Direct Connection of OML Frequency Extenders to Keysight's PNA-C (E836xC) VNA for 1-Path 2-Port S-Parameter Measurements

Introduction

For full two-port S-parameter measurements to extend PNA-C vector network analyzers beyond their internal operating frequency range with OML millimeter wave frequency extension modules, it is necessary that the PNA-C vector network analyzer connects to a millimeter-wave controller, N5260A. This paper describes a procedure that allows the PNA to work with OML millimeter wave frequency extension modules without the use of Keysight's millimeter head controller, N526xA. The setup is limited to 1-path, 2-port measurements without the controller; however, this configuration might be ideally suited for applications requiring only S11 and S21 measurements (e.g., antenna range measurements).

PNA prerequisites to function without the millimeter wave controller are,

1. Keysight's PNA vector network analyzer (C-series; not available for prior models?)
2. Option H11 (IF Access)
3. Option 014 (Configurable Test Set)
4. Option 080 (Frequency Offset Mode) installed
5. Option 081 (Reference Channel Switch)
6. Option UNL (Extended Power Range and Bias-Tees)
7. The most current version of the firmware for the E836x

OML extension modules requirements are,

1. OML's T/R & T modules for S11 and S21 measurements, respectively
    a. T/R module requires Option RLA, T module requires Option LOA
2. Two OML's DC power supplies with 7-pin circular jack connections: +12VDC, 3A
    a. As an alternative, an external power supply can be substituted
3. Three RF phase stable cables (1m or 2m length), K(m/m)
4. Three IF cables (1m or 2m length), SMA (m/m)
5. One RF power splitter (splits LO from PNA to drive modules)
6. One SMA(M/M) adapter

OML millimeter wave frequency extension modules are simply "plug n' play" after configuring the PNA for millimeter wave measurements.

Hardware Connection

Connect the PNA, OML millimeter wave frequency extension modules, and DC power supply as shown in Figure 1 and Figure 2. Figure 1 shows the front panel view; whereas, Figure 2 shows the rear panel view.

N**ote:** RF and LO cables must be phase stable RF cables.

