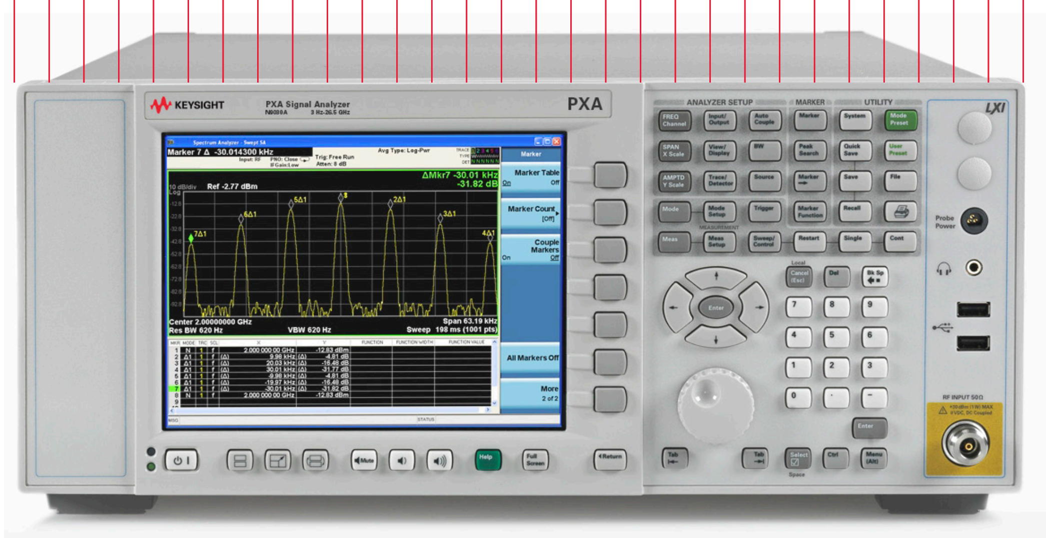
Keysight Technologies
External Source Control
X-Series Signal Analyzers
Option ESC

Demo Guide



KEYSIGHT
TECHNOLOGIES

External source control for X-Series signal analyzers (Option ESC) allows the Keysight PXA, MXA, EXA, and CXA to control the Keysight Technologies, Inc. PSG, MXG, or EXG signal generators for scalar stimulus-response measurements up to 50 GHz. This demonstration guide helps you understand how to:

– Set up connections between the signal analyzer and the signal source

– Perform stimulus-response tests to characterize filters, amplifiers, and mixers

– Apply normalization and open/short calibration to improve measurement accuracy

Demonstration Preparation

The demonstrations use an X-Series signal analyzer and Keysight signal generator. Option UNZ is recommended for MXG and EXG X-Series signal generators to obtain the fastest tracking speed. Keystrokes surrounded by [ ] indicate front-panel keys; keystrokes surrounded by { } indicate softkeys located on the display.

The sweep modes that Option ESC offers include:

– Standard sweep
– Harmonic sweep
– Power sweep
– Offset sweep
– Reverse sweep

Table 1. Minimum equipment configuration requirements

Product type/ instrument	Model number	Required configurations
PXA, MXA, EXA, and CXA signal analyzer	N9030A, N9020A, N9010A, or N9000A	• Option ESC • Firmware Version A.12 or later
MXG RF signal generator	N5181A or N5182A	• Firmware Rev. A.01.80 or later
MXG MW signal generator	N5183A	• Firmware A.01.80 or later
EXG X-Series RF signal generator	N5171B or N5172B	• Firmware B.01.01 or later
MXG X-Series RF signal generator	N5181B or N5182B	• Firmware B.01.01 or later
PSG signal generator	E8257D E8267D	• Firmware C.06.15 or later

Demonstration Setup

Connect the X-Series and MXG

Figure 1 shows the system set up for this demonstration. The X-Series controls the MXG via the VISA (virtual instrument software architecture) interface which uses a connection of LAN, GPIB, or USB. In this document, we will use a LAN connection. For information about how to set up the GPIB or USB connection, please refer to the instructions displayed on the analyzer screen by pressing **[Source], {Select Source ...}.** Additionally, more detailed information can be found in the X-Series **Help** files. To access the Help files, press **[Help], [Source], {Select Source...}, {Add Source to List};** then press **{USB}, {Add Installed USB Sources}** for USB connection, or press **{GPIB}** for GPIB connection.

The LAN connection can be made either through a LAN cross-over cable (red) or through the office LAN environment by using two normal LAN cables connected to the X-Series and the MXG, respectively.

The frequency reference lock-up between the analyzer and source is not required, but may increase the accuracy. The pair of BNC cables for the triggering are only required for the hardware trigger with which the maximum measurement speed can be achieved. Two pairs of the trigger in/out connectors in the X-Series (Trigger 1 and Trigger 2) can be used interchangeably.

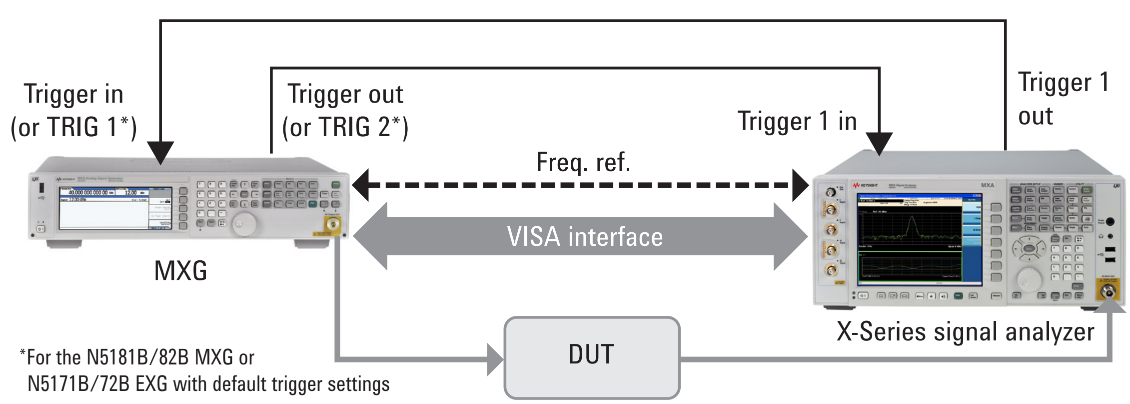


Figure 1. Setup of the demonstration system

Configuring the IP addresses

The X-Series with Option ESC controls the MXG through a LAN connection based on the TCP/IP protocol. The TCP/IP protocol can only be established with correct IP addressing. The first step is to assign an IP address to the X-Series upon connecting the X-Series and the MXG with a crossover LAN cable. To assign an IP address to the X-Series analyzer, you need to log in to the instrument as the "administrator" and change the TCP/IP properties. This is done using a USB mouse and a keyboard.

