Signature™ Option 52
Phase Noise Measurements
Software User Guide

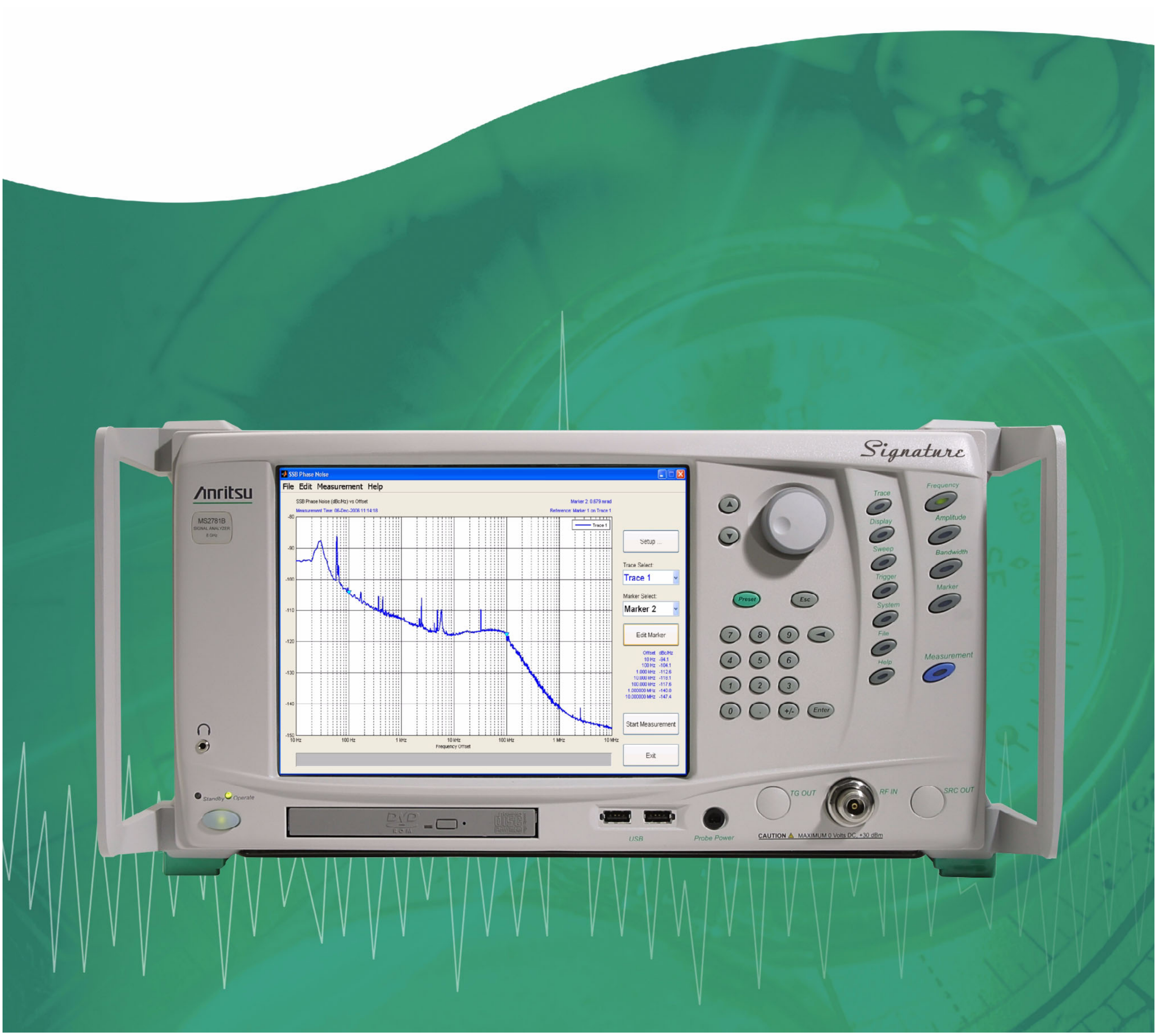

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Table of Contents

Chapter 1 General Information

1-1 About this Guide

This software user guide provides general operating information for the series MS2780 Option 52 Phase Noise Measurement application.

> **Note:** Before using the Phase Noise Measurement application, users should become familiar with Signature's general instrument operation and its user interface.

Associated Documentation

This guide is a supplement to the MS278XB's document set containing the following:

- Operation Manual Part Number: 10410-00273
- Programming Manual Part Number: 10410-00274

Conventions

Throughout this manual, the terms MS278XB and analyzer will be used interchangeably to refer to the instrument. The term DUT is used in place of device under test.

Path names may be used to represent the keystrokes and button presses for a desired action or procedure. The path name generally begins with a front panel key, keyboard key, or menu selection followed by additional menu selections, each separated by a vertical line (|). Front panel key names and menu selections are presented in the manual as they are on the system, that is in initial caps, all uppercase letters, or with symbols as appropriate.

> **Note:** In cases where a sub-menu is automatically expanded by accessing the main menu, the path shows that sub-menu as part of the selection.

1-2 Software Description

The MS278XB Option 52 provides the Signature user with the tools needed to easily measure and graph the phase noise of their DUT. The data can also be exported for use within other applications. Option 52 is a Windows application that controls Signature to provide a fully automated measurement engine.