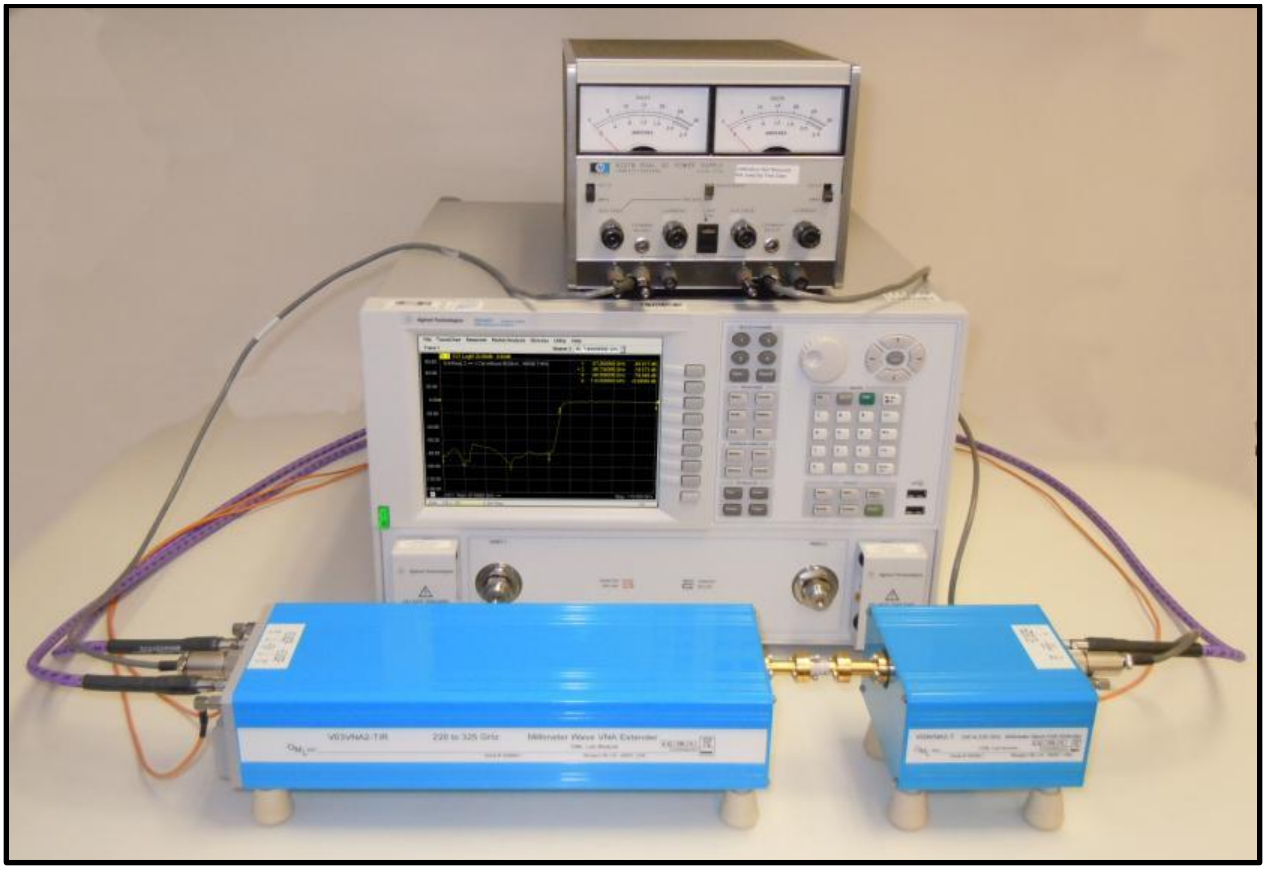


Figure 1. Shown is the front view of the overall millimeter wave setup consisting of Keysight's PNA, OML's VNA extension modules,power supply, and interconnects. Note that this setup does not include the N526xA millimeter-wave controller. Left to right, OML T/R and T modules are shown with a through connection. The RF, LO, and IF signals are connected to the rear panel of the PNA. In this configuration, the setup supports enhanced calibrations for S11 and S21 measurements.

Hardware Connection (continued)

Rear panel interconnects are shown in Figure 2.

