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Understand System Phase Noise Performance with Absolute and Additive Measurements

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Many electronic devices are subject to short-term, random fluctuations in phase, referred to as phase noise. This phenomenon impacts signal quality in communications systems by increasing symbol errors or reduces sensitivity in radar systems by masking low power return signals. Engineers can use phase noise analyzers to measure the phase noise performance of an entire system or individual components. In this application note, learn how high-performance phase noise analyzers are particularly effective in quantifying the magnitude of phase noise with absolute and additive measurements.

Key Applications and Challenges

Phase noise affects system performance in many applications. Consider the following examples that demonstrate the impact high phase noise can have on radar and digital communications systems.

Radar Systems

Figure 1 shows a simplified radar system block diagram. In these systems, the local oscillator (LO) and amplifiers can be a significant source of phase noise. The LO provides an intermediate frequency (IF) signal, which could be modulated for up-conversion to the final transmitted frequency. This same LO also enables the received signal to be down-converted to an IF for digitization and further processing. Ideally, the LO is a discrete continuous wave (CW) tone at a single frequency. However, in practice, the LO signal contains imperfections, including phase noise, shown as the red spectral elements in Figure 1.

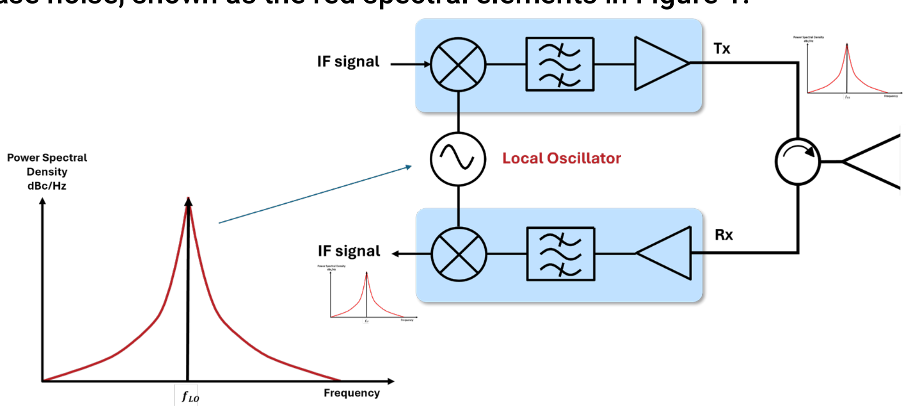

Figure 1: A simplified block diagram of a radar system with LO phase noise contributions.

Radar systems are greatly affected (i.e., the receiver is desensitized) by high phase noise because it can mask the radar return. This is illustrated in Figure 2, where the dark blue sidebands are from a low phase noise LO, the red sidebands are from an LO with higher phase noise, and the light blue arrow is the down-converted radar return signal. The LO with higher phase noise masks the smaller radar return signal.

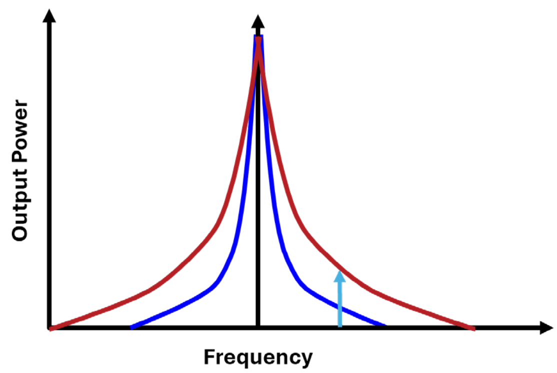

Figure 2: Radar return (light blue arrow) is masked by high LO phase noise (red sidebands) and revealed by low LO phase noise (dark blue sidebands).

Digital Communications Systems

Phase noise affects digital communications systems as well. The more complex the modulation schemes in a communications system, the more a component's phase noise can affect the system's overall performance. Figure 3 shows a simplified view of a receiver subsystem to illustrate how phase noise affects the system. The LO enables the received signal to be down-converted to an IF, allowing the received signal to be digitized and processed. Much like in the radar subsystem, the ideal LO should generate a discrete, CW frequency tone.