Instructions	Keystrokes (mouse clicks)
To assign the IP address of the X-Series analyzer, log off the defaulted user (*Instrument*).	**Start** > **Log Off** > **Log Off**
Log in the "administrator."	At the login prompt enter: User name: administrator Password: keysight4u
Assign an IP address and a subnet mask to the X-Series through "Control Panel" ("Category View" being the default setting) of the analyzer's Windows operating system.	**Start** > **Control Panel** > **Network and Internet Connections** > **Connections**; right click **Local Area Connection** to get a pull-down menu; and select **Properties** > In the General tab of the **Local Area Connection Properties** dialog box, select **Internet Protocol (TCP/IP),** and click **Properties.** In the General tab of the **Internet Protocol (TCP/IP) Properties** dialog box, check the **Use the following IP address** button, and enter: IP address: 192.168.100.1 Subnet mask: 255.255.255.0 Click OK > OK
Log off the "administrator."	**Start** > **Log Off** > **Log Off**
Log on the defaulted user (Instrument.)	At the login prompt enter: User name: Instrument Password: measure4u

Second, assign an IP address to the MXG as follows:

Instructions	Keystrokes
Assign an IP address and a subnet mask to the MXG.	On MXG: **[Utility], {I/O Config}, {LAN Setup}, {Config Type}, {Manual}, {Manual Config Settings}, {IP Address}, {Clear Text}, [192.168.100.3], {Enter}, [Return], {Proceed with Reconfiguration}, {Confirm Change (Network will Restart)}**

Third, add the MXG to the controlled source list in the X-Series and verify the connection:

Instructions	Keystrokes
Enter the external source control mode in X-Series and add the controlled source to the list.	**[Source], {Add Source to List}, {LAN}, {Enter LAN Address}, [192.168.100.3], {Enter}, {Add}**; the source added to the list will appear
Select the source.	**[Source], {Select Source...}**, highlight the source to be controlled by the mouse click or [↑]/[↓], **{Select Highlighted Source}**
Verify the source connection.	**{Verify current source connection}**

Figure 2 shows the source list and results of “Verify the current source connection” along with the instructions about the USB connection, GPIB connection, and LAN connections.

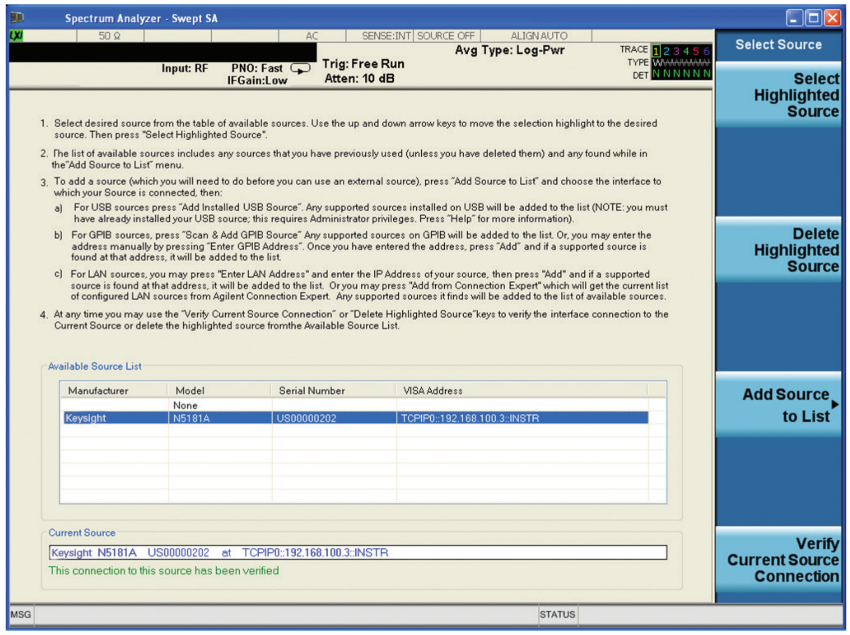


Figure 2. A screen from an X-Series signal analyzer for demonstrating the source list

Demonstrations

Demonstration 1:

Filter tests with “standard sweep”

Filters are one of the most important and most commonly used frequency selective devices. With the external source control capability, you can easily characterize a filter’s behavior by using the X-Series coupled with a supported external source. In this section, we use an 880 MHz band-pass filter as a device under test (DUT) to determine its pass-band width, ripple, and shape factor. In the “standard sweep” mode, the X-Series sweeps synchronically with the MXG at the same start and stop frequencies, and sweep rate.

Connect one port of the filter to the MXG RF output, and the other to the X-Series RF input as shown in Figure 3.

The “standard sweep” is the default setting of the “source” mode. In the standard sweep the start and stop frequencies of the source and analyzer are identical, as is their sweep rate.