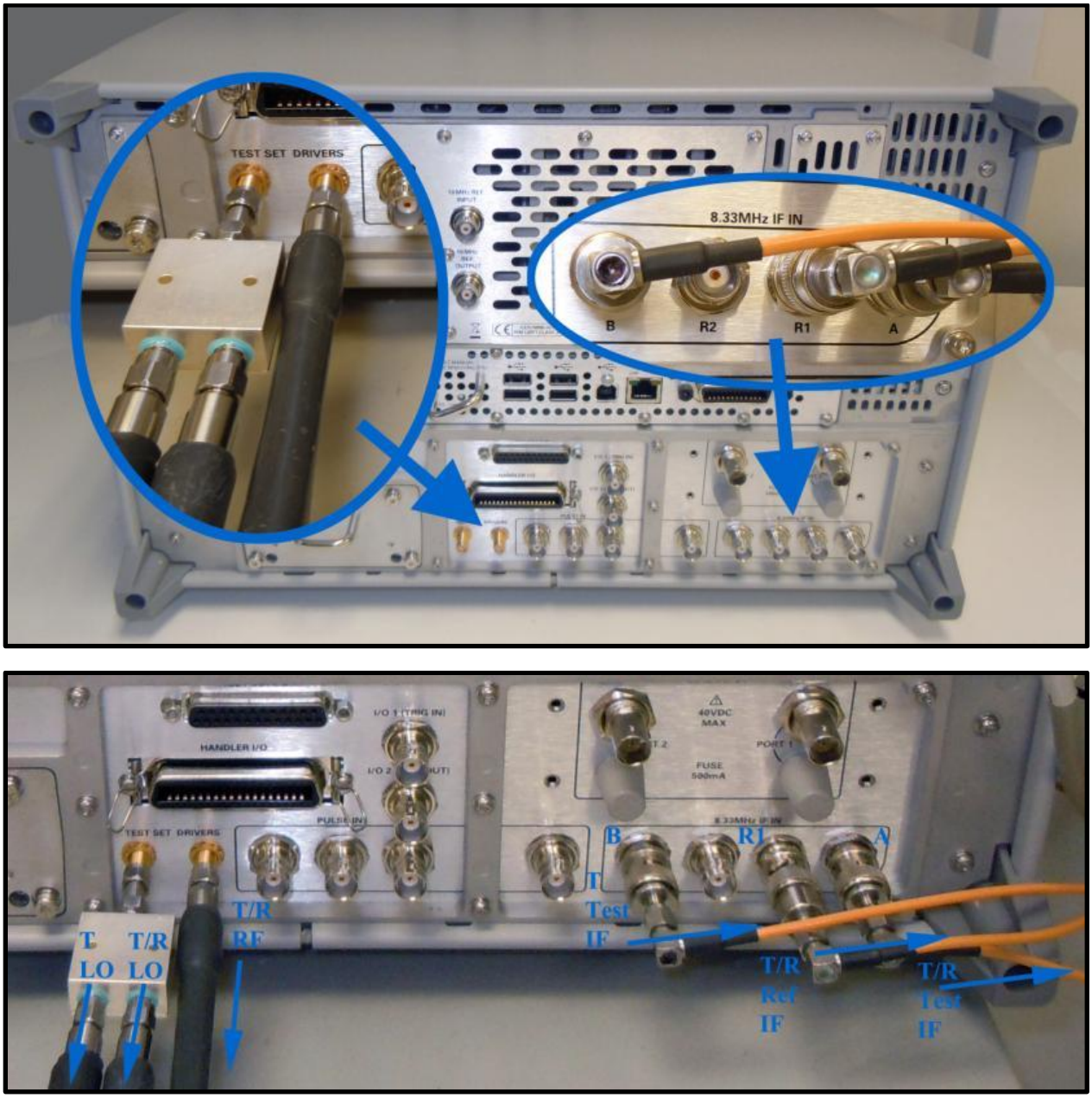


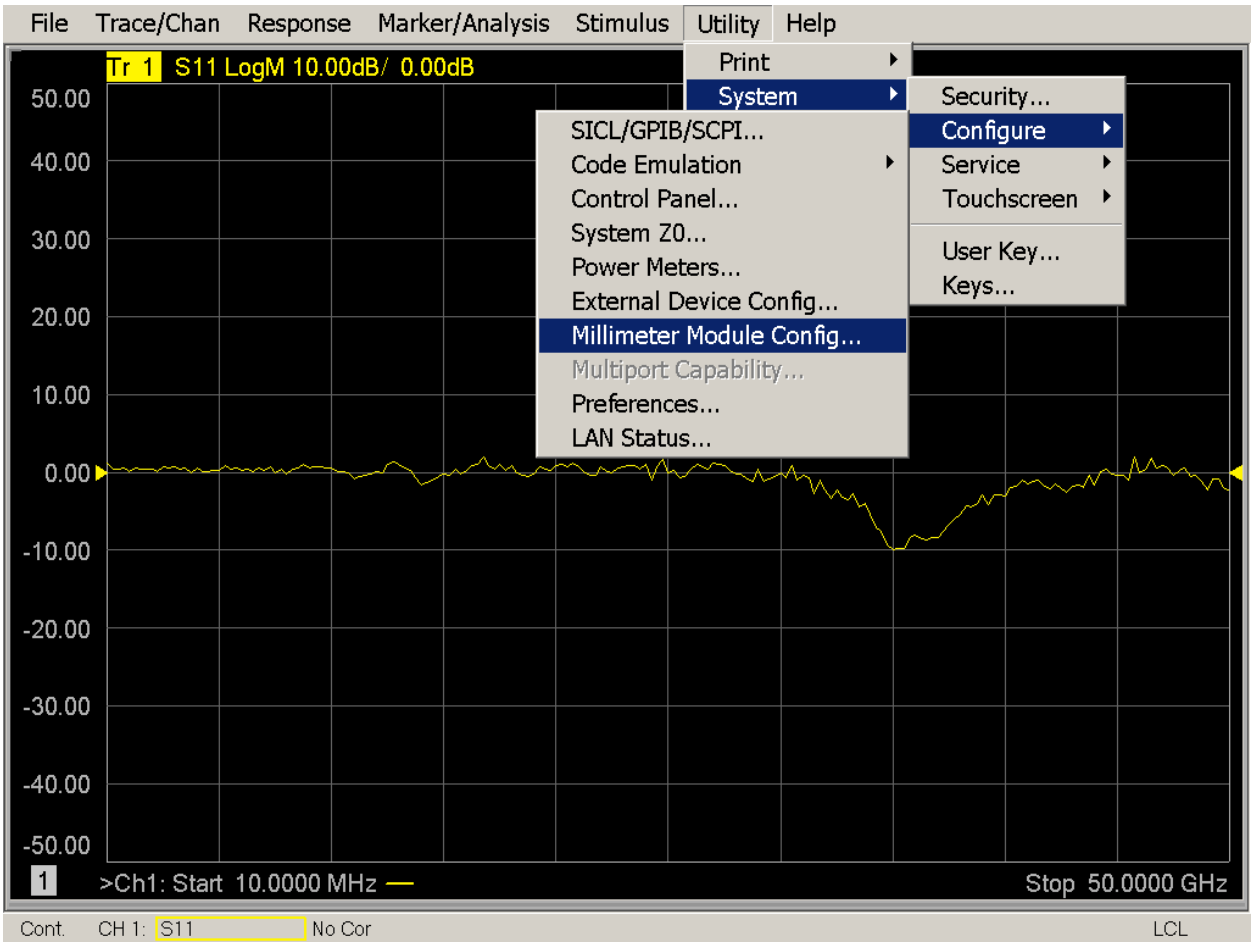
Figure 2. Shown is the rear view (including close-ups) of the overall millimeter wave setup consisting of Keysight's PNA, OML's VNA extension modules, and interconnects. Note that this setup does not include the N526xA millimeter-wave controller. On the left, phase-stable RF cables are connected to the Test Set Drivers output; the LO is split as shown. On the right, the IF cables are connected as shown to access the PNA's receivers for S11 and S21 measurements.

PNA Instrumentation Configuration

Once the hardware connections are in place, the following steps describe the procedures for configuring the system for S11 and S21 measurements.

> **Note:** Keysight's PNA is running on firmware version A.09.22.08 for the screen displays captured in this procedure. Different firmware versions may have slightly different displays.