The Phase Noise Measurement application is not currently supported through GPIB or Web Services remote programming.

1-3 Software Installation

The Phase Noise Measurement application is designed to be installed on Signature. Either an MS278XA or MS278XB instrument with Signature software version 3.17 or higher is required.

To install the Signature Option 52 Phase Noise Measurement application onto a Signature instrument, close all applications (including the Signature application), insert the installation CD, and follow the on-screen instructions. The installation program first copies the installation files to the Signature's hard disk, and then begins the installation. If the MATLAB Component Runtime version 7.5 is not detected, it will also be installed (it is suggested to install this into the C:/Signature/MCR directory). The final phase of installation copies the Help system files to Signature's hard disk.

When installation is complete, an OK dialog is presented to reboot the system and finalize the install process.

Chapter 2 Graphical User Interface Overview

2-1 Introduction

This chapter provides descriptions of the graphical user interface (GUI). The GUI is displayed on the LCD touch screen and can be accessed through direct touch or with a pointing device such as a mouse. After Launching the Phase Noise Measurement Application, you can access the measurement setup parameters and application controls found in the following sections:

- Measurement Setup Dialog
- Edit Trace Dialog
- Edit Marker Dialog
- Printer and Page Setup

2-2 Launching the Phase Noise Measurement Application

The Phase Noise Measurement application measures the phase noise of the largest signal that is within the currently set frequency range. Prior to making a Phase Noise Measurement, the DUT should be set up and connected to Signature's RF input. To ensure that the analyzer input is not overloaded, the signal being measured should be greater than the sum of all of the other signals present at the analyzer input. The best measurement results are obtained when the DUT's signal level is near 0 dBm.

The Phase Noise Measurement application is launched from Signature's main GUI through the following:

Measurement | Measurement | Measurement Type: | Phase Noise

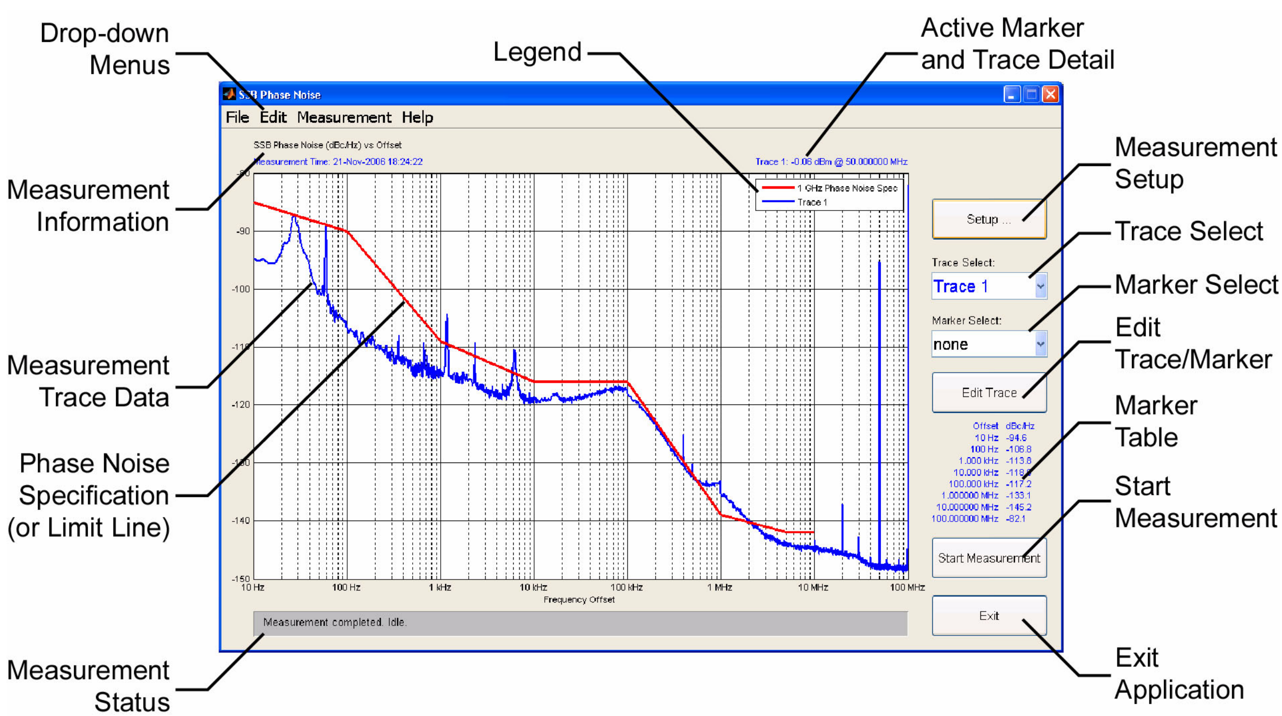


Figure 2-1. Main SSB Phase Noise Display

> **Note:** When an external keyboard is connected to Signature, ALT TAB can be used to switch between the Signature GUI and the Phase Noise application so that you can change the analyzer setup prior to making a measurement. No measurement will be started until the Start Measurement button has been selected.