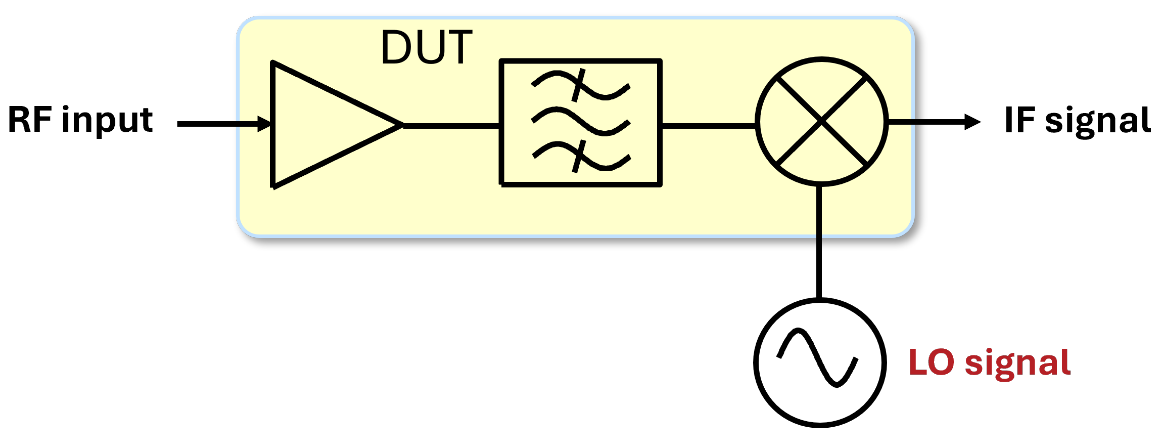

Figure 3: A receiver subsystem block diagram.

The QPSK signal in Figure 4a has some phase noise causing the constellation points to rotate in phase. However, each symbol can be accurately decoded because the symbols do not exceed the symbol boundaries. In this example, the phase noise performance of the LO does not affect the symbol error rate (SER) of the signal.

That same phase noise performance is now applied to a 16 QAM signal (Figure 4b). The receiving devices will misinterpret the transmitted symbols due to the excessive phase noise, causing worse SER performance.

To achieve better SER performance in a 16 QAM signal, the communications system requires a lower phase noise LO, as depicted in Figure 4c.

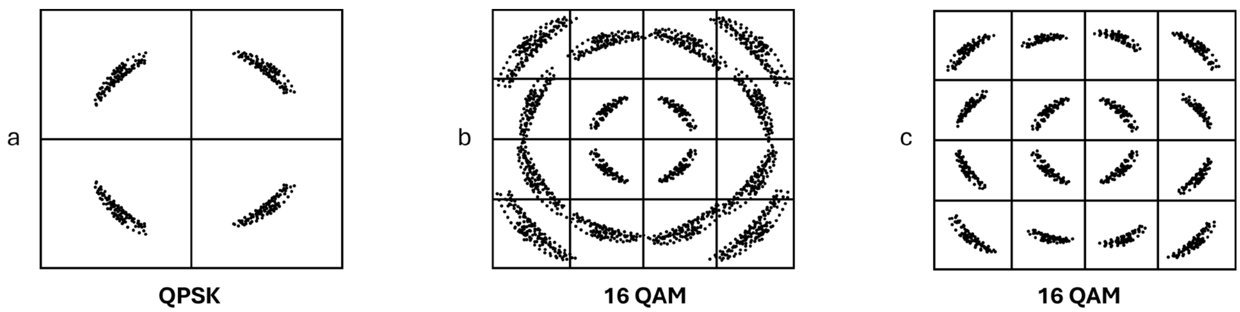

Figure 4: High phase noise doesn't affect SER for a QPSK signal (a) but increases it for a 16 QAM signal (b), where a low phase noise LO (c) is required for ideal performance.

Absolute Phase Noise Measurements

If a system is suspected of generating excessive phase noise, a diagnostic approach involves measuring the phase noise of the overall system and subsystem/components to determine which elements are the most significant contributors. This section will review how to perform an absolute measurement, which is used to characterize single port devices such as signal generators or oscillators, using a Maury Microwave HA7062D Real-Time Phase Noise Analyzer of the Holzworth product line.

Instrument Configuration

An absolute phase noise measurement instrument configuration begins with connecting the rigid jumpers to the front panel, as indicated by the arrows in Figure 5.

