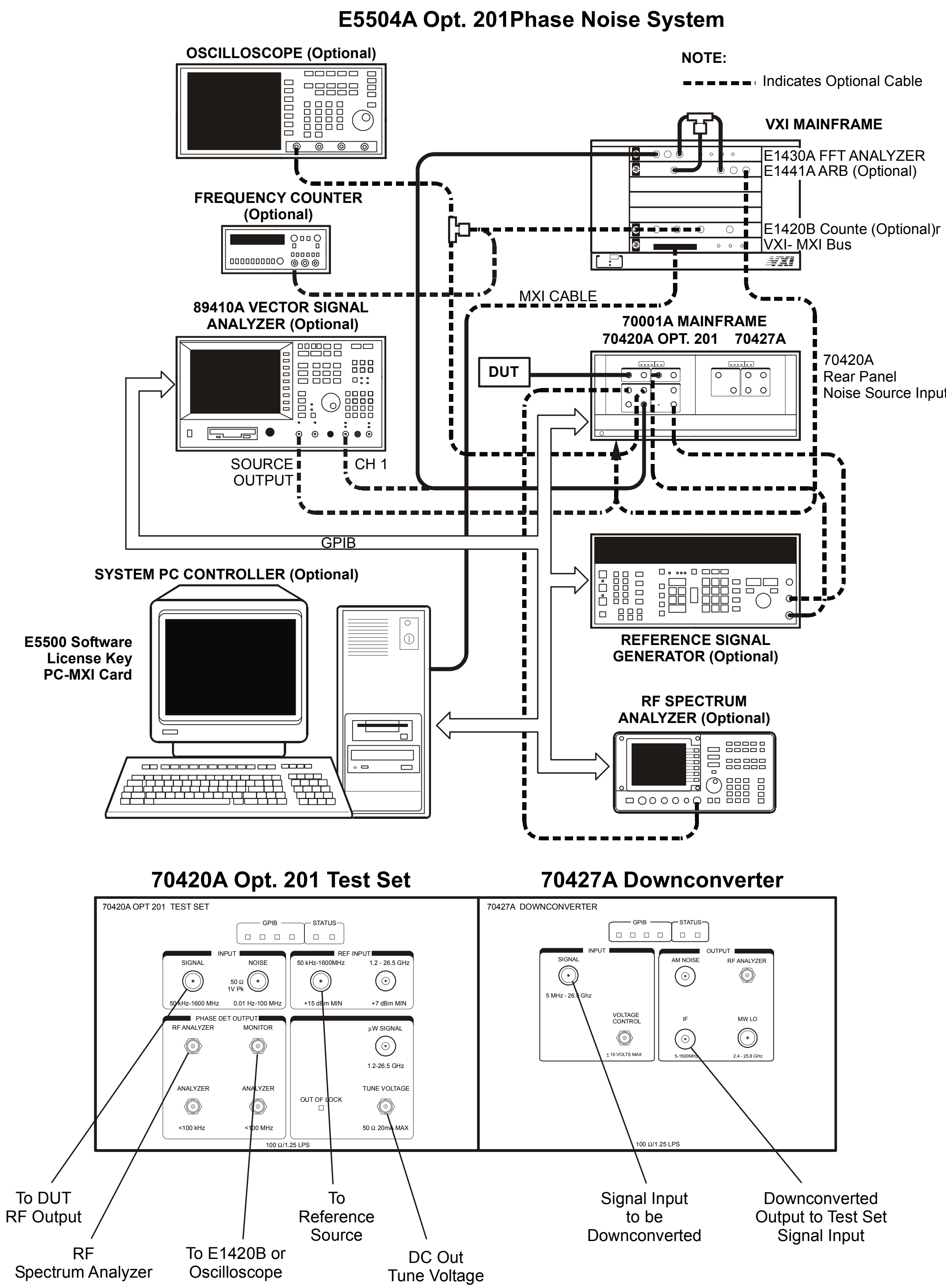


Figure 18-13E5504A Opt. 201 Connect Diagram

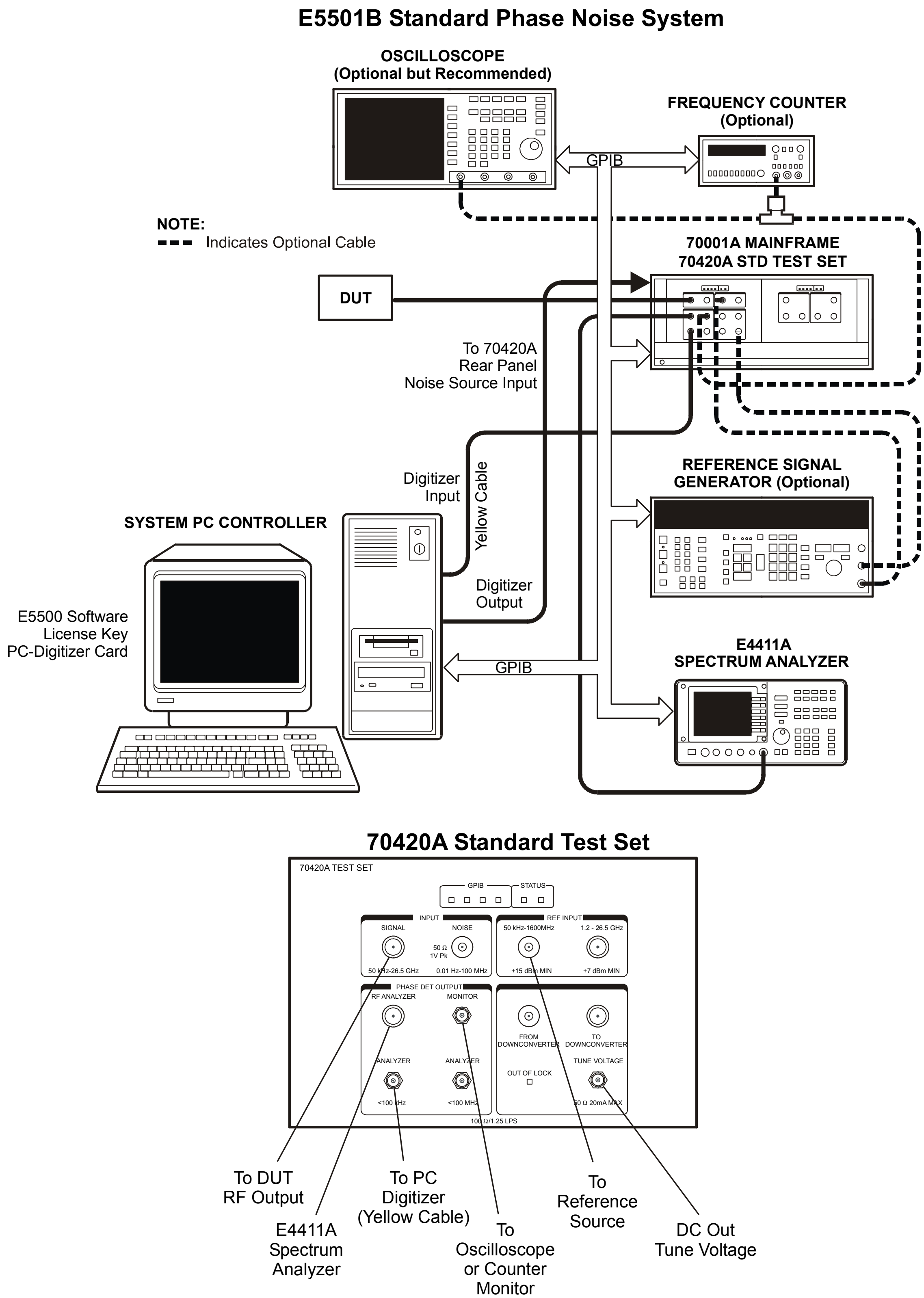
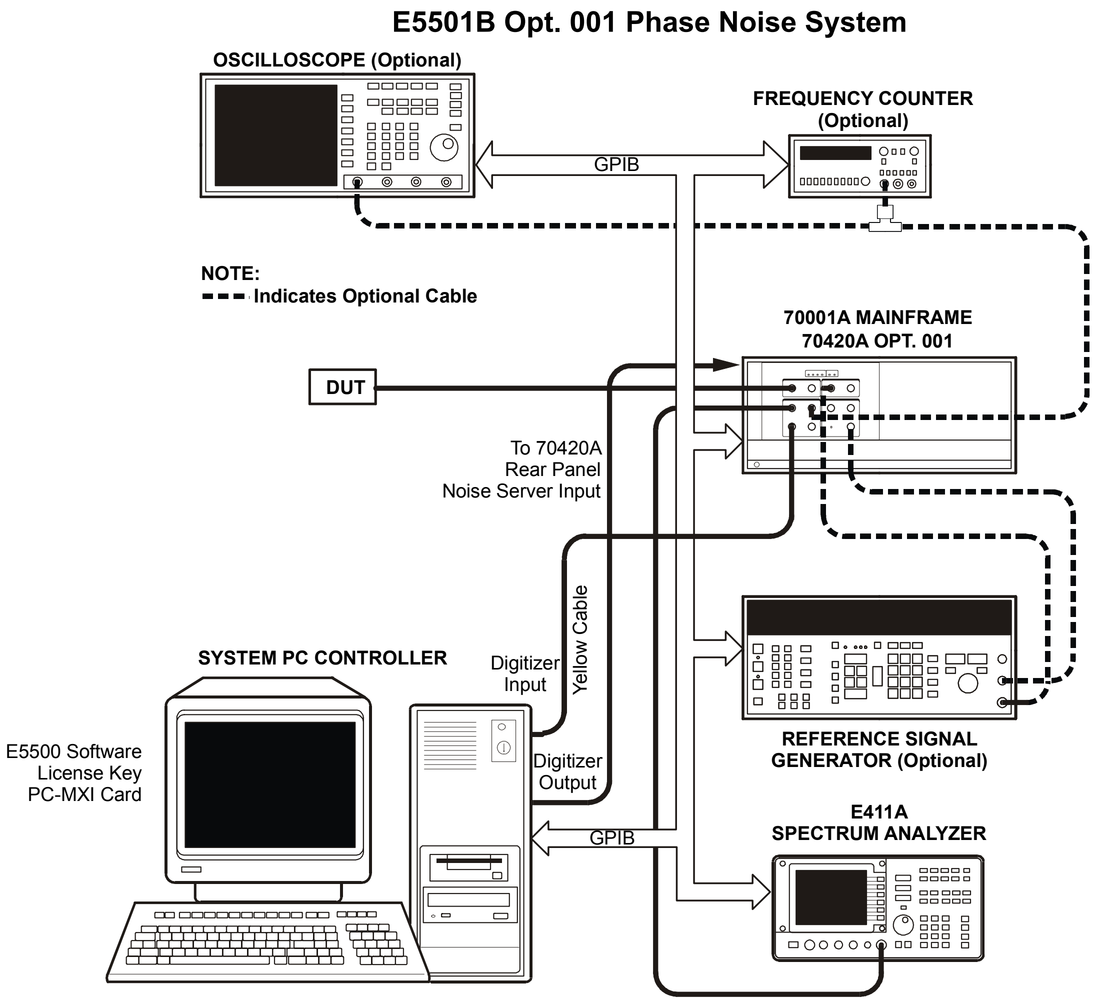