Notes on the Phase Noise GUI

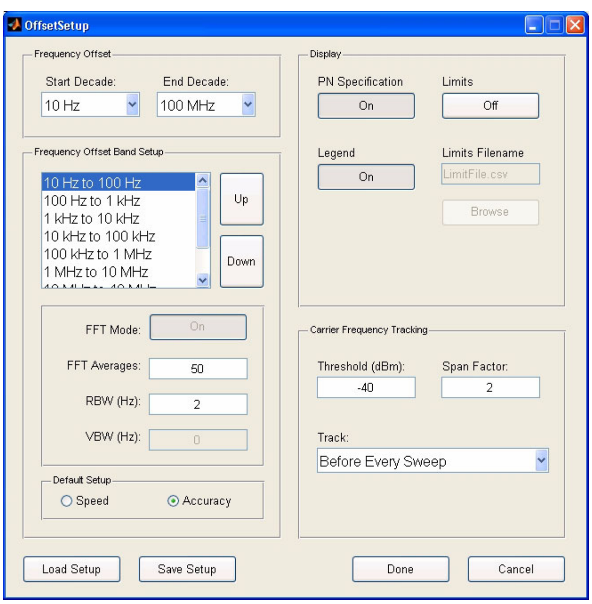
The Phase Noise GUI displays up to eight user-defined offset markers for the selected trace as shown in the lower right corner of Figure 2-1. The Marker Table color corresponds to the color of the selected trace. The markers are defined in the file C:\MS278XX\Option52\Setup\markertable.txt. An example of markertable.txt is given below:

```
This is a comment line
12
120
12000
1.2e3
120000
1200000
18000000
099000000
```

The file can have up to nine text lines. The first line must be a comment line and is ignored. The offsets are displayed in the same order as the table. The actual reported values are the closest data points to the specified offsets in the file.

2-3 Measurement Setup Dialog

The Measurement Setup dialog is accessed from the main GUI via the Setup... button or from the Measurement | Setup... drop-down menus.



Frequency Offset:
The frequency offset sets the start and stop decade for the measurement graticule.

Frequency Offset Band Setup:
The frequency offset band setup configures each measurement band with unique settings.

FFT Mode On:

FFT Averages: 0 to 10,000 or
RBW (Hz): 0.1 to 100,000

FFT Mode Off (swept mode):

Sweeptime (s): 0.005 to 10,000 seconds
RBW (Hz):10 to 8,000,000
VBW (Hz): 0 to 10,000,000 (0 = Auto)

Default Setup:
The Speed and Accuracy selections change the FFT Mode, FFT Averages or Sweeptime, RBW, and VBW to be optimized for speed or accuracy.

Display:
Toggles the Signature phase noise specification line, user defined limit lines, and Legend On or Off.

Carrier Frequency Tracking:
Selects the carrier frequency tracking feature and sets the Span Factor and Threshold value.

Saved Setups:
Setups can be saved as .mat files and later reloaded.

Figure 2-2. Offset Setup Dialog

Notes on the Display

The display options include On/Off toggle buttons for the MS278XB phase noise specifications and for user defined limit lines. When toggled On, the lines are plotted on the phase noise graph.

Note: The phase noise specification is correct for a 1 GHz carrier frequency.

The user defined limit lines are defined in a comma separated value (.csv) file format. This file can be made using a text editor, and then saved to any directory that is accessible to the application. The file must have a CSV extension. The phase noise measurement application has a browse feature that allows you to locate and load the limit line file.

The first line of the file is for comments and is ignored by the application. The second line of the file contains the starting frequency followed by the specification limit. The following lines of the file contain the frequency of the following steps and their specification limits. An example user defined limit line file is shown below:

```
This file shows the test specification for our xyz oscillator
10, -40
100, -70
10000, -110
100000, -115
```

By clicking on a measurement trace, you can check whether all of the measurement points are below the limit line. If all of the measured points are on or below the limit line, there will be a green “Pass” displayed in the status window. If any points are above the limit line, there will be a red “Fail” displayed in the status window.

Notes on Carrier Frequency Tracking

Carrier frequency tracking allows the selection of one of the following four different modes of carrier frequency tracking. In each mode, the carrier power is measured at the start of the noise measurement and checked against the threshold. If no signal is found above the threshold, then the measurement will terminate.

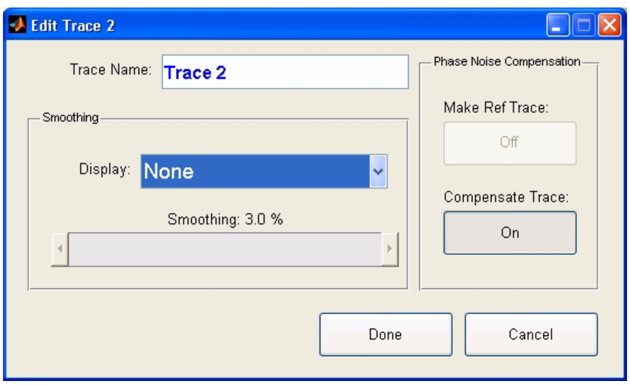
- **Use SPA Center Frequency:** This mode does not measure the carrier frequency. It assumes that the carrier is at the center frequency of the MS278XB at the time that the measurement is started. This results in taking the least time to begin a noise measurement.
- **1st Measurement Only:** This mode only measures the carrier frequency at the beginning of the first noise measurement by repeatedly centering the signal and decreasing the initial span setting of the MS278XB until the carrier frequency has been accurately determined. When the first noise measurement is successfully completed, the same carrier frequency is used for all subsequent measurements. However, if all of the current measurements are deleted or a different carrier frequency tracking mode is selected for a new measurement, then the carrier frequency will be measured again at the beginning of the new measurement.
- **Every Measurement:** This mode measures the carrier frequency at the beginning of each noise measurement by repeatedly centering the signal and decreasing the initial span setting of the MS278XB until the carrier frequency has been accurately determined.
- **Each Band in Measurement:** This mode measures the carrier frequency at the beginning of the noise measurement by repeatedly centering the signal and decreasing the initial span setting of the MS278XB until the carrier frequency has been accurately determined. The carrier frequency is then measured again at the start of each new band by beginning with a span that is set to (span factor) × (lowest offset frequency in the band).