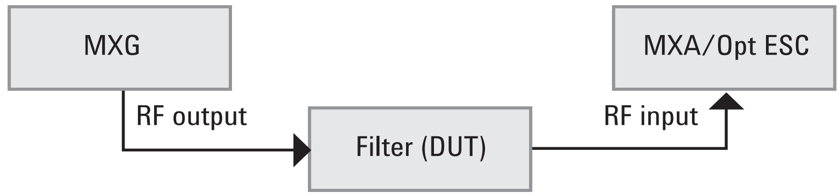


Figure 3. Setup for filter tests

Instructions	Keystrokes
Preset signal analyzer.	**[Mode Preset]**
Set signal analyzer sweep range from 800 to 950 MHz.	**[FREQ], {Start Freq} [800] {MHz}, {Stop Freq} [950] {MHz}**
Enter external source control mode.	**[Source]**
Start source tracking.	**{Source mode} {Tracking}**
Turn on the source RF output.	Toggle **{RF output}** to underline “On”
Adjust number of sweep point, if needed.	**[Sweep/Control], {Points} [601] {Enter}**
Determine bandwidth at 3 dB roll-off.	**[Marker] {Select Marker 1} {Normal},** rotate the knob to center of the pass band; **[Meas Setup], {N dB Point}, [-][3]{dB}.** Read the bandwidth at -3 dB roll off. Refer to Figure 4.
Determine the filter’s shape factor (–60 dB vs. –3 dB.)	**[Meas Setup], {N dB Point}, [-][60]{dB}.** Read the bandwidth at -60 dB roll off. Refer to Figure 6. The shape factor (-60 dB vs. -3 dB) of this filter can be easily calculated from this reading and the one obtained in the preceding step.
Determine the passband ripple.	**[Marker] {More} {All Markers Off}, [AMPTD] {Ref Level} [10] {dBm}, {Scale/Div} [1] {dB}, [SPAN] [50] {MHz}, [Marker] {Normal}, [Peak Search] {Delta}**, rotate the knob to move the delta marker to the trough of passband. Refer to Figure 6.

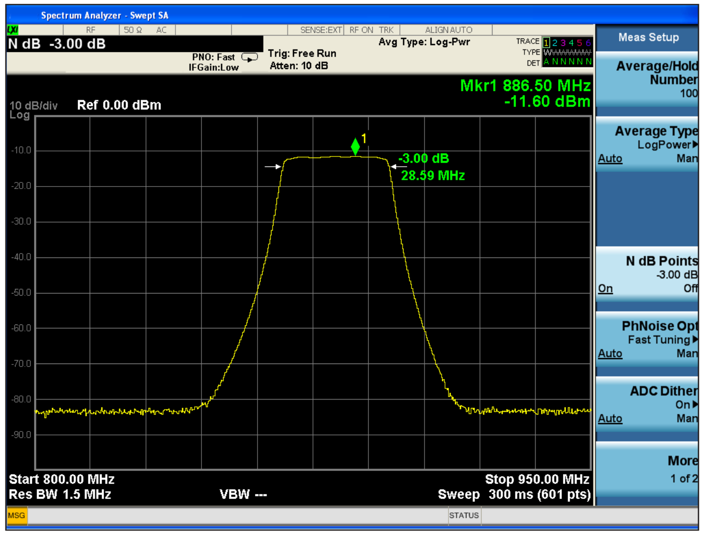


Figure 4. Determine –3 dB bandwidth of the filter

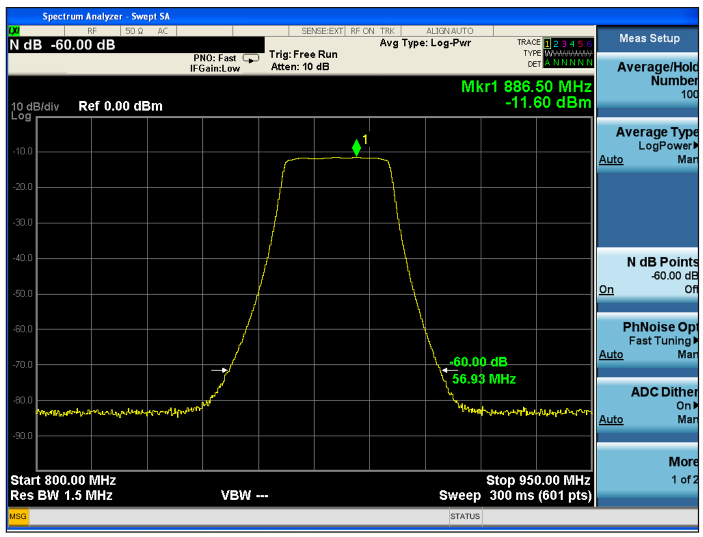


Figure 5. Determine shape factor by applying the N-dB point markers

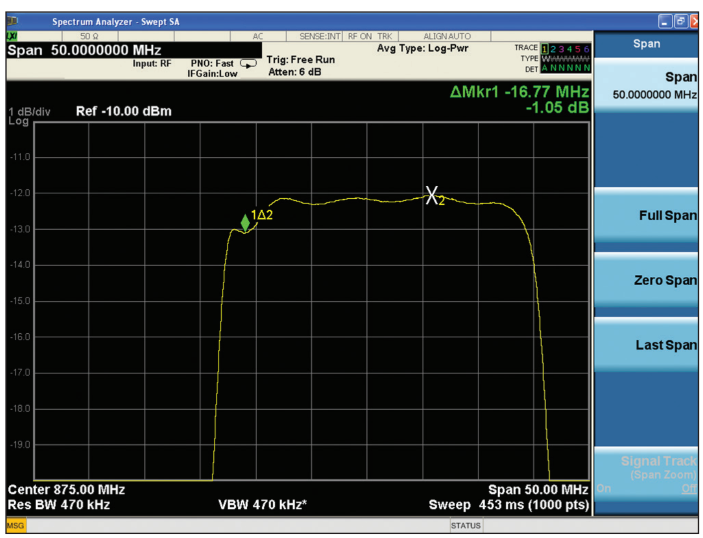


Figure 6. Measure the passband ripple for the filter

Demonstration 2:

Amplifier harmonic tests with "harmonic sweep"

Amplifiers are the most common active devices. Harmonic distortion is one of the critical characteristics when evaluating the quality of an amplifier. This demonstration measures harmonic distortion for a Keysight 8447F amplifier (9 kHz to 1,300 MHz) with the "harmonic sweep" setting in the X-Series external source control. In the "harmonic sweep" mode, the following frequency relationship holds

$$Freq_{SS} = \alpha \cdot Freq_{SA}$$

where, α is a multiplier and can further divided into a numerator and denominator (α: multiplier = numerator/denominator). $Freq_{SS}$ is the frequency of the signal source, and $Freq_{SA}$ is the frequency of the signal analyzer. The multiplier α is the ratio of the start and stop frequencies of the source, and sweep rate of the signal source to that of the signal analyzer. The numerator and denominator are both integers and can be set by the user individually.

Connect the input port and output port of the amplifier to the MXG RF output and to the X-Series RF input, respectively (Figure 7.)