Figure 18-14E5501B Standard Connect Diagram



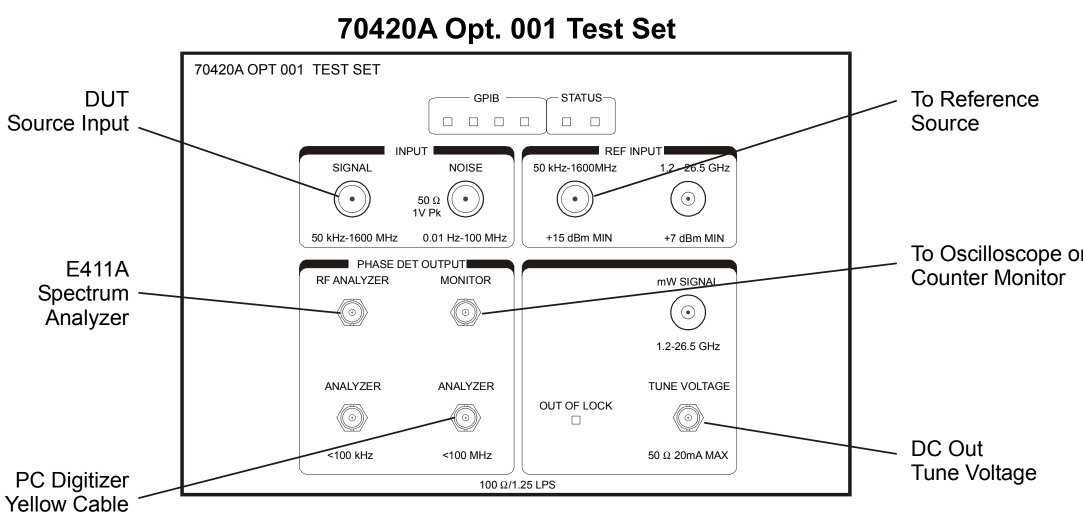


Figure 18-15E5501B Opt. 001 Connect Diagram

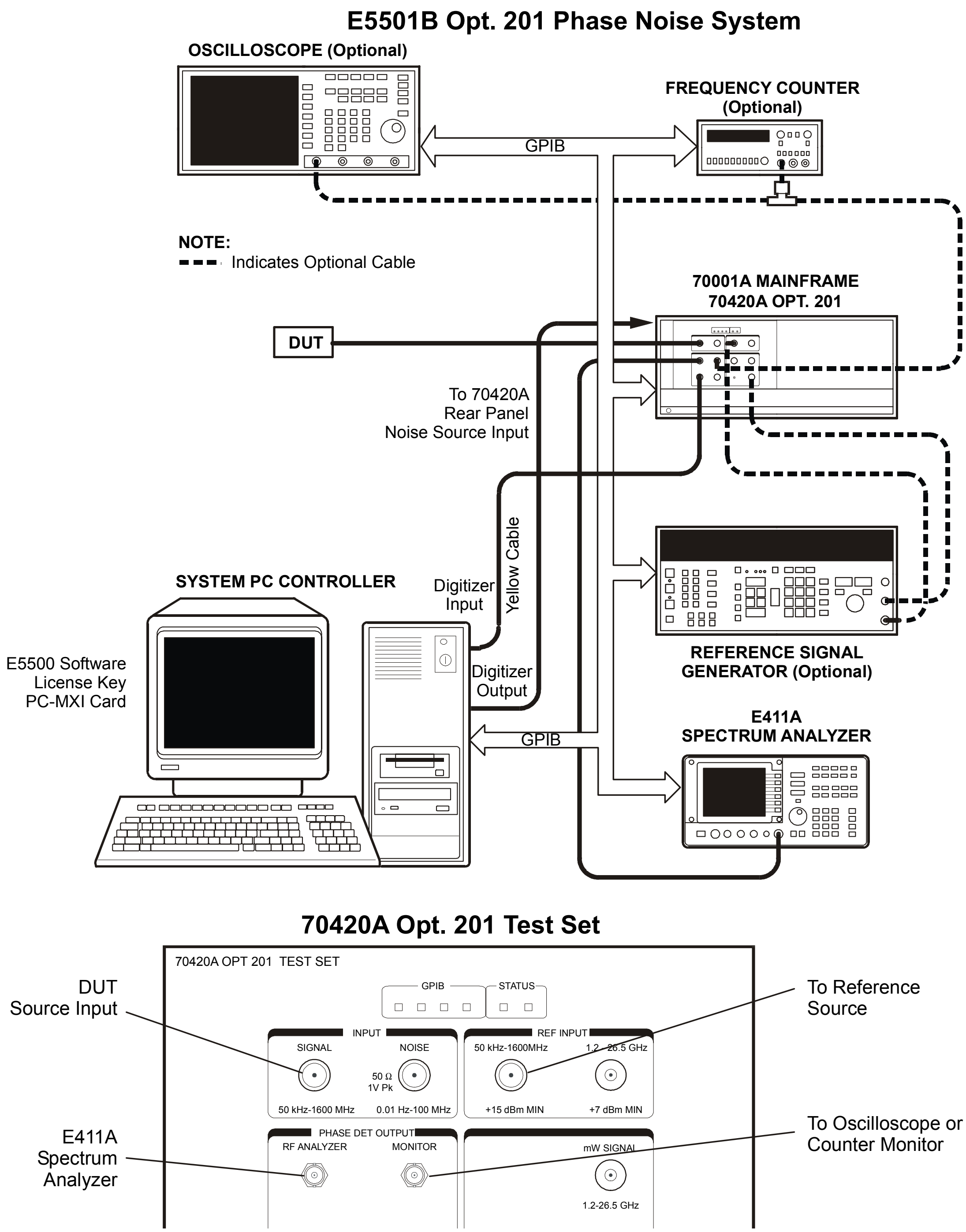


Figure 18-16 E5501B Opt. 201 Connect Diagram

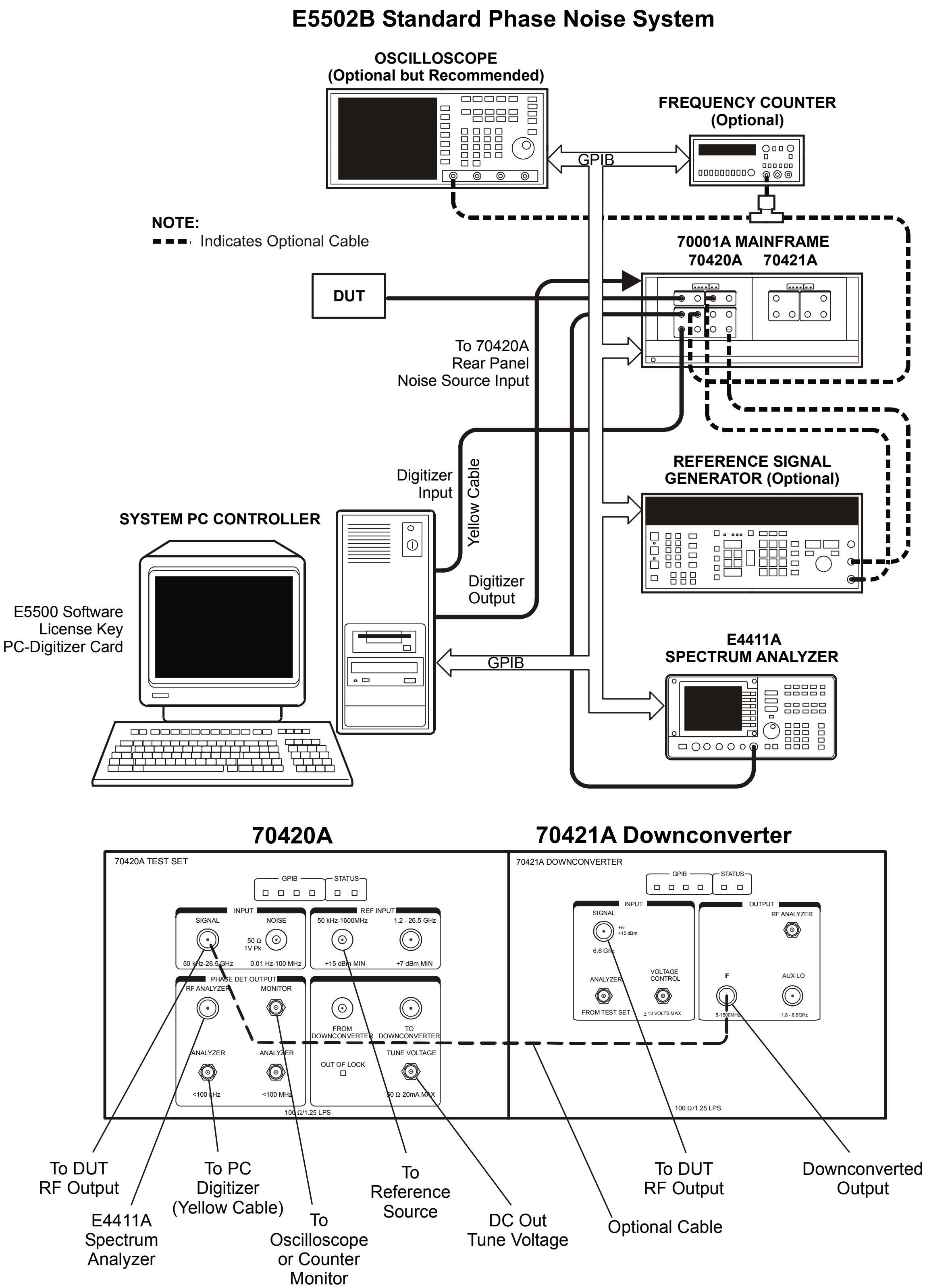


Figure 18-17E5502B Standard Connect Diagram

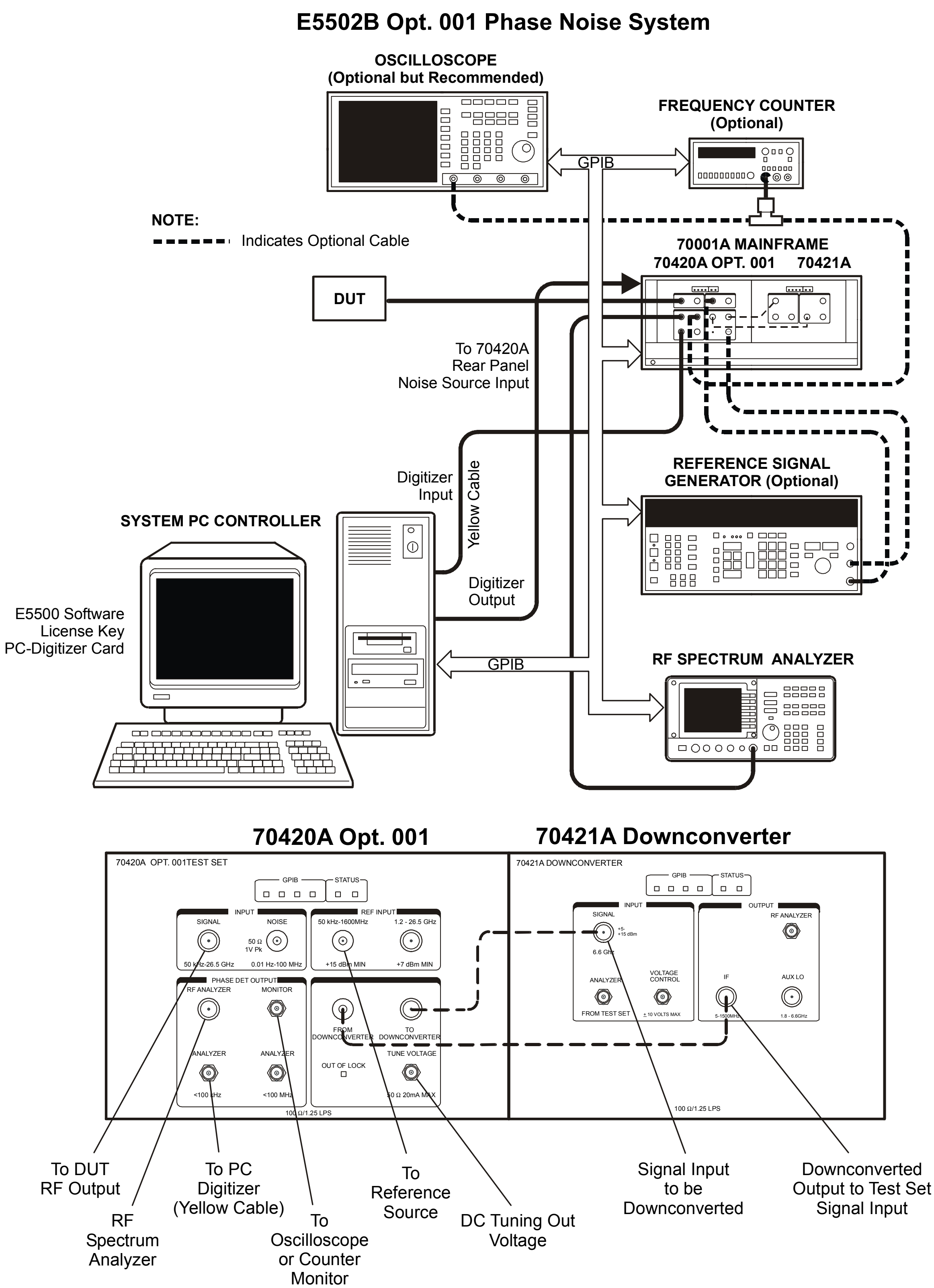


Figure 18-18 E5502B Opt. 001 Connect Diagram

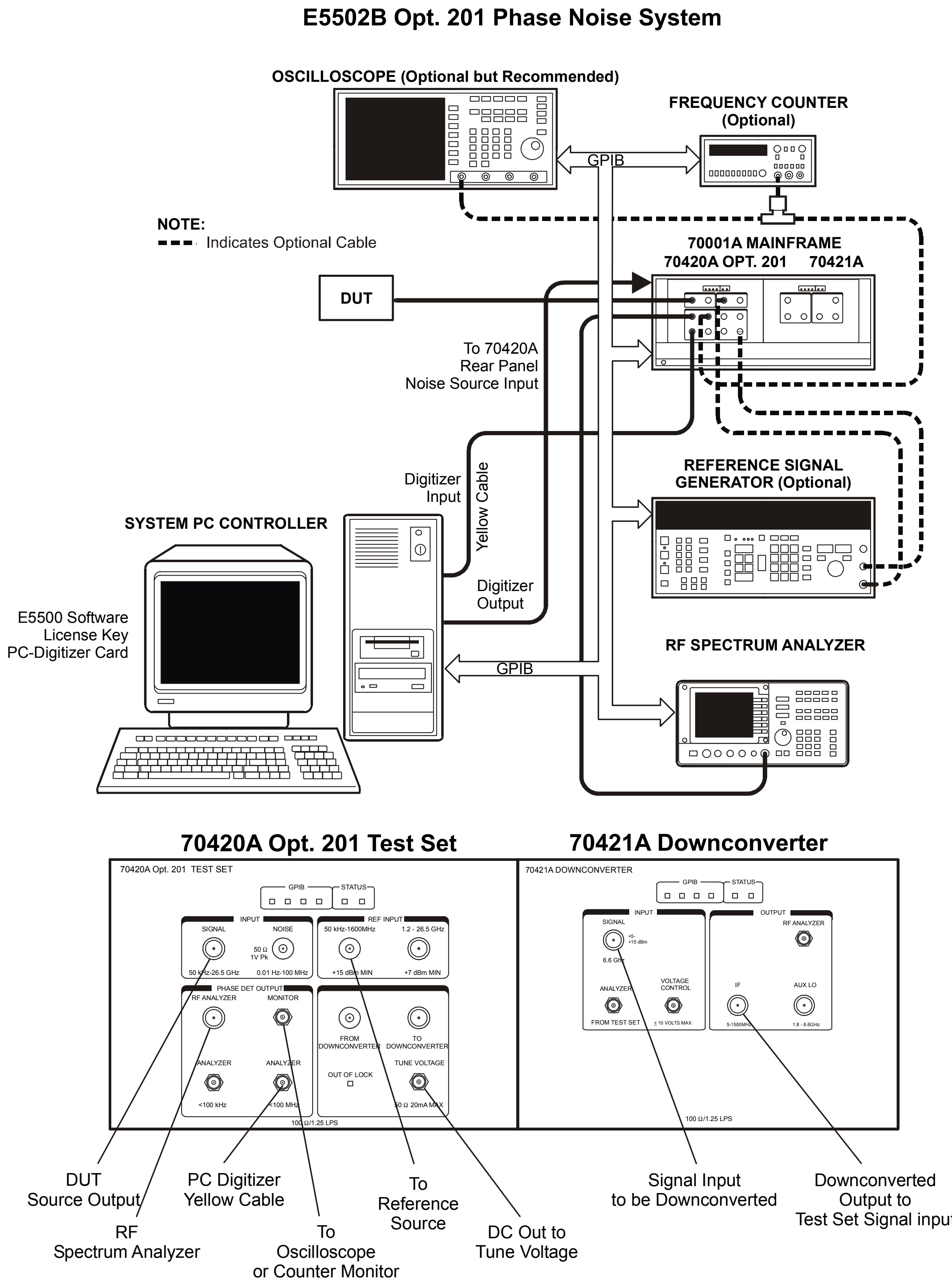


Figure 18-19E5502B Opt. 201 Connect Diagram

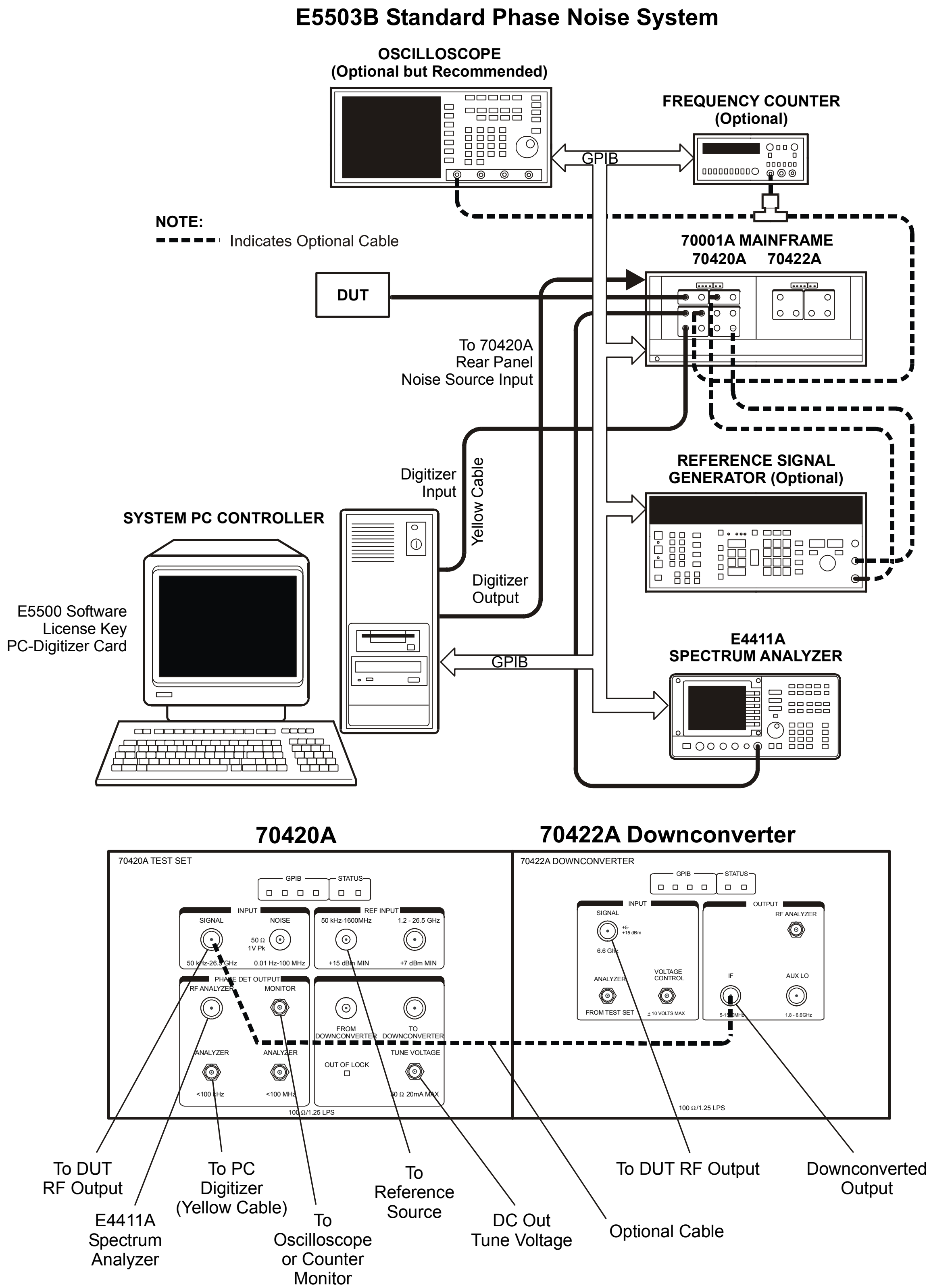


Figure 18-20E5503B Standard Connect Diagram

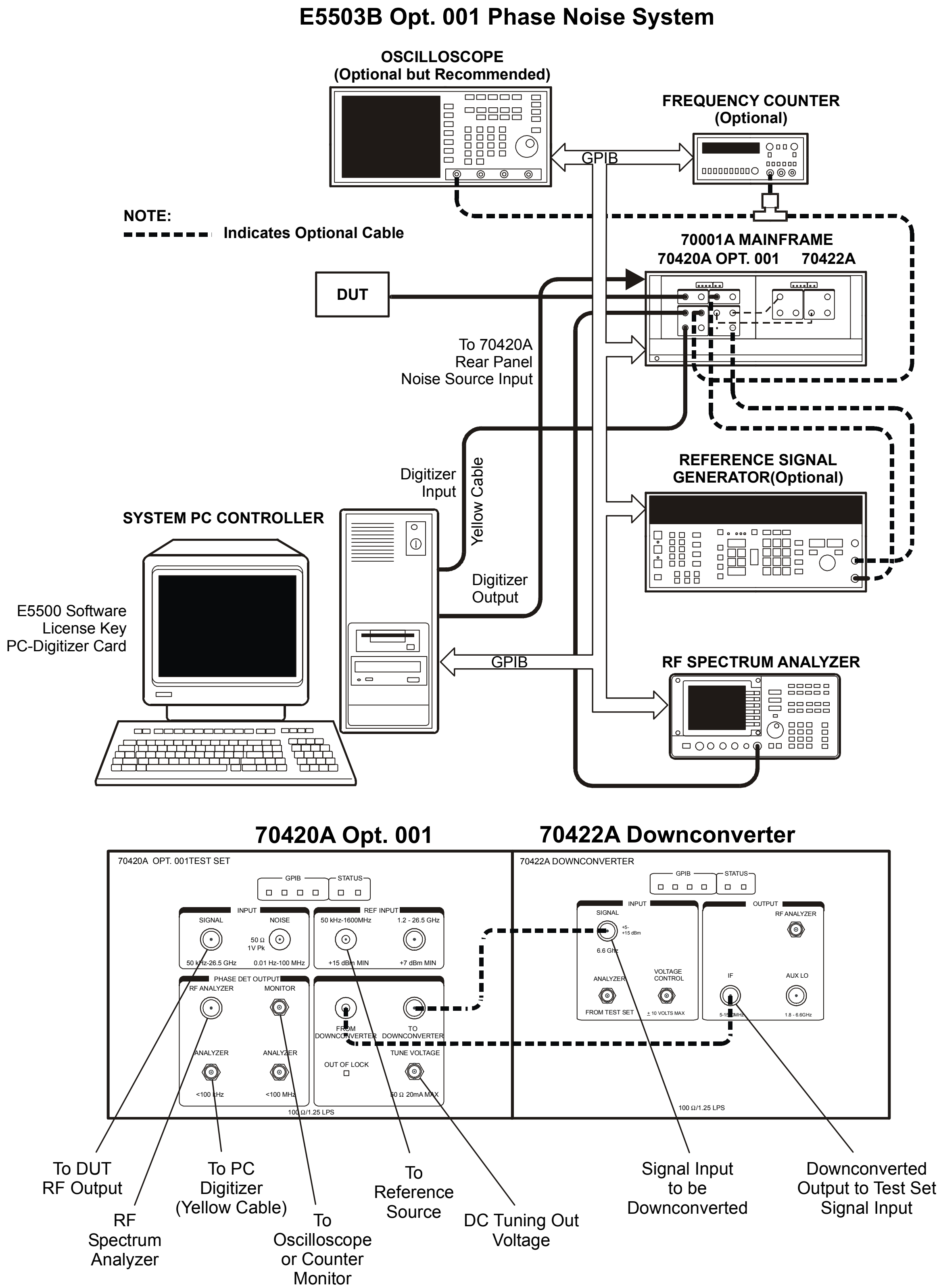


Figure 18-21 E5503B Opt. 001 Connect Diagram