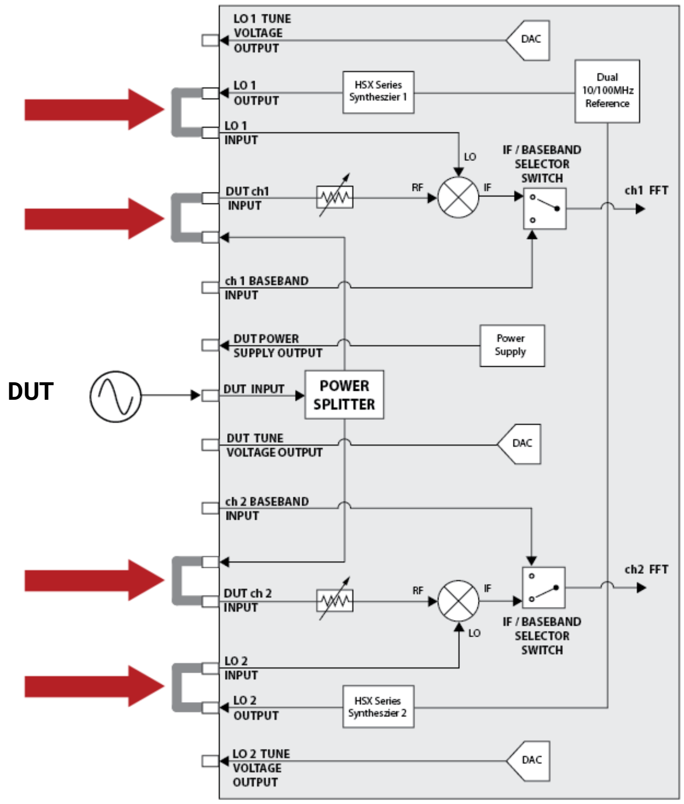

Figure 5: An absolute phase noise measurement setup with four rigid coaxial jumpers (red arrows) connected to the phase noise analyzer's front panel.

The HA7062C and HA7062D require a device under test (DUT) with a signal power between -5 dBm to 20 dBm and a stable carrier frequency. The example DUT for this section is a Maury Microwave HSX9001B Multi-Channel RF Synthesizer of the Holzworth product line, outputting a 100 MHz, 10 dBm CW signal connected to the HA7062D via the DUT Input port on the front panel of the instrument.

GUI (Software) Configuration

Instrument Connectivity

STEP 1: Connect to the phase noise analyzer by opening the Devices menu on the right-hand side of the GUI.

STEP 2: Press the Locate Devices button in the section below the working area of the instrument's display. If the instrument is connected to the computer either via a USB cable or through the LAN, the software will be able to detect the instrument, and it will appear in the Devices section of the menu (Figure 6).

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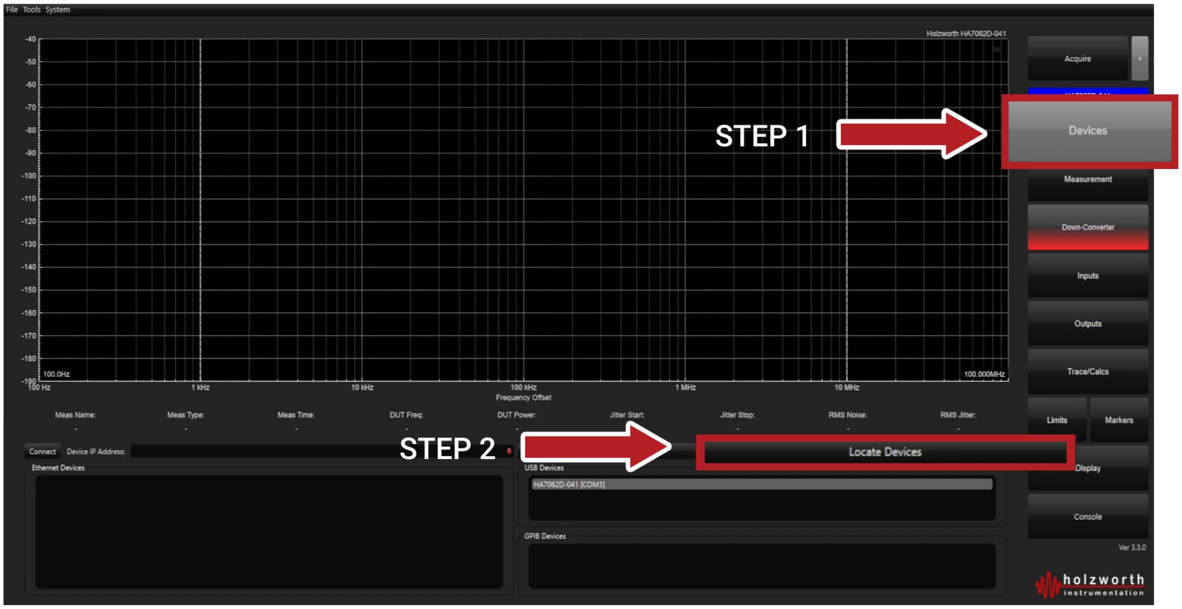