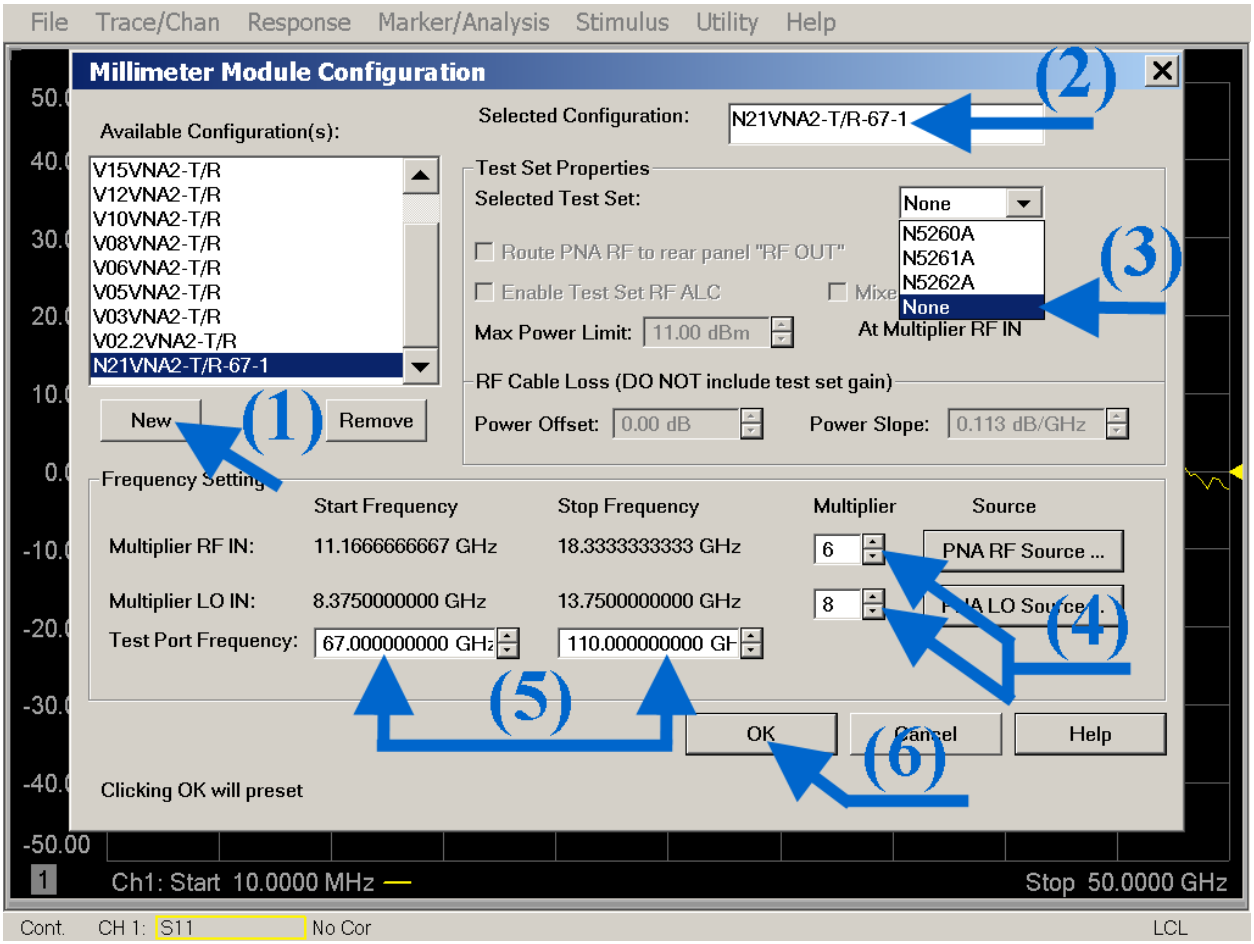
1. Configure the PNA to run without the millimeter head controller, N526xA.
   a. With mouse, select Utility/System/Configure/Millimeter Module Config…



Millimeter Module Configuration

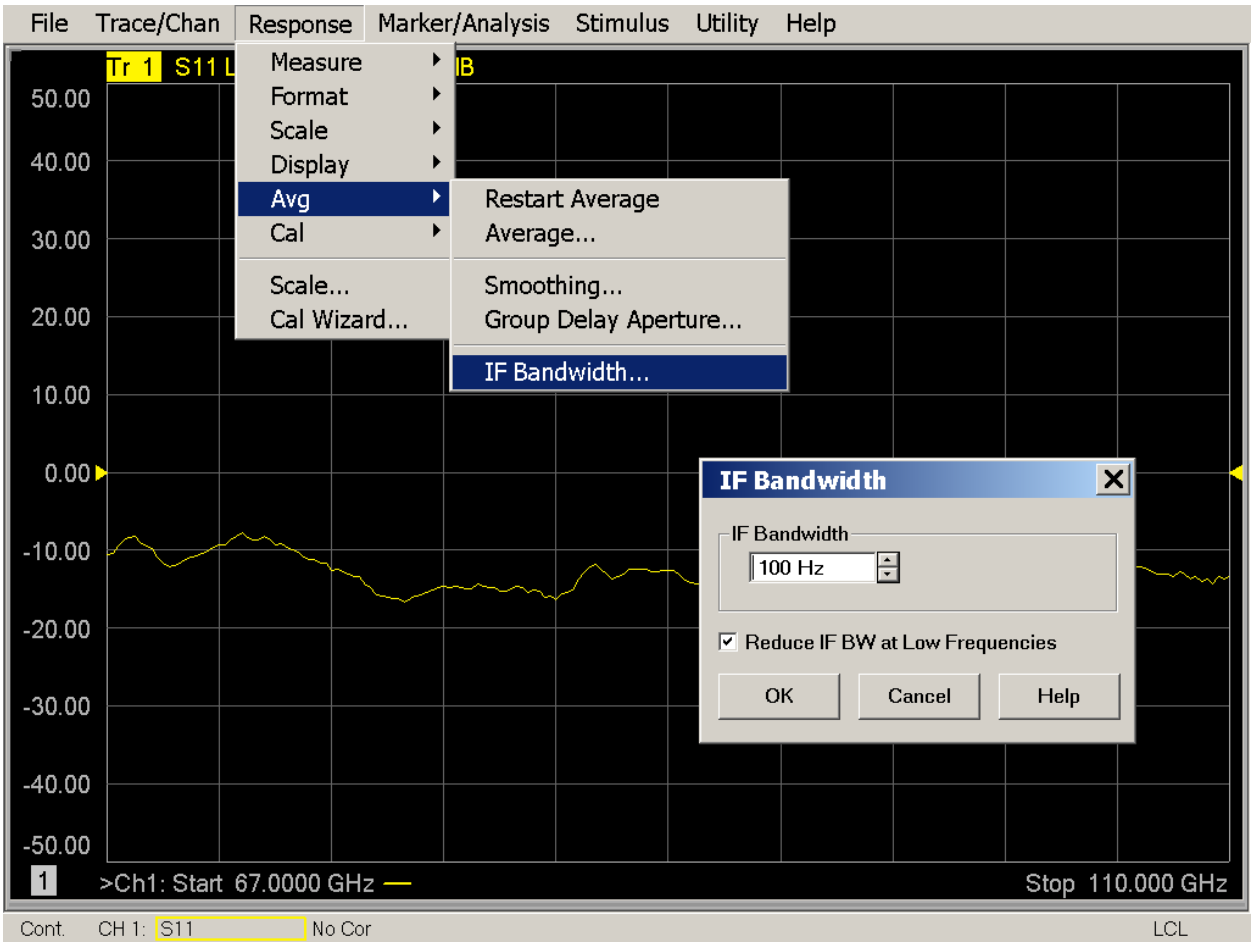
By default, the PNA will display in this Millimeter Module Configuration the default Start & Stop Frequency of the vector network analyzer. For millimeter-wave coverage, one will need to manually adjust the Start & Stop Frequency for the desired waveguide band as shown in the following screen capture.