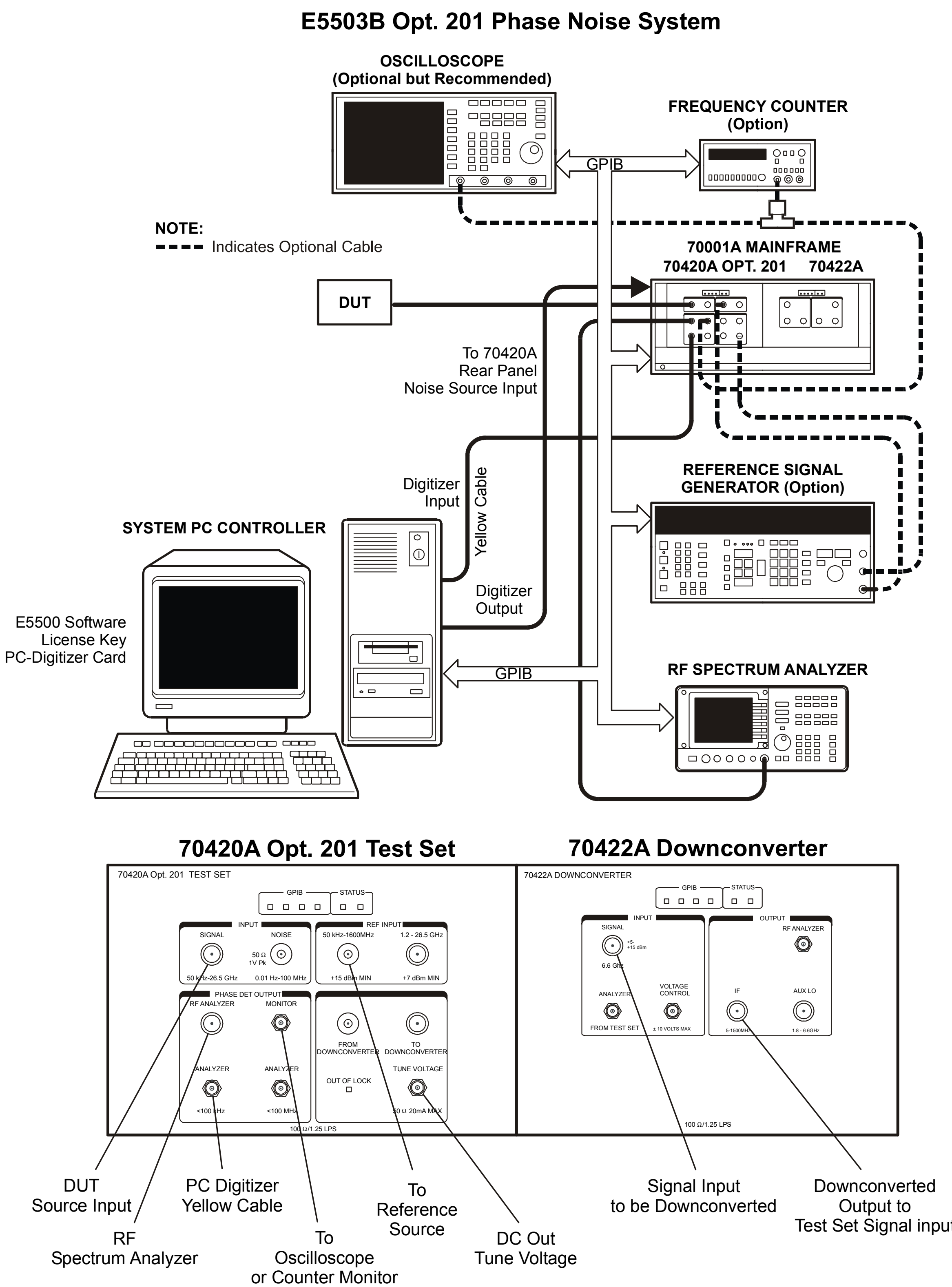


Figure 18-22E5503B Opt. 201 Connect Diagram

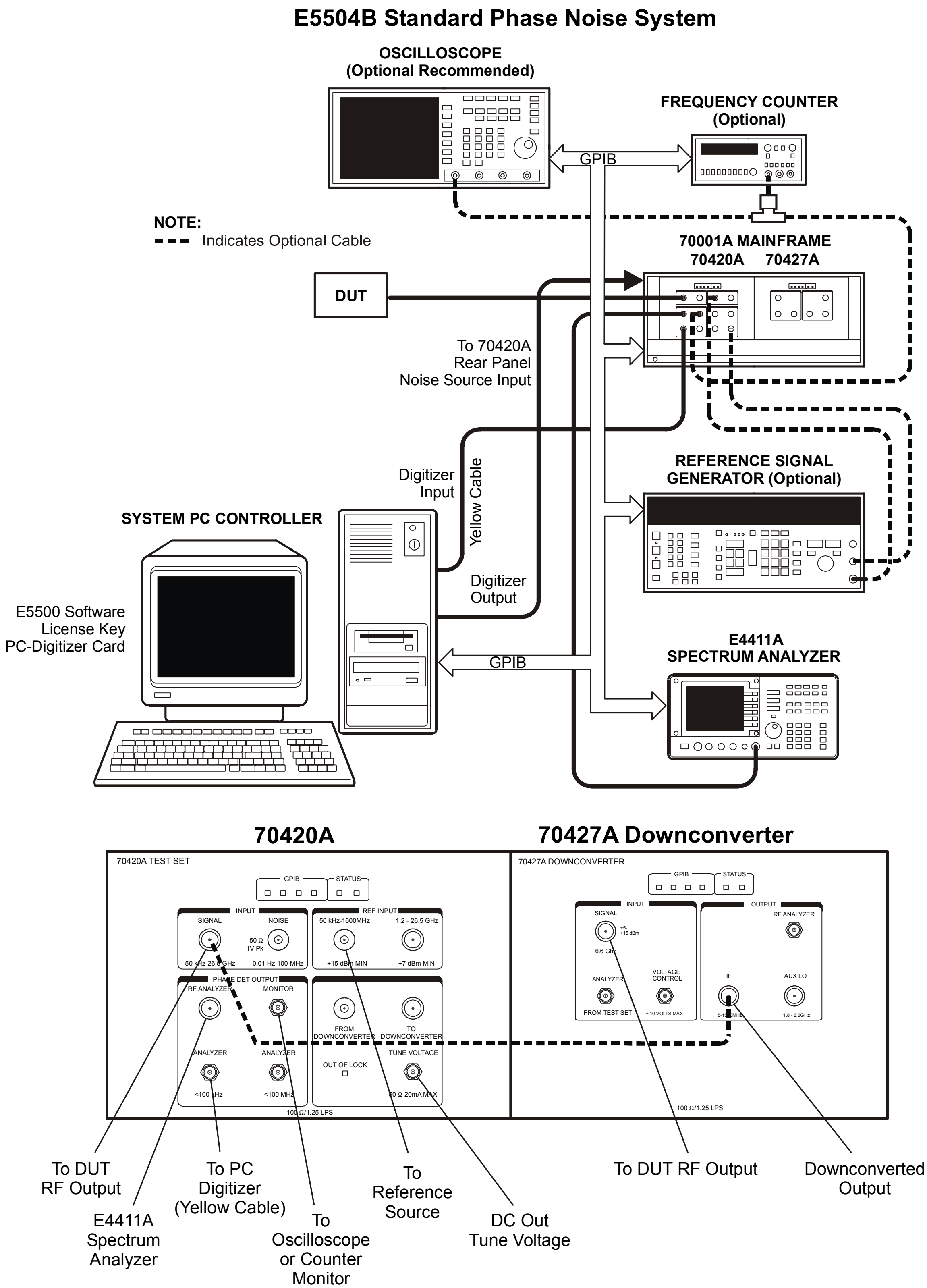


Figure 18-23E5504B Standard Connect Diagram

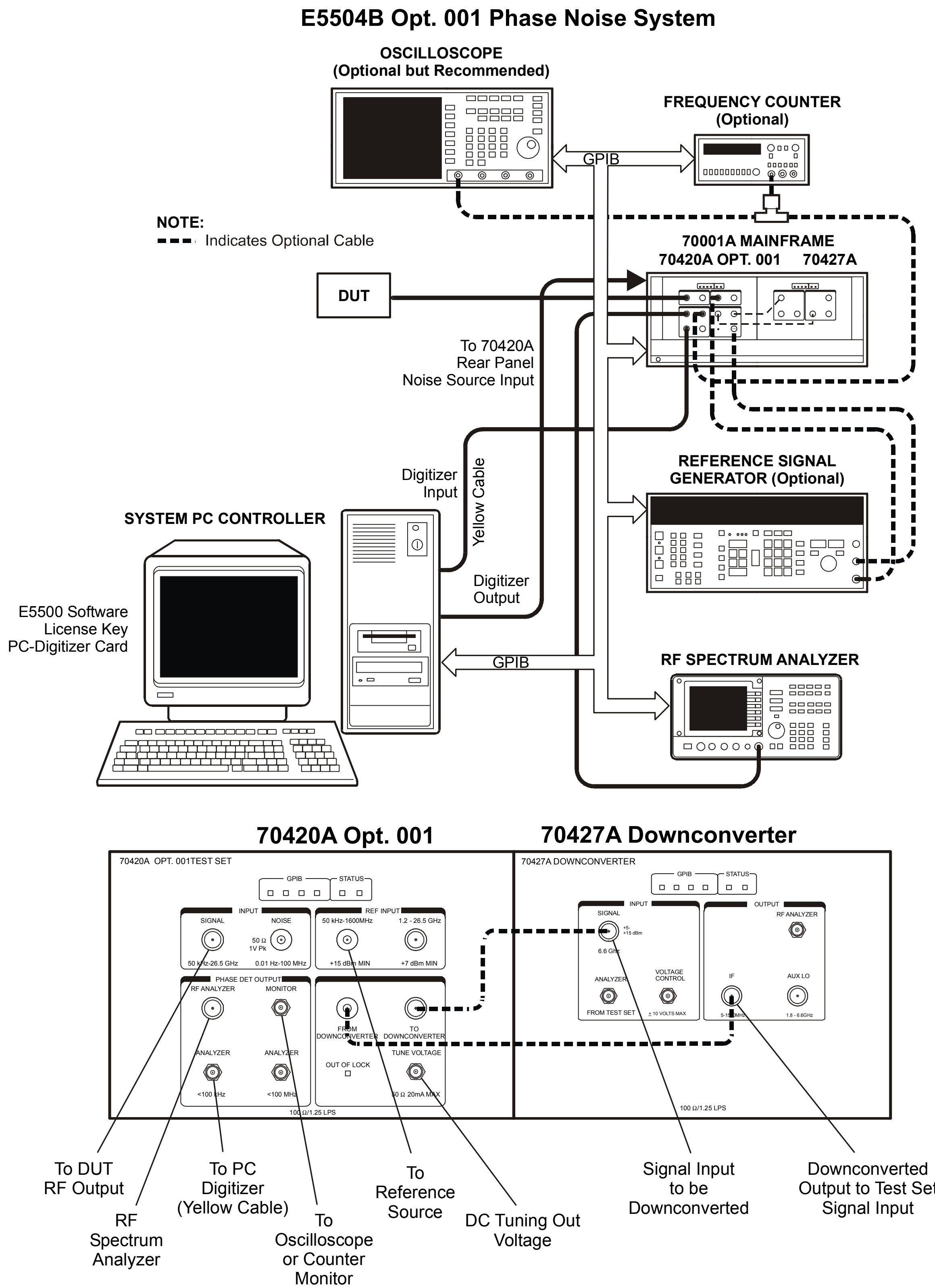


Figure 18-24E5504B Opt. 001 Connect Diagram

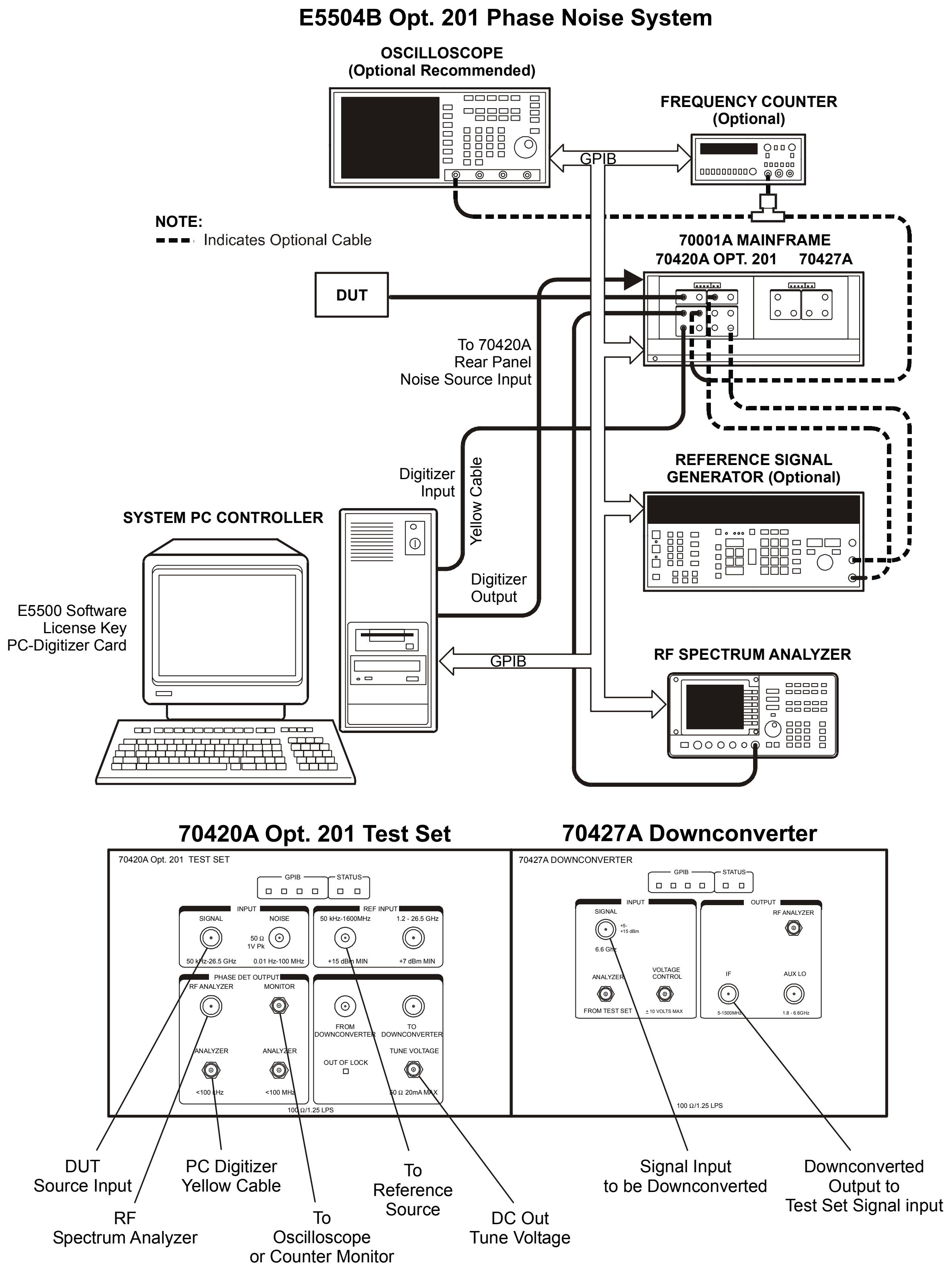


Figure 18-25E5504B Opt. 201 Connect Diagram

19

System Specifications

Specifications

Reliable Accuracy

The Agilent E5500 phase noise system minimizes measurement uncertainty by assuring you of accurate and repeatable measurement results.