  For example, if the span factor is set to 2 and a noise measurement from 100 Hz to 100 kHz is performed, then, after measuring the noise of the 100 Hz to 1 kHz band, the span is set to 2 × 1 kHz and the carrier is measured again. After measuring the noise of that band, the span is changed to 2 × 10 kHz and the carrier frequency is measured once again. After measuring the noise of that band, the span is changed to 2 × 100 kHz and the carrier frequency is measured once again.

2-4 Edit Trace Dialog

The Edit Trace dialog is accessed from the Phase Noise Measurement application GUI via the Edit Trace button. The Edit Trace functions apply only to the active trace, which can be selected from the Select Trace drop-down combo box or by left clicking (or touching) a displayed trace.

> **Note:** The Edit Trace button and the Edit Marker button share the same button location. The function of the button is determined by the active selection from the Trace Select and Marker Select drop-down combo boxes or by clicking (or touching) on a displayed trace or marker.



Trace Name:
By default, the traces are labeled Trace 1, Trace 2, etc. The trace name can be edited.

Smoothing:
Select None, Both or Smoothed Only.

"Smoothed Only" smooths the selected trace. "Both" adds a new, smoothed trace in addition to the original trace.

Adjust the smoothing slider for the amount of desired smoothing.

Phase Noise Compensation:

Make Ref Trace: Toggles the current trace as a reference trace.

Compensate Trace: Toggles trace compensation On or Off for the current trace.

Figure 2-3. Edit Trace Dialog

Notes on Trace Smoothing

Because of the nature of noise, obtaining measurement results with small peak-to-peak variation is very time consuming. This is because each point needs to have several measurements taken to average out to a final value. With an RMS detector in swept mode, the averaging is done with a long sweep time, whereas in FFT mode this is done by averaging the results of many FFTs.

There are times, however, when a smooth trace is desired without allowing for the time necessary for each point to average out to a final value, and the user is willing to degrade the accuracy so that they can acquire results more quickly.

Trace Smoothing provides this option by doing a moving average on the measured data. Each point on a smoothed trace is the average of the power of a fixed number of measured data points on each side of, and including that particular point.

Notes on Phase Noise Compensation

Phase Noise Compensation is a two-step process that characterizes the noise of the Signature using a very clean reference and subtracts this noise from a phase noise measurement. The requirements for the very clean reference are as follows:

- The reference needs to have phase noise that is at least 10 dB lower than both the Signature and the DUT being measured.
- The power of the MS278XB's reference level setting needs to be as close to the same power output of the DUT as possible. Otherwise, at offset frequencies above 1 MHz, the instrument's noise floor between the two measurements will be different by roughly the same amount as the difference in the power levels.

When phase noise compensation is used, two phase noise plots need to be generated by measuring the phase noise of the very clean reference and the phase noise of the DUT. The power level and frequency of the reference need to be as close as possible to the DUT to ensure that the Signature has the same noise floor in both.

The measurements should be performed using settings for the RBW and either number of averages or sweep time that minimize the point-to-point fluctuations in the measured data. Using the Accuracy Mode in the measurement setup provides a good starting point and can be further refined, depending upon the specific requirements.

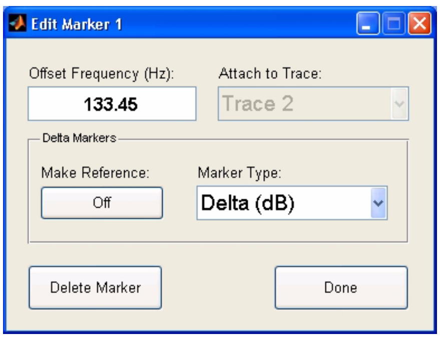
Since the frequencies of the DUT and the very clean reference may not be the same, **Every Measurement** is a good selection for the carrier frequency tracking in the measurement setup. Either set the initial span and center frequency so that both the DUT and reference frequency will be within the set frequency range or re-tune the Signature before the start of each measurement.

After making the noise measurements using the very clean reference and the DUT, select the trace for the clean reference and under the Edit Trace menu, select **Make Ref Trace On**. Then, select the trace for the DUT and under the Edit Trace menu, select **Compensate Trace On**. The reference trace remains unchanged and the DUT trace will reflect the removal of the noise of the reference trace.