The defaulted "standard sweep" (multiplier numerator = multiplier denominator = 1) is useful in characterizing the amplifier's frequency responses.

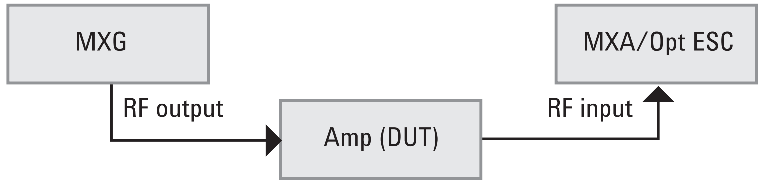


Figure 7. Setup for amplifier harmonic tests

Instructions	Keystrokes
Preset the signal analyzer.	**[Mode Preset]**
Set the signal analyzer sweep range from 20 MHz to 3 GHz.	**[FREQ]**, **{Start Freq} [20] {MHz}**, **{Stop Freq} [3] {GHz}**
Enter external source control mode.	**[Source]**
Adjust the source RF output amplitude to a lower level. *This step is of particular importance for the amplifier tests as excessive RF power may damage the amplifier and/or the analyzer front-end.*	**{Amplitude} [–40] {dBm}**
Return to the menu of source mode.	**[Return]**
Start source tracking.	**{Source Mode} {Tracking}**
Turn on the source RF output.	Toggle **{RF Output}** to underline "On"
Characterize the amplifier's frequency response with "standard sweep."	Both the multiplier numerator and denominator are defaulted to "1." This defaults the "standard sweep." Refer to Figure 8 for the result.
Adjust number of sweep points, if needed.	**[Sweep/Control]**, **{Points} [601] { Enter}**
Use marker functions to quantify the amplifier's frequency response.	**[Marker] [Peak Search]**, **[Marker] {Delta}**, then rotate the knob to move the delta marker to different frequency for the amplitude difference in dB.

Set harmonic sweep for the higher harmonic measurements. The signal analyzer measures the responses at α times higher start/stop frequencies and sweep rate than that of the stimulus signals from the signal source.

Instructions	Keystrokes
Continue from the instrument settings at the end of table shown above.	
Back to the main menu for external source control mode.	**[Source]**
Set the multiplier denominator to two for the second harmonic measurement.	**{Frequency} {Multiplier Denominator} [2] {Enter}**. The multiplier numerator is defaulted to "1."
Adjust number of sweep points, if needed.	**[Sweep/Control], {Points} [601] {Enter}**. Refer to Figure 9 for the second harmonic measurement result.
Use marker functions to quantify the amplifier's frequency response.	**[Marker] [Peak Search], [Marker] {Delta}**, then rotate the knob to move the delta marker to different frequency for the amplitude difference in dB.
View source setup.	**[Source] {More 1 of 2} {Source Setup} {Show Source Capabilities & Settings...}**. Refer to Figure 10.
You may set the denominator to 3 for the third harmonic, to 4 for fourth harmonic, and so on.	

Set harmonic sweep for the sub-harmonic measurements. The signal analyzer measures the responses at α times lower start/stop frequencies and sweep rate than that of the stimulus signals from signal source.

Instructions	Keystrokes
Continue from the instrument settings at the end of table shown above.	
Back to the main menu for external source control mode.	**[Source]**
Reset the multiplier denominator to 1.	**{Frequency} {Multiplier Denominator} [1] {Enter}**
Set the multiplier numerator to 2 for the sub-harmonic (½ harmonic).	**{Multiplier Numerator} [2] {Enter}**
Adjust number of sweep point, if needed.	**[Sweep/Control], {Points} [601] {Enter}**. Refer to Figure 11 for the ½ sub-harmonic measurement result
Use marker functions to quantify the amplifier's frequency response.	**[Marker] [Peak Search], [Marker] {Delta},** then rotate the knob to move the delta marker to different frequency for the amplitude difference in dB
You may set the numerator to 3, 4, ... for different orders of the sub-harmonic measurements (1/3, ¼, ...).	

Figure 8. "Standard sweep" for measure the frequency responses of the amplifier

Figure 9. Harmonic sweep (multiplier = ½) for the second order harmonic measurement for the amplifier (some abnormality appears for this DUT at 203.5 MHz stimulus for its second harmonic behavior as shown at the marker)

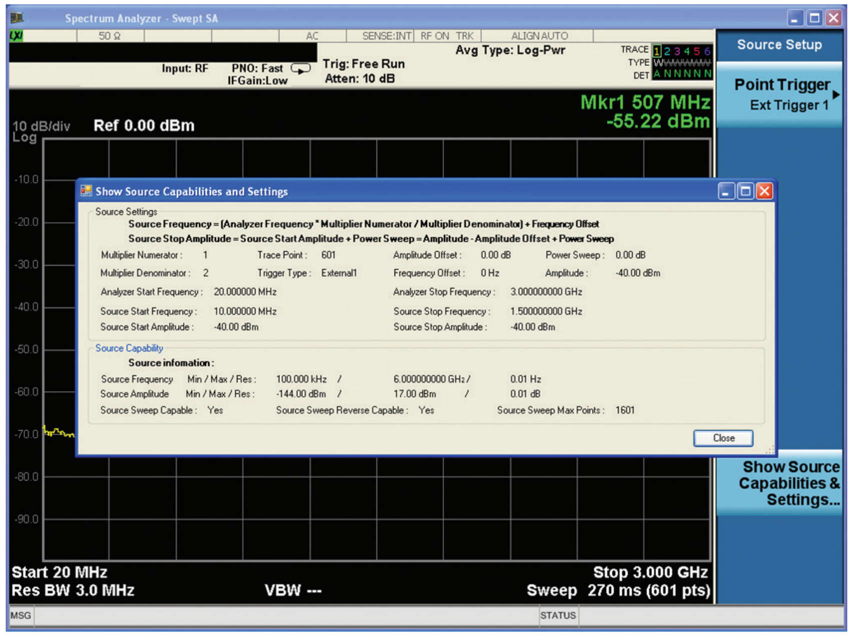


Figure 10. "Show Source Capabilities & Settings" indicates key information of the signal source and signal analyzer settings