Table 19-1 RF Phase Detector 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 19-2 AM Detector 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 E5500 to meet its accuracy specifications, the following 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.

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.

20

Connector Care and Preventive Maintenance

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. For more information on connector care, please refer to the documentation that came with your calibration kit.

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: 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 Agilent Technologies 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 the connectors
- Eliminates radio frequency interference (RFI) from affecting your measurements

The torque required depends on the type of connector. Refer to Table 20-1. Do not overtighten the connector. Torque wrenches are supplied in the calibration and verification kits that came with the system.

CAUTION: Never exceed the recommended torque when attaching cables.

Table 20-1 Proper Connector Torque

Connector	Torque cm-kg	Torque N-cm	Torque in-lbs	Wrench Part Number
Type-N	52	508	45	8710-1935
2.4 mm	9.2	90	8	8720-1765
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

CAUTION: Use caution when mating SMA connectors to any precision 2.4 mm or 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 2.4 mm or 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 Ultrajet. This product is recommended by the United States Environmental Protection Agency and contains chlorodifluoromethane. You can order this aerosol from Agilent Technologies (see Table 20-2).
2. Use an alcohol wipe to wipe connector surfaces. Wet a small swab with alcohol (from the alcohol wipe) and clean the connector with the swab.

3 Allow the alcohol to evaporate off the connector before making connections

Table 20-2 Cleaning Supplies Available from Agilent Technologies

Product	Part Number
Ultrajet	9310-6395
Alcohol wipes:	92193N
Lint-Free cloths:	9310-4242
Small foam swabs:	9300-1270
Large foam swabs	9300-0468

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.

Removing and Reinstalling Instruments

General Procedures and Techniques

This section introduces you to the various cable and connector types used in the system. See Figure 20-1 and Figure 20-2. Read this section before attempting to remove an instrument! EA connector type may have unique considerations. For example, some connectors are loosened by turning them clockwise, others by turning counter clockwise.

Always use care when working with system cables and instruments.