Figure 6: Ensure proper connections via the Devices menu.

STEP 3: You will need to select the instrument's serial number. If you have multiple Holzworth product line instruments connected to the computer, they will also appear.

STEP 4: Once the instrument is selected, the instrument's serial number will appear in blue above the Devices menu button (Figure 7).

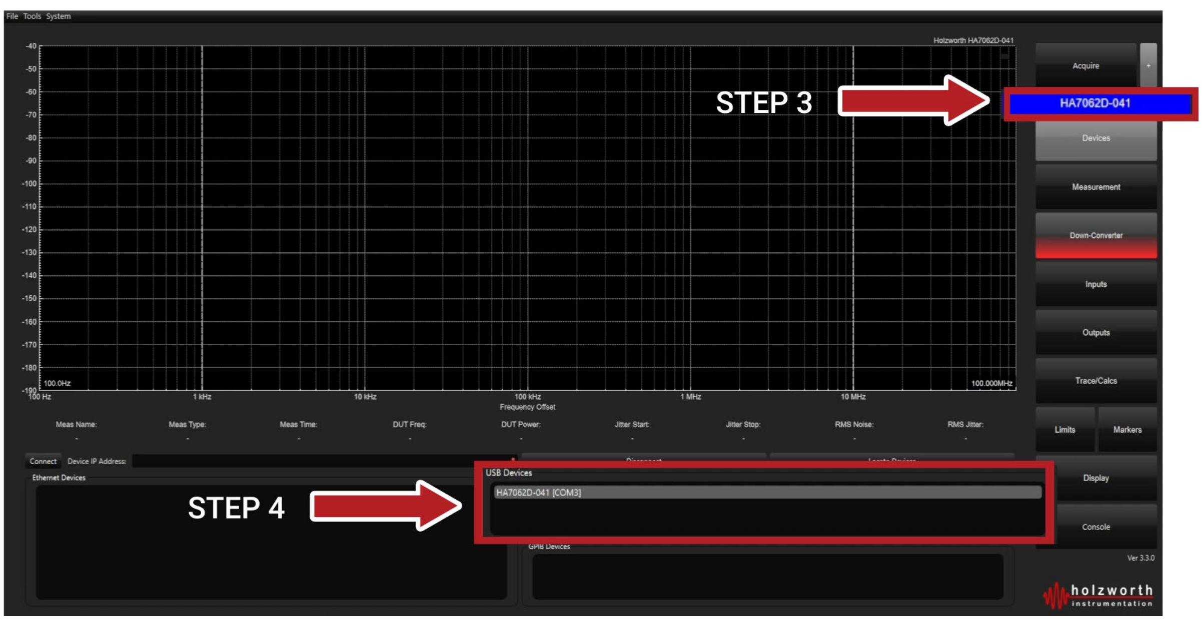

Figure 7: Complete the connection to the phase noise analyzer.

Absolute Measurement Configuration

STEP 1: Select the Measurement menu on the right-hand side of the GUI.

STEP 2: Confirm that Measurement Type is set to Absolute.

STEP 3: Set the Frequency Span to be from 1 Hz to 10 MHz.

STEP 4: Maximize the working area of the display by pressing the Measurement menu button on the right-hand side of the GUI.

STEP 5: Press the Acquire button to capture the signal.