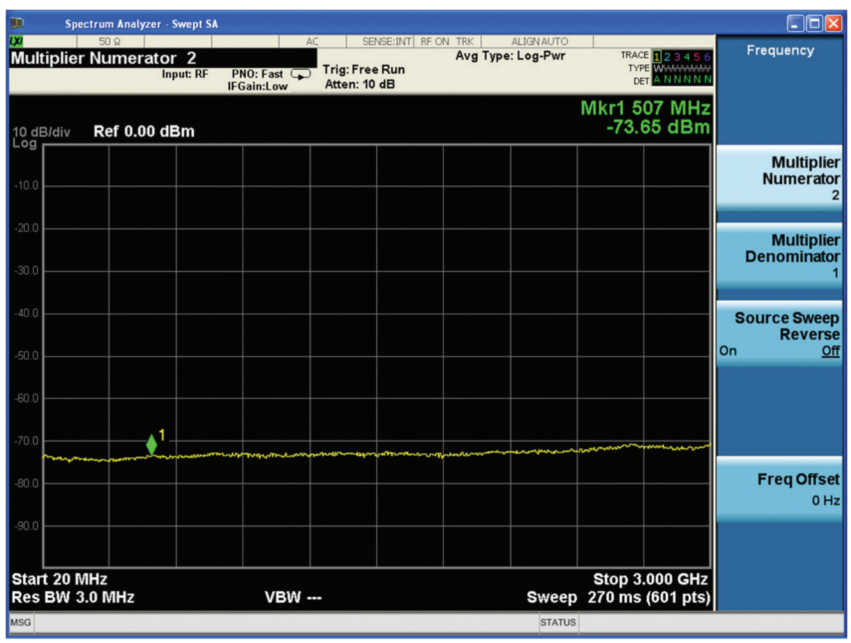


Figure 11. Harmonic sweep (multiplier = 2/1) for the sub-harmonic measurement for the amplifier

Demonstration 3:

Amplifier linearity tests with "power sweep"

Another important parameter in characterizing an amplifier is the gain compression or how the amplifier behaves in saturation. Gain compression limits the amplifier's dynamic range. The "power sweep" mode in Option ESC enables you to easily measure the gain compression. This demonstration will perform the CW gain compression measurement. The external source is controlled so that its power out is swept linearly as the frequency remains constant, such as setting the analyzer for zero sweep span.

Connect the input and output ports of an amplifier to the RF output of the MXG and the RF input of the X-Series, respectively (Figure 12.)

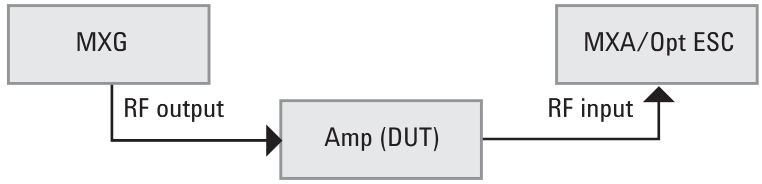


Figure 12. Setup for amplifier gain compression tests

Instructions	Keystrokes
Preset the signal analyzer.	**[Mode Preset]**
Set the signal analyzer center frequency to 870 MHz, and zero span.	**[FREQ] {Center Freq} [870] {MHz}, [SPAN] {Zero Span}**
Set the signal analyzer amplitude reference level to +20 dBm.	**[AMPTD] {Ref Level} [20] {dBm}**
Enter ESC mode.	**[Source]**
Set the initial level of the power sweep to –100 dBm.	**{Amplitude} [–100] {dBm}**
Set the power sweep range to 80 dB.	**{Power Sweep} [80] {dB}**
Note: It is of paramount importance to carefully set the initial power sweep level and range properly according to the input limits of the amplifier and analyzer, and the amplifier's gain specifications. Excessive RF power may damage the amplifier and/or analyzer front-end.	
Return to the menu of source mode.	**[Return]**
Start source tracking.	**{Source Mode} {Tracking}**
Turn on the source RF output.	Toggle **{RF output}** to underline "On"
Adjust number of sweep point, if needed.	**[Sweep/Control], {Points} [601] {Enter}**
Use marker functions to characterize the amplifier's power responses, such as the cut-off level, linear region, and 1-dB compression.	**[Marker]**, then rotate the knob to move the marker to the appropriate input power (X-axis) to characterize the amplifier's power response. Refer to Figure 13 for the result.

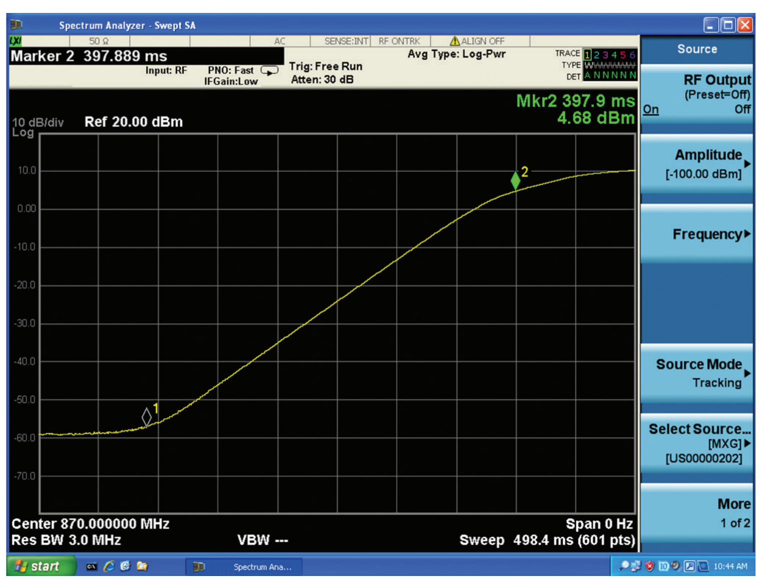


Figure 13. The power sweep at a fixed frequency tests the amplifier's cut-off level, linear region, and gain compression

Demonstration 4:

Mixer tests with "offset sweep"

Mixers are widely used as frequency translation devices. They provide a signal at the output whose frequency is the sum and difference of the signals on the two inputs. The "offset sweep" mode available in Option ESC allows you to measure the behavior of a mixer while synchronizing the MXG to sweep with a certain offset frequency, to generate an appropriate intermediate frequency (IF) span.