2-5 Edit Marker Dialog

The Edit Marker dialog is accessed from the Phase Noise Measurement application GUI via the Edit Marker button. The Edit Marker functions apply only to the active marker, which can be selected from the Select Marker drop-down combo box or by left clicking (or touching) a displayed marker.

Note: The Edit Marker button and the Edit Trace button share the same button location. The function of the button is determined by the active selection from the Marker Select and Trace Select drop-down combo boxes or by clicking (or touching) on a displayed trace or marker.



Offset Frequency:
Specifies the marker's frequency offset relative to the carrier.

Attach to Trace:
Specifies the trace to which the marker is applied.

Make Reference:
Sets the current marker as a reference marker for the markers of other types.

Marker Type:
Sets the current marker type as one of the following:

- Delta Marker (dB)
- Integrated Noise Marker (radians)
- Integrated Noise Marker (degrees)
- Integrated Noise Marker (seconds)

If no marker is selected as a reference marker, then the marker value is given relative to the carrier power (dBc).

Delete Marker:
Removes the indicated marker from the display.

Figure 2-4. Edit Marker Dialog

Notes on Marker Type

If there is a single marker, it will automatically show the offset frequency and the noise level at that offset frequency relative to the carrier power level, normalized to a 1 Hz bandwidth (dBc/Hz). This marker information is displayed above the Legend and active trace. When multiple markers have been added to the phase noise plot, several options are available:

- **Make Reference Off** for all of the markers: The selected marker indicates the offset frequency of the marker and its dBc/Hz noise level. This is the default setting when a marker is added.
- **Make Reference On** for one of the markers allows the following options:
  - **Delta (dB):** Selecting the reference marker displays the offset frequency and dBc/Hz noise level of the reference marker. Selecting a different marker displays the difference of the frequency and power between the selected marker and the reference marker.
  - **Integrated Noise (radians):** This marker type displays the integrated noise, in radians, between the selected marker and the reference marker. The power in coherent spurs is not treated differently than the phase noise power, which may skew some measurements since the spur level is decreased by $10 \times LOG_{10}$ (Resolution Bandwidth Filter's Power Bandwidth). The Integrated Noise in radians is calculated as follows:

$$Integrated\ Noise(radians) = \sqrt{2 \times \int_{f1}^{f2} 10^{\left(\frac{SSB\ \phi\ Noise_{dBc/Hz}}{10}\right)} df}$$

  - **Integrated Noise (degrees):** This marker type displays the integrated noise, in degrees, between the selected marker and the reference marker. The power in coherent spurs is not treated differently than the phase noise power, which may skew some measurements since the spur level is decreased by $10 \times LOG_{10}$ (Resolution Bandwidth Filter's Power Bandwidth). The Integrated Noise in degrees is calculated as follows:

$$Integrated\ Noise(degrees) = \frac{180°}{\pi rad} \sqrt{2 \times \int_{f1}^{f2} 10^{\left(\frac{SSB\ \phi\ Noise_{dBc/Hz}}{10}\right)} df}$$

  - **Integrated Noise (seconds):** This marker type displays the integrated noise, in seconds, between the selected marker and the reference marker. The power in coherent spurs is not treated differently than the phase noise power, which may skew some measurements since the spur level is decreased by $10 \times LOG_{10}$ (Resolution Bandwidth Filter's Power Bandwidth). The Integrated Noise in seconds is calculated as follows:

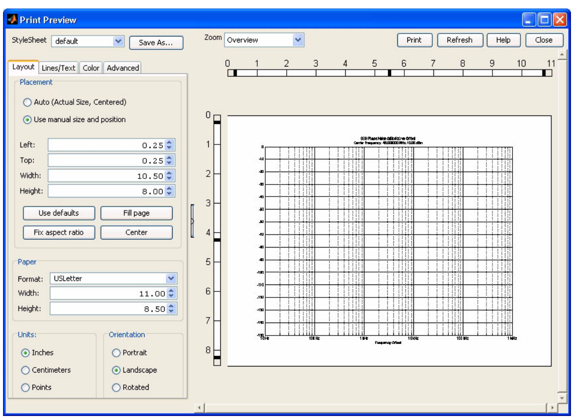
$$Integrated\ Noise(seconds) = \frac{1}{2\pi \times f_{carrier}} \sqrt{2 \times \int_{f1}^{f2} 10^{\left(\frac{SSB\ \phi\ Noise_{dBc/Hz}}{10}\right)} df}$$

2-6 Printer and Page Setup

The Page Setup and Print Preview dialogs are accessed from the File drop-down menu. These dialogs let you configure the layout of the measurement, graphing and printing parameters, and other advanced processing parameters.

Note: Before printing is possible, a local or remote printer must be installed. Refer to the MS278XB Operation Manual for details on installing a printer.

As shown below, the printer and page setup parameters can be saved as a StyleSheet for later recall. The Zoom can be manually set up to 400% or to Overview for full-page viewing. When the page is set up, you can press the Print button to send the graph to a previously installed printer.