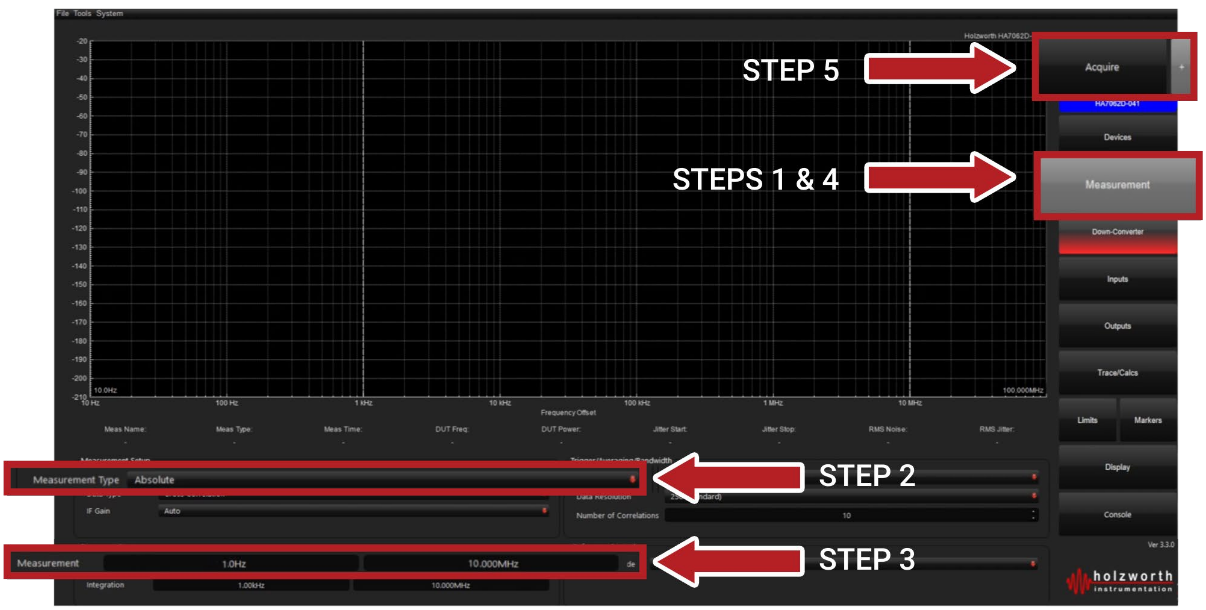

Figure 8: Configure the measurement type, frequency span, and display area before acquiring an absolute phase noise measurement.

To start understanding the absolute measurement, we will first look at the data listed below the captured phase noise plot. This section will display information directly corresponding to the measurement, specifically the measurement type (Figure 9a), measurement time (Figure 9b), DUT (carrier) frequency (Figure 9c), and DUT (carrier) power (Figure 9d).