Connect the RF input and IF output of the mixer to the MXG RF output and the X-Series RF input, respectively. For the mixer tests we need an additional signal source to generate a CW signal with a fixed frequency as the LO input. Refer to Figure 14 for the test system setup.

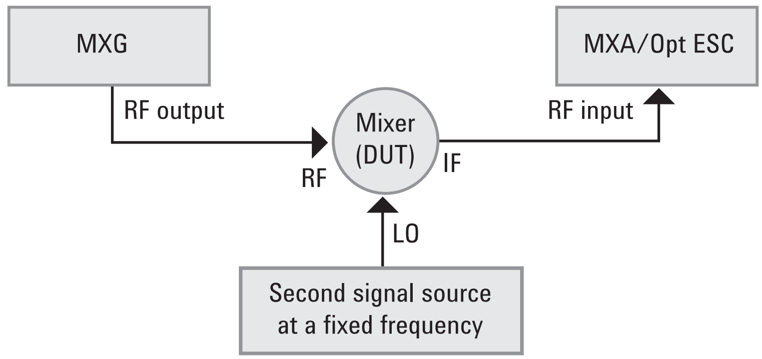


Figure 14. Setup for mixer tests

Instructions	Keystrokes
Set the second signal source to 700 MHz and 5 dBm RF output as the fixed LO signal.	On second MXG signal generator: **[FREQ] [700] {MHz}, [AMPLD] [5] {dBm}**, toggle **[Mod On/Off]** to turn off the modulation (LED indicator off); toggle **[RF On/Off]** to turn on the RF off (the LED indicator is lit)
Preset the signal analyzer.	**[Mode Preset]**
Set the signal analyzer start frequency = 800 MHz and stop frequency = 1.3 GHz.	**[FREQ] {Start Freq} [800] {MHz}, {Stop Freq} [1.3] {GHz}**
Enter external source control mode.	**[Source]**
Turn the "offset sweep" mode on and set the offset to 700 MHz (same as the fixed LO frequency).	**{Frequency} {Freq Offset} [700] {MHz}**
Return to main menu.	**[Return]**
Set the source RF out level to 0 dBm.	**{Amplitude} [0] {dBm}**
Turn on source tracking.	**[Source] {Source Mode} {Tracking}**
Turn on source RF output.	[Return], toggle **{RF output}** to underline "On." Refer to Figure 15 for the result of mixer's IF out.
Check the source setting.	**[Source] {More 1 of 2} {Source Setup} {Show Source Capabilities & Settings...}**. Refer to Figure 16.

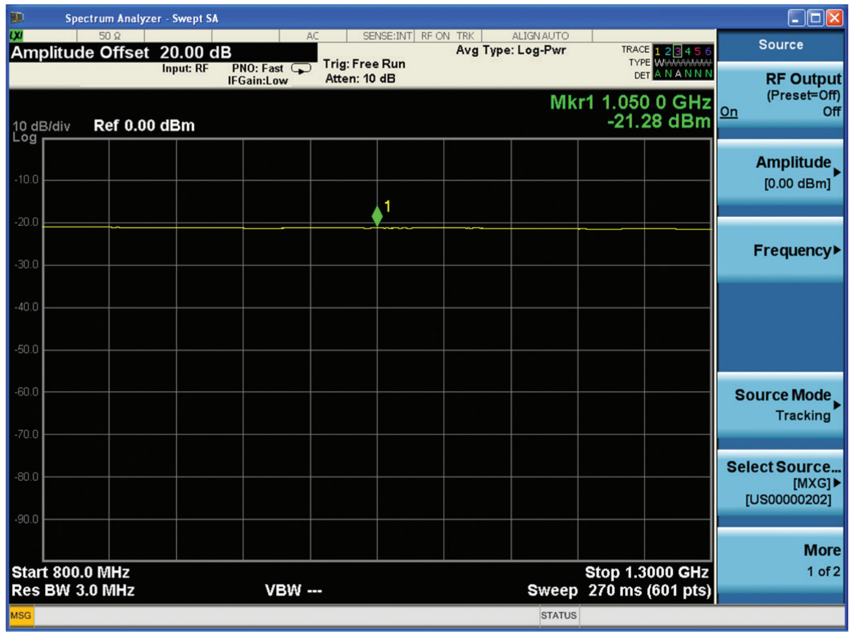


Figure 15. Mixer’s IF output when frequency offset is set to 700 MHz

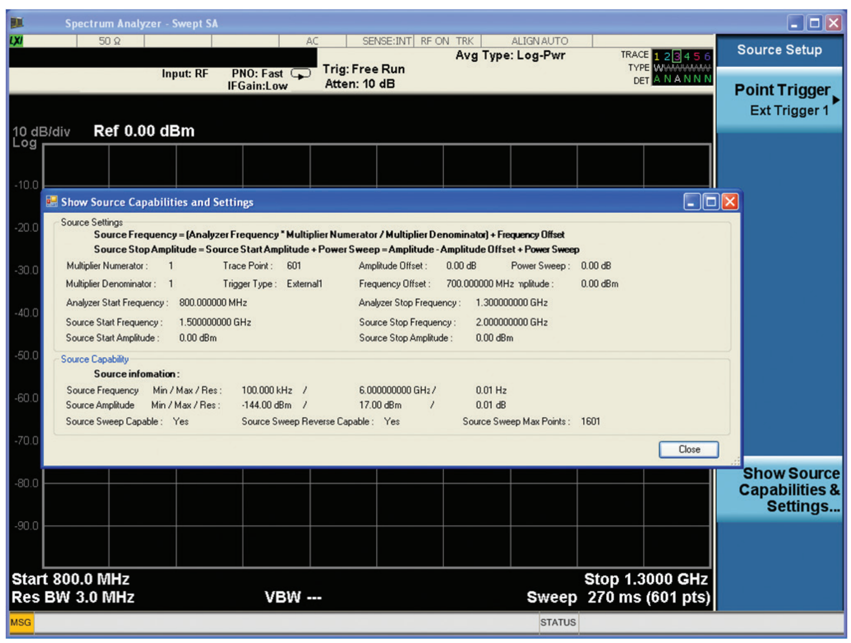


Figure 16. “Show Source Settings” demonstrates that the signal analyzer sweeps from 800 MHz to 1.3 GHz and the signal source from 1.5 to 2.0 GHz

In some use cases, particularly for analyzing negative mixing products in a mixer, a “reverse sweep” becomes desirable. By enabling the reverse source sweep, the signal analyzer controls the source such that it sweeps from a higher frequency to a lower frequency while the signal analyzer itself always sweeps from a lower frequency to a higher frequency.