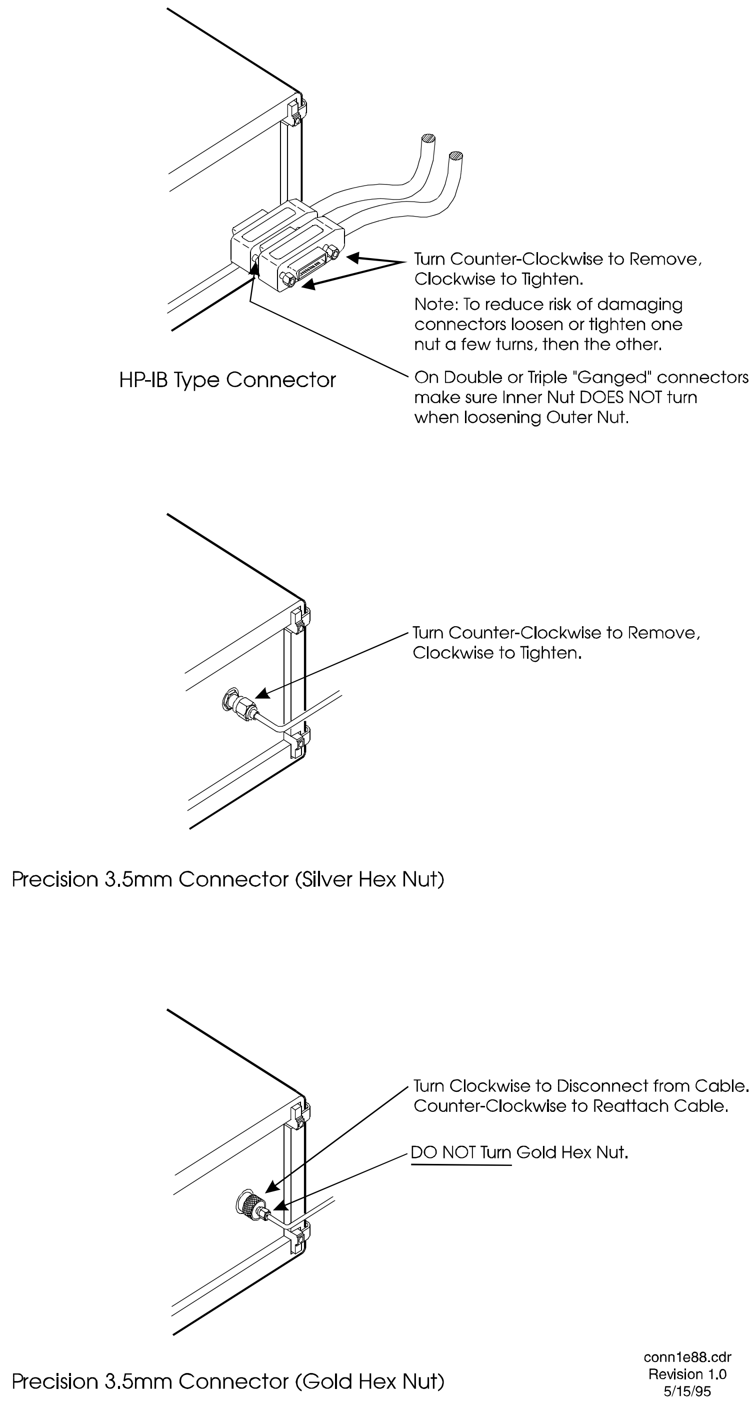


Figure 20-1 GPIB and 2.4 mm Connectors

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 2.4 mm and 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 2.4 mm (or 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 (part number 8720-1765). This wrench may be ordered from Agilent Technologies.

Semirigid cables are metal tubes, custom-formed for this system from semirigid coax cable stock.

2.4 mm (or 3.5 mm) connectors with a gold hex nut. The semirigid cables that go 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 a small amount until alignment is correct the connectors mate. When the two connectors are properly aligned, turning the instruments connector body will pull in the semirigid cable’s connector. Tighten firmly by hand.

2.4 mm (or 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:

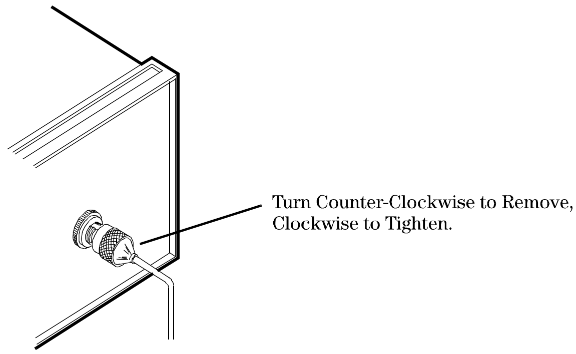
- Carefully insert the male connector center pin into the female connector. (Try to make sure the cable is aligned with the instrument connector properly before joining them.)
- Turn the silver nut clockwise by hand until it is snug, then tighten with an 8 inch-lb torque wrench (part number 8720-1765). This wrench may be ordered from Agilent Technologies.

Bent Semirigid Cables

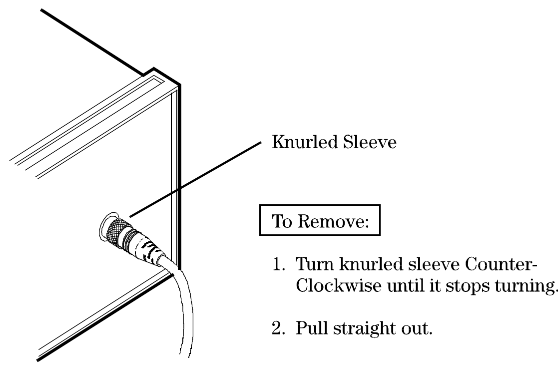
Semirigid cables are not intended to be bent outside of the factory. An accidental bend that is slight or gradual may be straightened carefully by hand. Semirigid cables that are crimped will affect system performance, and must be replaced. Do not attempt to straighten a crimped semirigid cable, its performance will not be restored.

Other Multipin Connectors

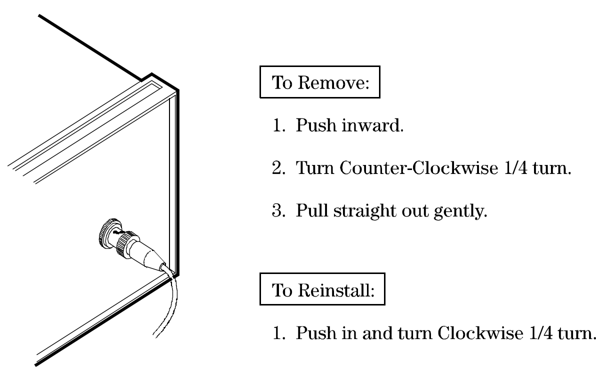
There are other multipin connectors in the system (Agilent MSIB, for example). These are sometimes held in place by a pair of screws.



Type-N Connector



Power Sensor Connector



BNC Connector

Figure 20-2 Type-N, Power Sensor, and BNC Connectors

MMS Module Removal and Reinstallation

To Remove an MMS Module

1. Set the mainframe line switch to OFF.
2. Remove all rear panel cables going to the module
3. On the bottom of the mainframe front panel is a dark-colored, horizontal access panel. Pry outward at the top of this panel to open it.
4. With an 8 mm hex-ball driver, loosen the module hex nut latch.
5. Go to the back of the system and press against the module's rear panel and slide the module forward several inches.
6. From the front of the system, pull the module out.

To Reinstall an MMS Module

1. Set the MMS mainframe line switch to OFF.
2. Check the GPIB address switch on the module for the correct address setting. Refer to the manual for the MMS module for information on the Agilent MSIB switch. For proper address settings, refer to the system information chapter.

CAUTION: Reinstalling an MMS module without setting the GPIB address will cause the system to malfunction. (Not all MMS modules use GPIB settings.)

3. On the bottom of the mainframe front panel is a dark-colored, horizontal access panel. If necessary, pry outward at the top of this panel to open it.
4. Slide the module into the mainframe.
5. Press against the front of the module while tightening the hex-nut latch (with an 8 mm hex-ball driver).
6. Close the access panel.
7. Go to the back of the system and connect intermodule cables.

Touch-Up Paint

Touch-up paint is shipped in spray cans. Spray a cotton swab with paint and apply it to the damaged area.

Table 20-3 Touch-up Paint

Touch-Up Paint Color	Where the Color is Used	Part Number
Dove Gray	Front panel frames Portions of front handles	6010-1146
French Gray	Side, top, and bottom covers	6010-1147
Parchment Gray	Rack mount flanges Front panels	6010-1148