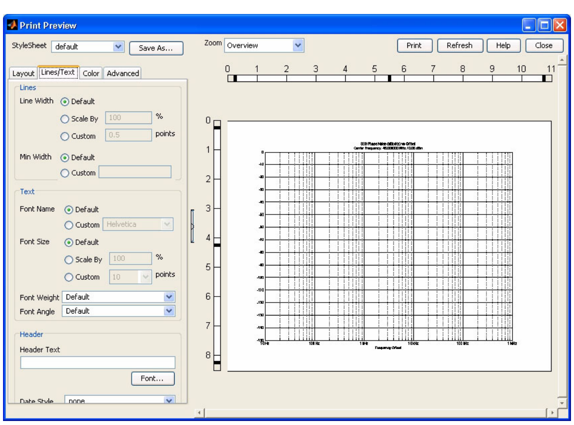
Placement:
The Placement group box allows you to select between Auto or Manual. When Manual is selected, the Left and Top margins can be specified as well as the Width and Height of the graph.

Paper:
The Paper group box lets you specify the size of the printer paper.

Units:
The Units group box lets you select Inches, Centimeters, or Points as the standard units.

Orientation:
The Orientation group box lets you select the paper orientation of Portrait, Landscape, or Rotated.

Figure 2-5. Printer Page Setup Dialog, Layout Tab

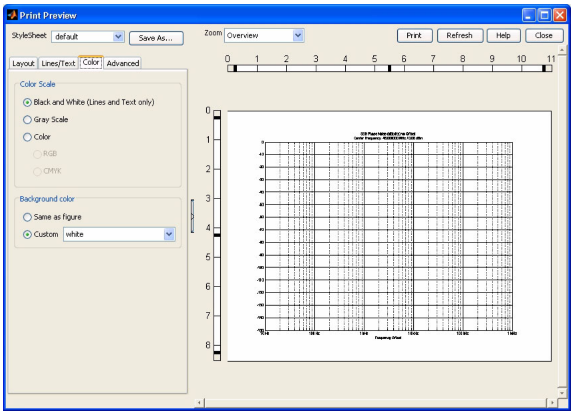


Lines/Text:
The Lines/Text group box lets you configure the graph's graticule scale.

Text:
The Text group box lets you select the font style and size, along with other font attributes.

Header:
The Header group box lets you type the graph's header text as well as select the date format, if desired.

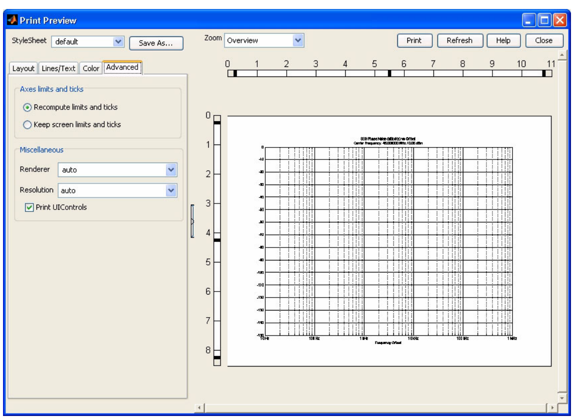
Figure 2-6. Printer Page Setup Dialog, Line/Text Tab



Color:
The Color Scale group box has options for selecting the color space of Black and White, Gray Scale, RGB, or CMYK.

Background Color:
The Background Color group box has selections for the background color of the plot.

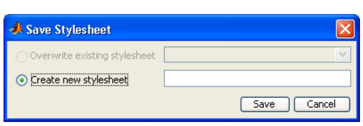
Figure 2-7. Printer Page Setup Dialog, Color Tab



Axes Limits and Ticks:
Recompute limits and ticks
Keep screen limits and ticks

Miscellaneous:
Renderer: default, Painters, ZBuffer
Resolution: selects screen and print resolution
Print UIControls: Prints the User Interface controls

Figure 2-8. Printer Page Setup Dialog, Advanced Tab



The printer page setup is saved as a stylesheet. Select to create a new stylesheet or overwrite an existing stylesheet.

Figure 2-9. Save Stylesheet Dialog

Chapter 3 Measurement Example

3-1 Introduction

This chapter illustrates how to make a common phase noise measurement. It is assumed that you have a basic understanding of spectrum analyzer measurements and that the MS278XB front panel and menu structure are familiar to you. Refer to the MS278XB's operating manual for a description of the instrument's menus and their structure. Once you are familiar with the instrument, you should be able to easily follow this illustration.

3-2 Phase Noise Measurement Example

This measurement example measures the phase noise of a 50 MHz signal from a DUT.

1. Set up the equipment as shown in the following diagram:

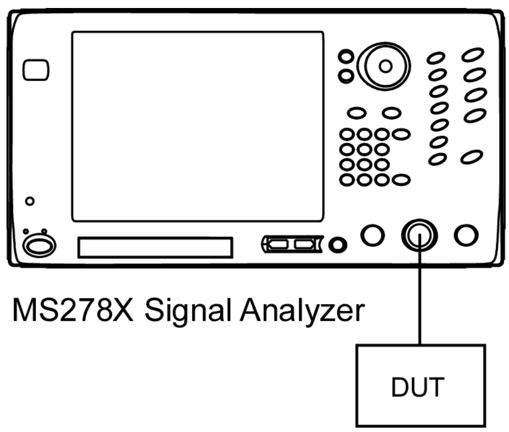


Figure 3-1. Phase Noise Measurement Setup

2. Preset the MS278XB
3. Set up the MS278XB as follows:
    - **a.** Center Frequency: 50 MHz
    - **b.** Span 1 MHz
    - **c.** Adjust the reference level such that the signal peak is near the reference level (top of the graticule).
    - **d.** Launch the Phase Noise Measurement application through the following menu sequence: Measurement | Measurement Type | Phase Noise
4. After the Phase Noise Measurement application loads, press the Setup button to configure the measurement as desired, and then press Done.
5. Press the Start Measurement button and wait for the measurement to complete.
6. After the measurement is completed, the measurement results can be manipulated by using the Edit Trace dialog, sent to a printer for hard copy printouts, or exported as a CSV file.