Instructions	Keystrokes
Set the second signal source to 2 GHz and 5 dBm RF output as the fixed LO signal.	On second MXG: **[FREQ] [2] {GHz}, [AMPLD] [5] {dBm}**, toggle **[Mod On/Off]** to turn off the modulation (LED indicator off); toggle **[RF On/Off]** to turn on the RF off (the LED indicator is lit)
Preset the signal analyzer.	**[Mode Preset]**
Set the signal analyzer start frequency = 800 MHz and stop frequency = 1.3 GHz.	**[FREQ] {Start Freq} [800] {MHz}, {Stop Freq} [1.3] {GHz}**
Enter ESC mode.	**[Source]**
Turn the “offset sweep” mode on ad set the offset to 2 GHz (same as the fixed LO frequency).	**{Frequency} {Freq Offset} [2] {MHz}**
Return to main menu.	**[Return]**
Set the source RF out level to 0 dBm.	**{Amplitude} [0] {dBm}**
Turn on “reverse” sweep.	**{Frequency}**, toggle **{Source Sweep}** to underline “On”
Turn on source tracking.	**[Source] {Source Mode} {Tracking}**
Turn on source RF output.	**[Return]**, toggle **{RF output}** to underline “On”
Check the source setting.	**[Source] {More 1 of 2} {Source Setup} {Show Source Capabilities & Settings...}**. Refer to Figure 17.

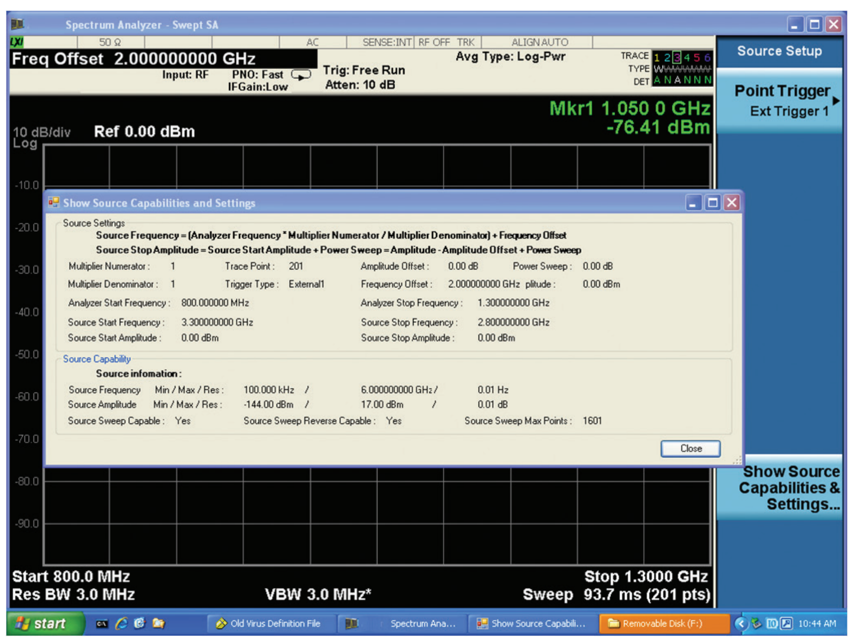


Figure 17. “Show source settings” indicates the source sweeps from a higher frequency to a lower frequency which is opposite to the signal analyzer sweep direction

Demonstration 5:

Normalization

Normalization is often used in a transmission measurement to correct for systemic errors. The frequency response of the test system must first be measured and then normalization is used to eliminate the frequency response errors caused by the system.

To measure the frequency response of the test system, set up the system as desired for the DUT tests. Then, replace the DUT with a "thru" connection (See Figure 18). Normalization is implemented under the signal analyzer's "Trace/Detector" menu. A filter used in the "standard sweep" section is employed here as the DUT.

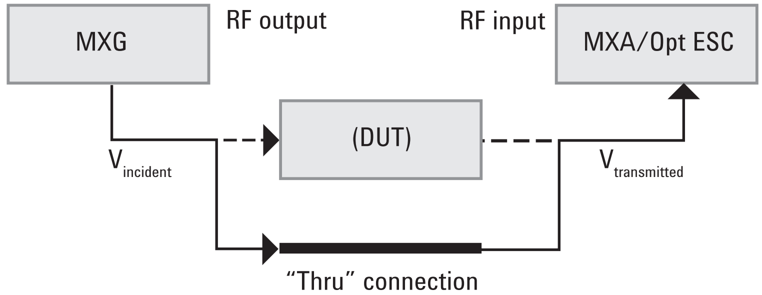


Figure 18. Setup for normalization

Instructions	Keystrokes
Preset the signal analyzer.	**[Mode Preset]**
Set the signal analyzer sweep range from 800 to 950 MHz.	**[FREQ], {Center Freq} [870] {MHz}, [SPAN] [150] {MHz}**
With the thru connection connected, measure the frequency response of the test system.	**[Source] {Source Mode} {Tracking}**, toggle **{RF Output}** to underline "On"
Adjust number of sweep point to 601.	**[Sweep/Control] {Points} [601] {Enter}**
Store the frequency response curve of the test system as the reference.	**[Trace/Detector] {More} {More} {Normalize} {Store Ref (1->3)}**
Replace the thru with the DUT by removing the thru connection and reconnect the DUT as shown in Figure 18 (with the dashed lines).	
Activate the normalization, and observe the active trace is now the ratio of the input to the stored reference in dB.	Toggle **{Normalize}** to underline "On" Refer to Figure 19