1. If a configuration has not been previously defined, we begin the configuration process by selecting New. Once created, available configurations are easy to select by simply highlighting the desired name.
2. You can specify a name for the configuration in the Selected Configuration field. In this example, we have entered 'N21VNA2-TR-67-1' for extended WR-10.
3. The selected test set should be set to None because we will bypass the N526xA test set and use the PNA in a standalone configuration.
4. Update the multipliers for RF and LO (reference multiplier values on module top label).
5. Enter the Start and Stop Frequencies corresponding to the millimeter modules.
6. Once these edits are completed, select OK to store and apply the settings. The PNA will re-boot in order to setup the selected millimeter module configuration.



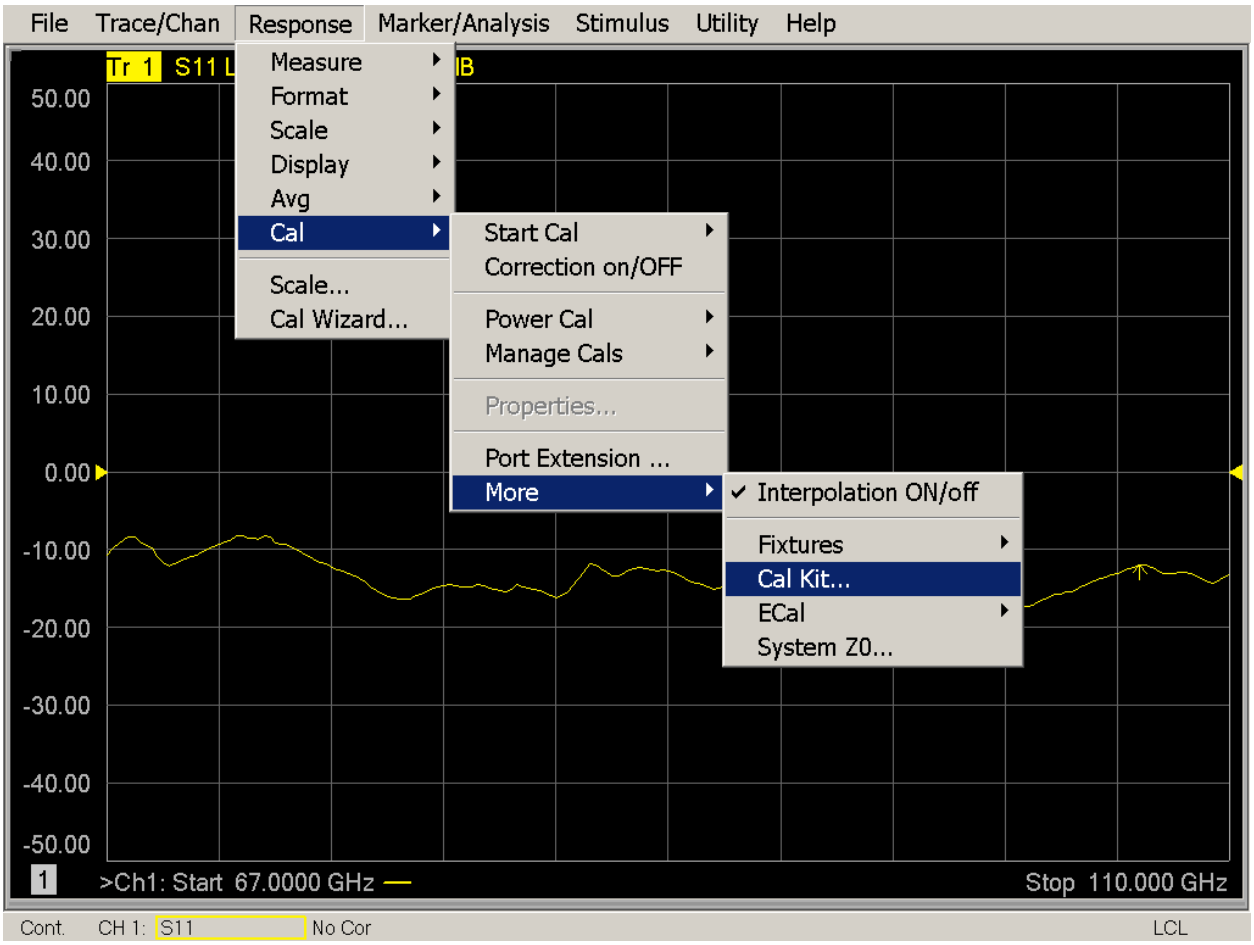
IF Bandwidth Selection

It's good practice to set the IF Bandwidth before calibration. For maximum accuracy or dynamic range, OML's performance is typically specified using IF Bandwidth selection of 10 Hz. For tuning requirements, selecting IF Bandwidth of 100 Hz will provide both reasonable accuracy and faster display updates. OML recommends using maximum IF Bandwidth setting of 100 Hz.



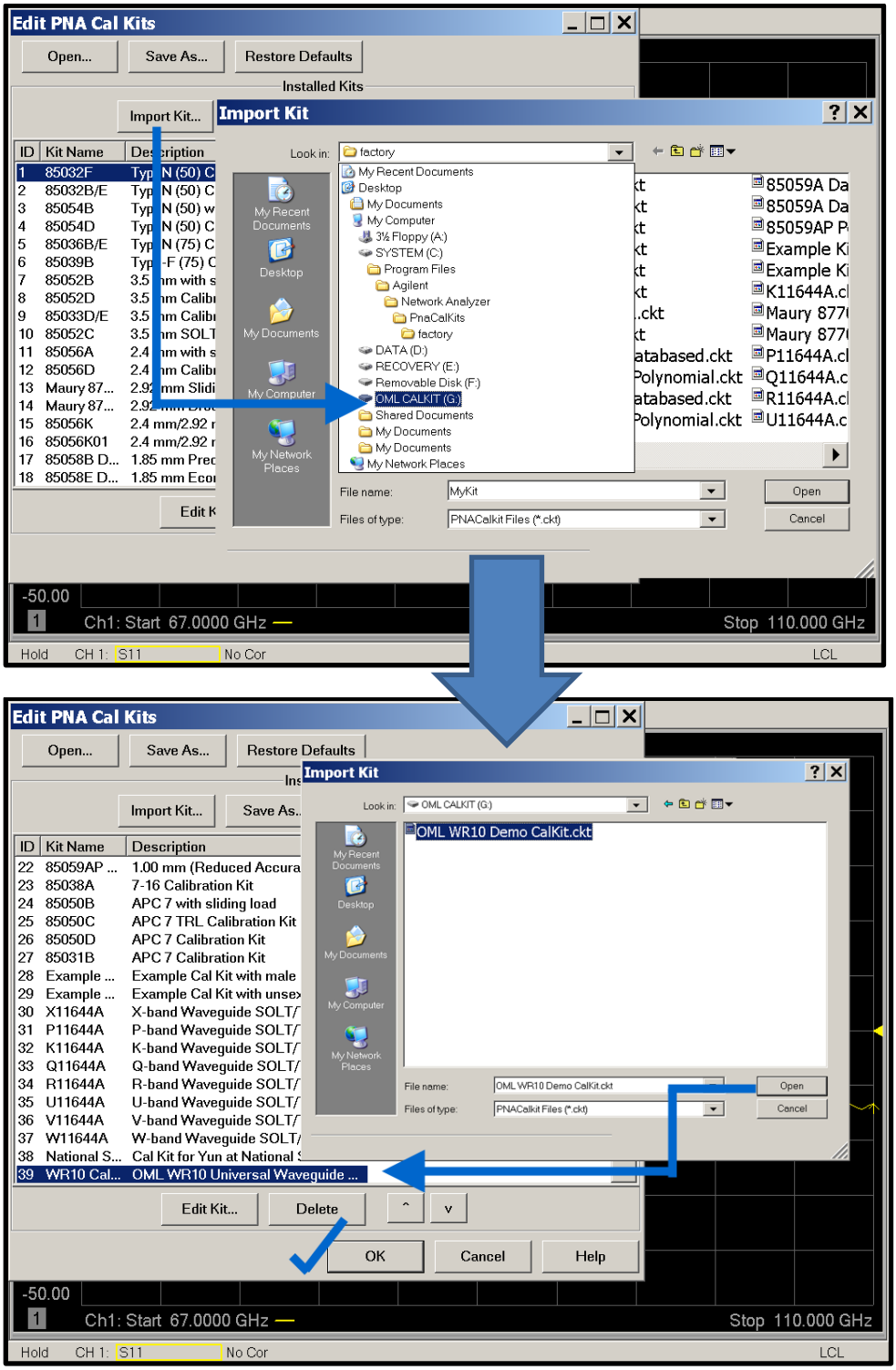
Load Calibration Kit Information (Step 1)

Prepare for calibration by importing waveguide calibration kit information from OML's USB Memory Stick. In the Response menu, initiate the import by selecting the Cal / More / Cal Kit… keystrokes.