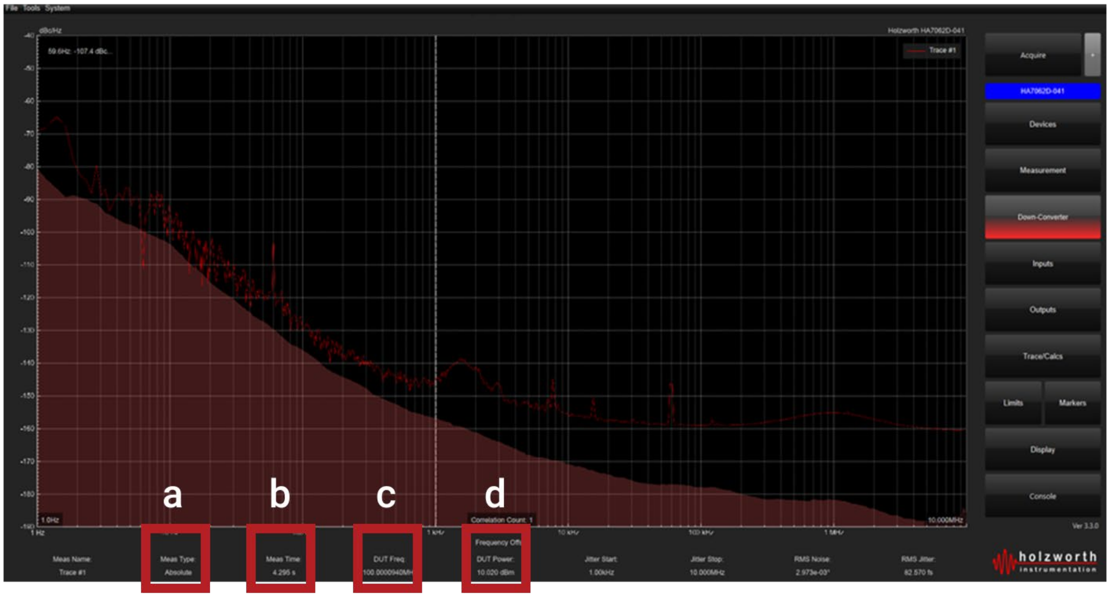

Figure 9: An absolute phase noise measurement plot for the HSX9001B RF Synthesizer and bottom menu of essential data (a through d).

With the carrier and the measurement type confirmed, we can closely examine the Figure 9 phase noise plot. The phase noise analyzer will not display the carrier portion of the CW signal but will display the single sideband phase noise with the frequency offsets at the bottom of the display. By removing the carrier signal from the display, the instrument can use more of its dynamic range to measure the signal's phase noise more accurately.

Additive Phase Noise Measurements

Additive measurements allow the phase noise analyzer to measure the phase noise contribution of subsystems or system components, furthering the understanding of the overall phase noise. In this section, we will review how to perform an additive measurement using the HA7062D.

Instrument Configuration

Compared to absolute measurements, the phase noise analyzer requires a different configuration to perform an additive measurement (Figure 10). Additional components include a 1 to 3 power splitter, two phase shifters, and an external signal source. The external signal source will generate a test signal to serve as the two LOs for the instrument and provide the DUT with the required operating signal.

The HA7062C and HA7062D can use either the Maury Microwave HX5100 Series Electronic Phase Shifters of the Holzworth product line or mechanical phase shifters to perform this measurement. For this demonstration, we will be using the HX5100-140M electronic phase shifters with a frequency range from 94 MHz to 187 MHz.

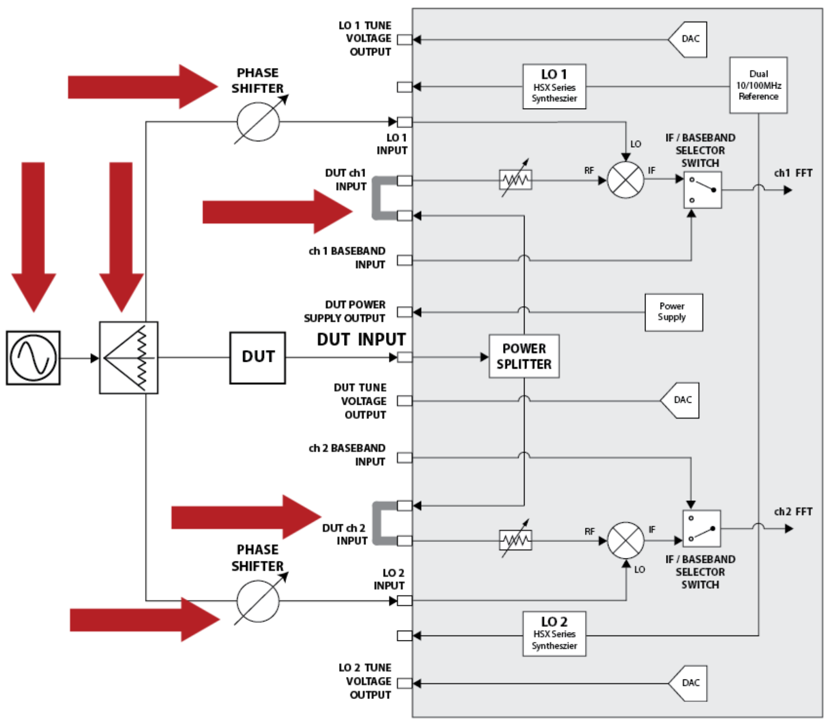

Figure 10: An additive phase noise measurement setup.

For additive measurements, the phase noise analyzer will only need two of the rigid jumper cables along with the additional phase shifters, power splitter, and signal source. The subsystem or the component will be placed within the testing system alongside the DUT. Note that the HX5100 electronic phase shifters will need to have their outputs connected to the LO inputs and the tune voltage must also be connected to the instrument. The phase noise analyzer's programmable power supply output is available if the DUT requires power.