The following is an example plot of the measurement when finished:

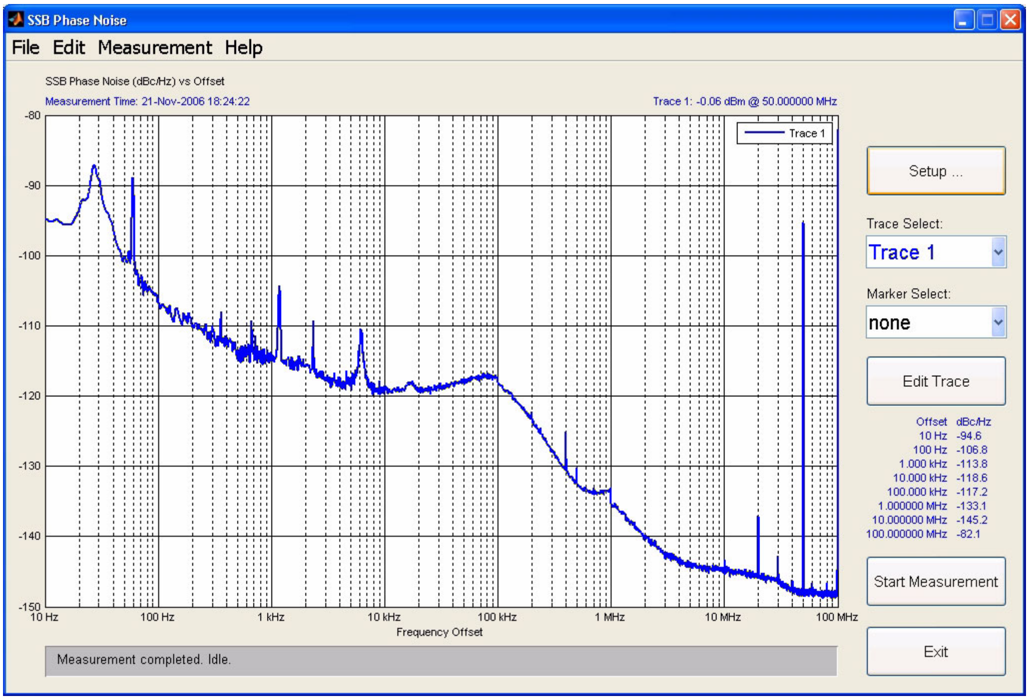


Figure 3-2. 50 MHz Phase Noise Measurement

Appendix A Phase Noise Tutorial

A perfect sine wave has a non-varying period equal to the reciprocal of the frequency:

```
T = 1/F
```

However, all actual signal sources have some undesired random noise modulation of their phase that causes their period to fluctuate from cycle-to-cycle even though the average period can be reasonably constant. This noise is called phase noise. When the frequency or phase of a sine wave is modulated with another sine wave, the total power does not change, but the spectral content changes from having all of the power at a single frequency to having sidebands on each side of the unmodulated frequency spaced at intervals equal to the modulation frequency. Bessel math functions can be used to determine the amplitude of the individual sidebands for any given amount of modulation. Broadband noise also distributes the RF power when it modulates the phase of a sine wave, but instead of producing discrete coherent sidebands, it creates a ‘skirt’ on each side of the desired frequency as is shown below:

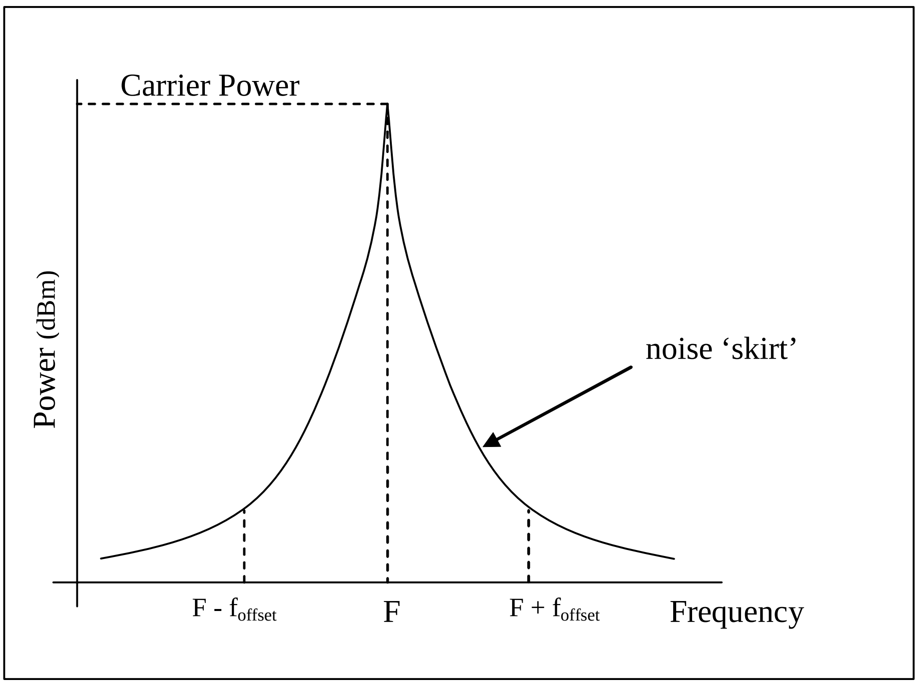


Figure A-1. Carrier Phase Noise

For convenience of use, phase noise is usually normalized to a 1 Hz bandwidth and specified at particular offsets from the carrier frequency. This spectral power density (noise power in a 1 Hz bandwidth) is compared to the carrier power in a ratio where the carrier power includes the power that makes up the noise skirts. When the power of the noise for both $F - f_{offset}$ and $F + f_{offset}$ are included, it is referred to as Double Side Band Phase Noise. But when only one of the offsets is measured, it is referred to as Single Side Band Phase Noise or SSB Phase Noise. Additionally, the ratio is most often expressed in decibels as follows:

$$SSB\,\phi\,Noise\,@\,f_{offset}\,\tfrac{dBc}{Hz} = 10 \times LOG_{10}\left|\frac{P_{noise}\left(F + f_{offset}\right)\tfrac{W}{Hz}}{P_{carrier}\,W}\right|$$

or

$$SSB\,\phi\,Noise\,@\,f_{offset}\,\tfrac{dBc}{Hz} = P_{noise}\left(F + f_{offset}\right)\tfrac{dBm}{Hz} - P_{carrier}\,dBm$$

Note that making a measurement with such a low bandwidth is very time consuming. Instead, a higher bandwidth is often used and the measurement is scaled accordingly. Provided that the noise power verses frequency is relatively flat over the measurement's power bandwidth, the ratio of the measurement's power bandwidth to the 1 Hz normalized bandwidth yields the power scaling factor:

$$SSB\phi\,Noise@f_{offset}\,\tfrac{dBc}{Hz} = P_{noise}\left(F + f_{offset}\right) dBm - 10 \times LOG_{10}\left(\tfrac{Power\,Bandwidth}{1\,Hz}\right) - P_{carrier}\,dBm$$

For example, a 100 Hz power bandwidth allows 100 times as much noise power through as a 1 Hz power bandwidth. Therefore, the measurement is scaled by 10 x LOG_{10}(100 / 1) = 20 dB. So, if a carrier measures –5 dBm and the noise measured at 10 kHz from the carrier using a power bandwidth of 100 Hz is –65 dBm, then:

$$SSB\phi\,Noise@10kHz = -65dBm - 20dB - \left(-5dBm\right) = -80\tfrac{dBc}{Hz}$$

Which means that, in this example, at 10 kHz away from the carrier, the RMS noise power in a 1 Hz bandwidth is 80 dB less than the carrier power.

The power bandwidths of the RBW filters in the MS278XB are about 6% wider than a "brick wall" filter of the same bandwidth, which means:

$$SSB\phi\,Noise@f_{offset}\,\tfrac{dBc}{Hz} = P_{noise}\left(F + f_{offset}\right) dBm - 10 \times LOG_{10}\left(\tfrac{RBW \times 1.06}{1\,Hz}\right) - P_{carrier}\,dBm$$

The 6% increased width only affects the reading by 0.25 dB.

Note: When measuring phase noise, the Carrier Power should be measured with a wide enough bandwidth to capture the significant power in the noise skirts.

This Phase Noise Measurement application does not identify spurs; therefore, their displayed levels are reduced by the scaling of the power bandwidth. For instance, if the measurement bandwidth is 10 kHz, a –60 dBc spur will look like it is about –100 dBc.

When measuring phase noise with a spectrum analyzer, both the analyzer's phase noise and its DANL can impact the measurement. The analyzer's setup should be tailored to mitigate this impact. For instance, the MS278XB can be set to optimize phase noise below 85 kHz or above 85 kHz. Also, when a large signal is near the displayed frequency range, the DANL is limited by the effective noise figure of the ADC. This becomes an issue at offset frequencies above 100 kHz.

By moving the start frequency above the carrier frequency by 100 kHz, a 3 kHz RBW filter knocks the carrier level down enough so that the reference level can be decreased by 20 dB. This adds gain to the IF that improves the DANL. Excess RF attenuation also limits the DANL.

Note: Moving the start frequency above the carrier and decreasing the reference level only helps swept mode because the filtering in FFT mode still allows large signals to reach the ADC.

To optimize the DANL without overloading the ADC, measure the carrier power level. If the carrier power is greater than 0 dBm, set the attenuation equal to the carrier power level; otherwise, set the attenuation equal to 0 dB. If the ADC does overload, then the attenuation should be increased.

AM noise on a source looks like phase noise when measured with a spectrum analyzer; the analyzer does not differentiate between them. However, phase noise measurements done with a spectrum analyzer make the assumption that the AM noise is much less than the phase noise, which is true with most quality sources.

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