Load Calibration Kit Information (Step 2)

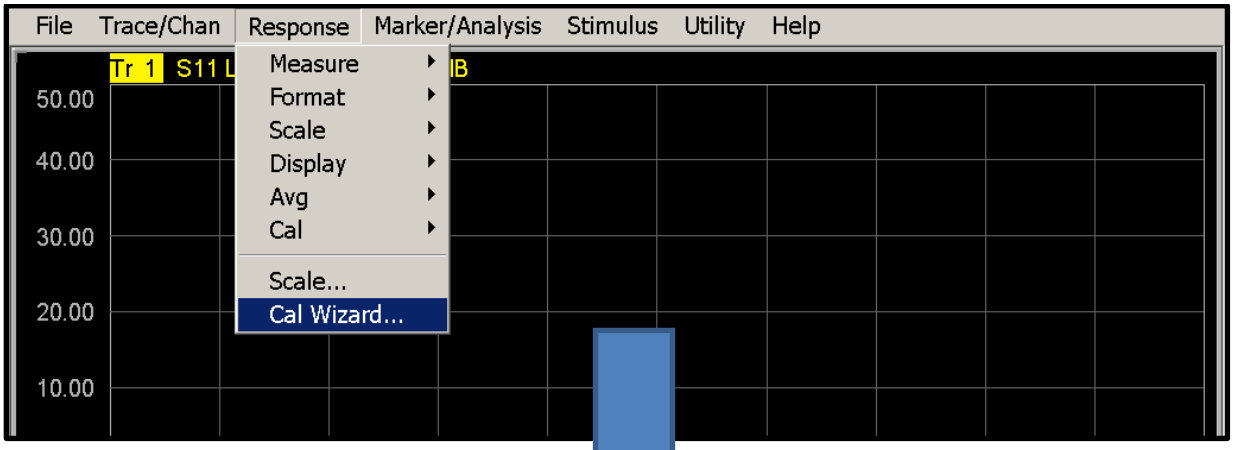
In the pop-up window, select ‘Import Kit’ and then navigate to ‘Open’ the desired ‘CalKit file.’ The following screen captures give an example of this sequence.