Both the HA7062C and HA7062D perform additive measurements from 10 MHz to 6 GHz. For high frequency (up to 50 GHz) additive measurements, the Maury Microwave HA7063A Downconverter pairs directly with the HA7062C or HA7062D phase noise analyzer.

GUI (Software) Configuration

Instrument Connectivity

STEP 1: Connect to the phase noise analyzer by opening the Devices menu on the right-hand side of the GUI.

STEP 2: Press the Locate Devices button in the section below the working area of the instrument's display. As long as the instrument is connected to the computer either via a USB cable or through the LAN, the software will be able to detect the instrument, and it will appear in the Devices section of the menu (Figure 6).

STEP 3: You will need to select the instrument's serial number. If you have multiple Holzworth product line instruments connected to the computer, they will also appear.

STEP 4: Once the instrument is selected, the instrument's serial number will appear in blue above the Devices menu button (Figure 7).

Additive Measurement Configuration

STEP 1: Select the Measurement menu on the right-hand side of the GUI.

STEP 2: Change the Measurement Type to Additive.

STEP 3: Set the Frequency Span to be from 1 Hz to 10 MHz (Figure 11).

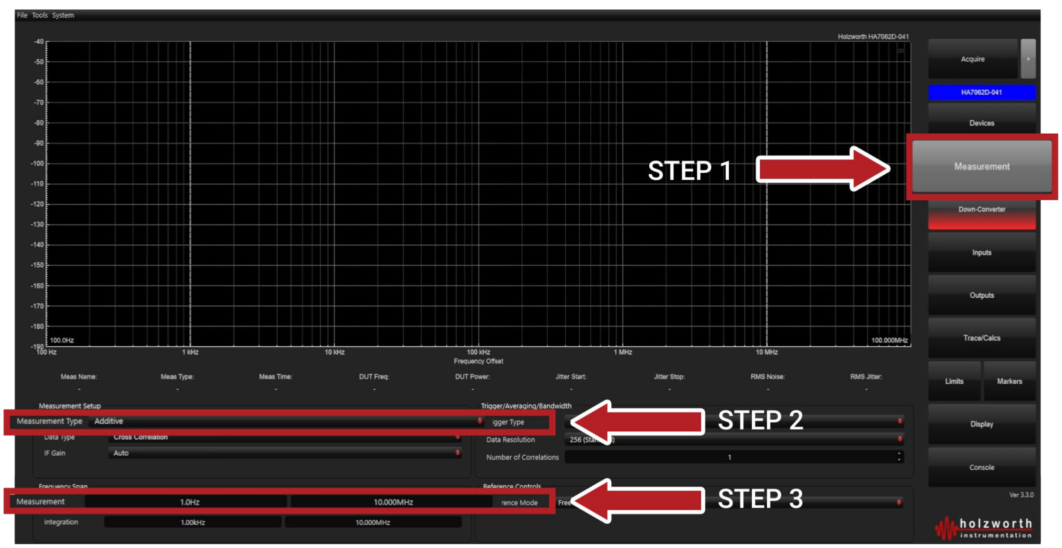

Figure 11: Setting up parameters in the Measurements menu of the GUI for an additive measurement.

STEP 4: Select the Inputs menu on the right-hand side of the GUI.

STEP 5: Confirm the Additive Setting is set to HX5100 within the DUT Inputs menu.

STEP 6: Maximize the working area of the display by pressing the Inputs menu button on the right-hand side of the GUI.

STEP 7: Press the Acquire button to capture the signal.