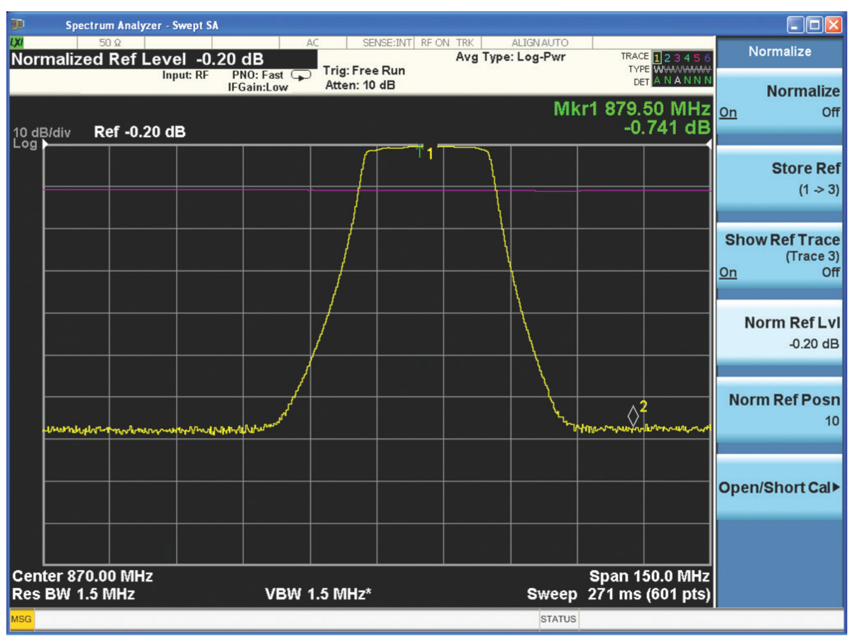


Figure 19. Results of "Normalization" with the reference (test system response) displayed in pink and the DUT response displayed in yellow and in dB relative to the reference

Demonstration 6:

Open/short calibration

The X-Series with a tracking source and an external directional coupler or directional bridge enables reflection measurements. Performing reflection measurements allows you to determine some critical characteristics for a device, such as reflection coefficient, return loss, and SWR (standing wave ratio). An open/short calibration is used for reflection measurements and corrects for system frequency response errors. Essentially, this type of calibration is a normalized measurement in which a reference trace is stored in memory and will then be subtracted from later measurement data.

A calibration created by measuring both an open and a short is more accurate than using only one or the other. Since the open data and short data are 180 degrees out of phase, they tend to average out the calibration errors.

Figure 20 is a diagrammatic presentation for reflection measurements and the open/short calibration. The Keysight E4440AU-015 (6 GHz return-loss measurement accessory kit) is recommended in case you need the accessory parts, such as a directional bridge, short, and coaxial cables, required for reflection measurements.

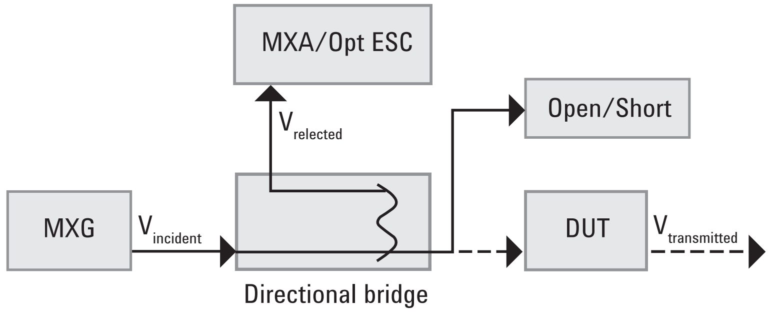


Figure 20. Setup for one-port open/short calibration

Instructions	Keystrokes
Preset the signal analyzer.	**[Mode Preset]**
Enter source tracking mode.	**[Source]**
Start the "Open/Short calibration."	**[Trace/Detector] {More} {More} {Normalize} {Open/Short Cal}**, Refer to Figure 21 for an example of graphical instructions.
Follow the graphical instructions given on the X-Series display, "Open" the bridge output and proceed.	**{Continue}**
Follow the graphical instructions given on the X-Series display, connect a coaxial "Short" to the output of the directional bridge and proceed.	**{Continue}**
Once done, exit from the "Open/Short Cal."	**{Done Cal}**

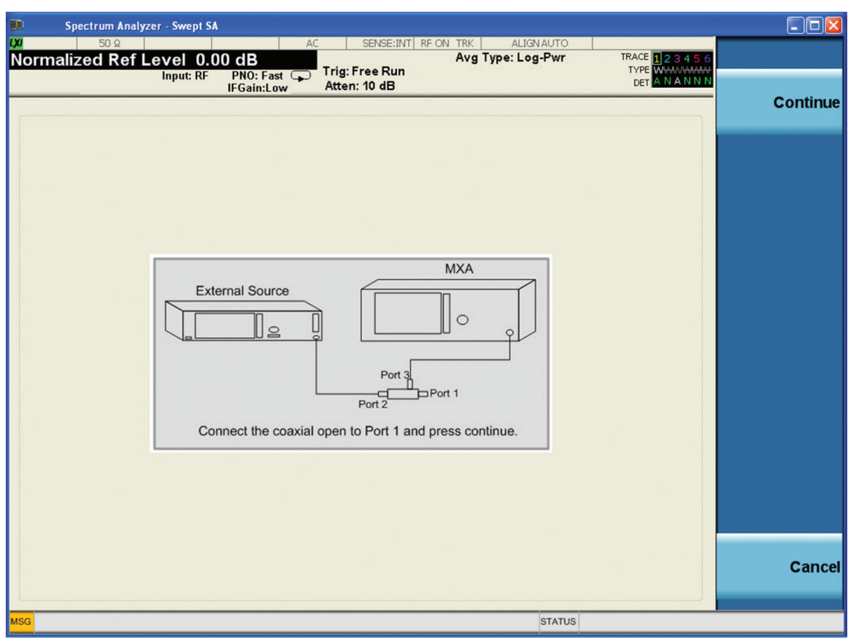


Figure 21. Graphical instructions displayed on the X-Series lead you through the open/short calibration procedure

Related Literature

"Option ESC Technical Overview" 5990-6088EN

Web

X-Series signal analyzers: www.keysight.com/find/X-Series

X-Series measurement applications: www.keysight.com/find/X-Series_apps

X-Series signal generators: www.keysight.com/find/X-Series_SG

PSG signal generator: www.keysight.com/find/PS

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