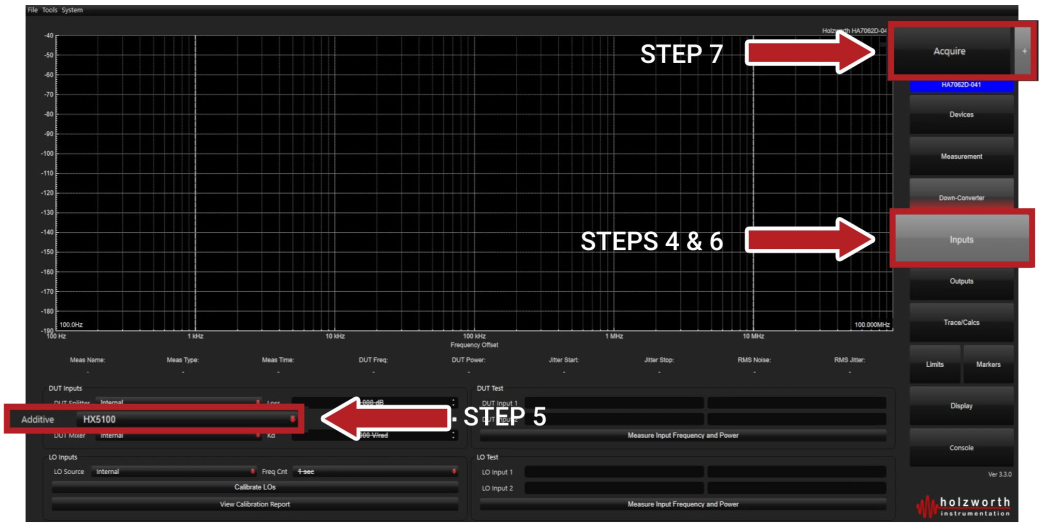

Figure 12: Configuring the Inputs menu and acquiring the additive phase noise measurement.

Users may need to increase the transmit power to account for the power splitter and cable loss. In the Figure 13 example, an HSX9001B provided a 15 dBm signal at 100 MHz through an amplifier (DUT) for the additive measurement. For reference, the absolute measurement provided a 10 dBm signal.

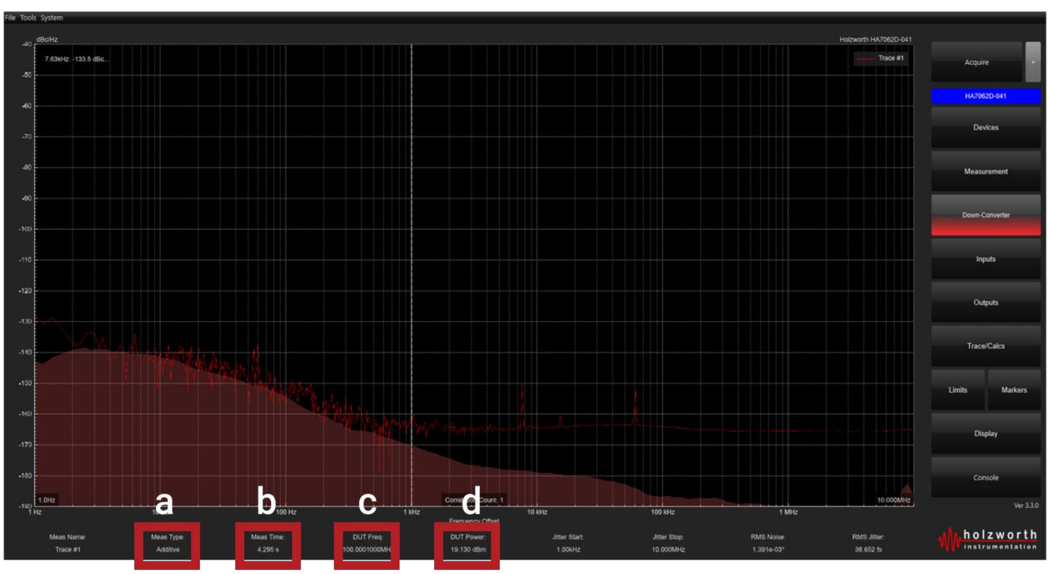

Figure 13: An additive phase noise measurement plot for the HSX9001B RF Synthesizer and bottom menu of essential data (a through d).

The bottom menu below the phase noise plot will display information directly corresponding to the measurement, such as the measurement type (Figure 13a), measurement time (Figure 13b), DUT (carrier) frequency (Figure 13c), and DUT (carrier) power (Figure 13d).

Regarding the Figure 13 plot, the phase noise analyzer will display the single sideband phase noise that is being added by the amplifier.

Benefits of Absolute and Additive Measurements

Absolute and additive measurements add to an engineer's diagnostic and debugging capability, allowing engineers to dive deeper into the phase noise performance of a DUT, subsystem, or individual component. The HA7062C and the HA7062D can easily perform absolute and additive measurements for thorough, high-performance phase noise analysis of the most advanced systems or devices.