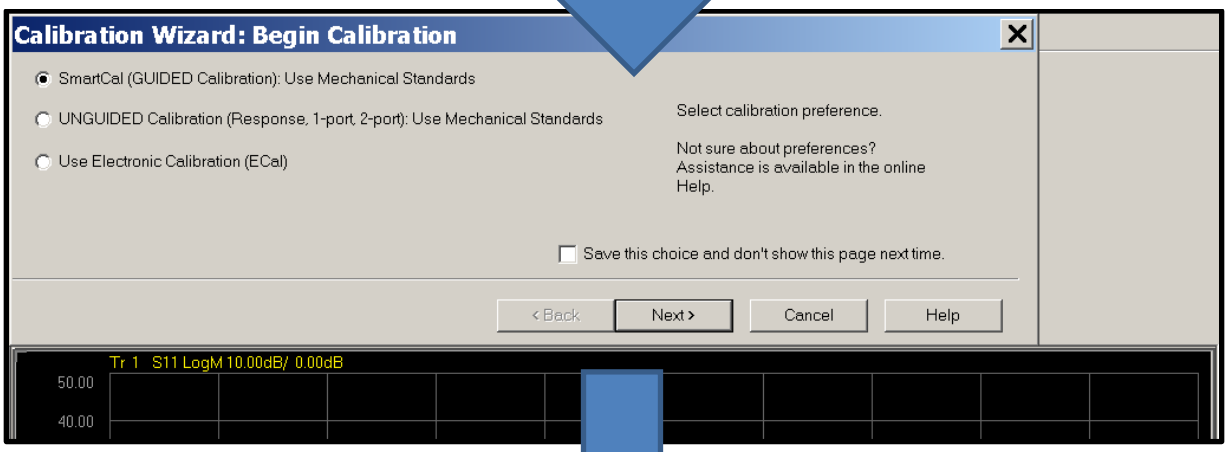


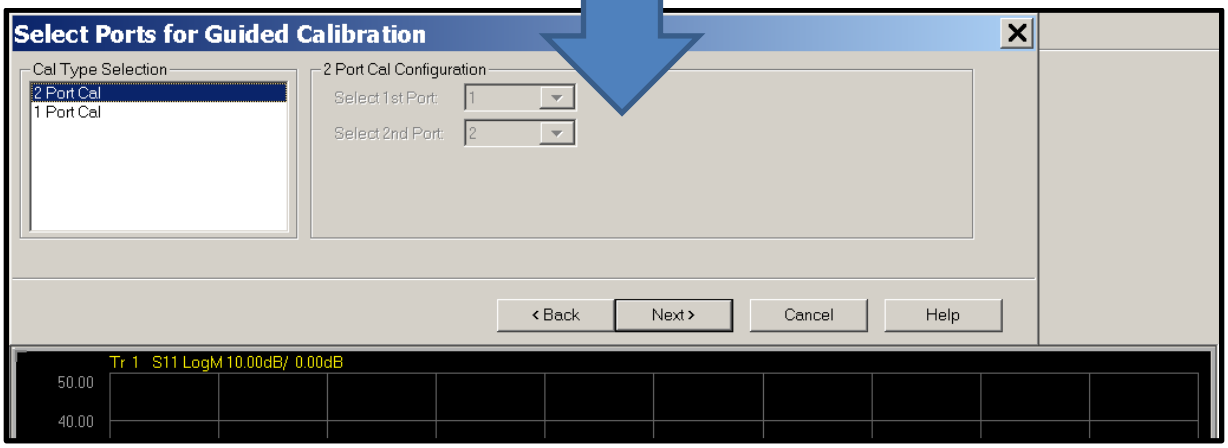
The Calibration Process (Setup Step 1)

As shown in the following sequential screen captures, we recommend using the SmartCal (Guided) menus to calibrate the millimeter wave system.

1. In the Response menu, launch the Cal Wizard
2. Select SmartCal
3. Select 2-Port Cal

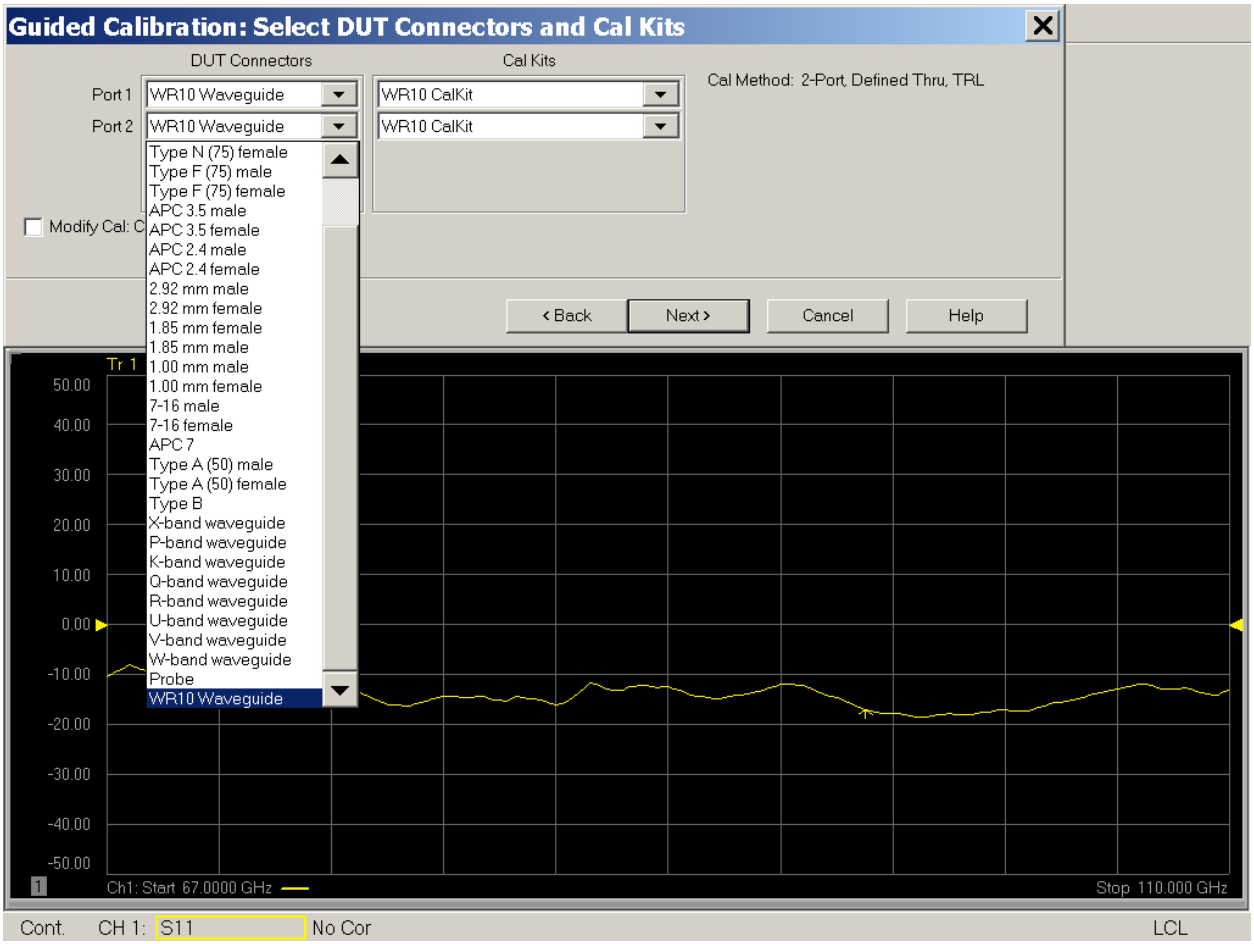






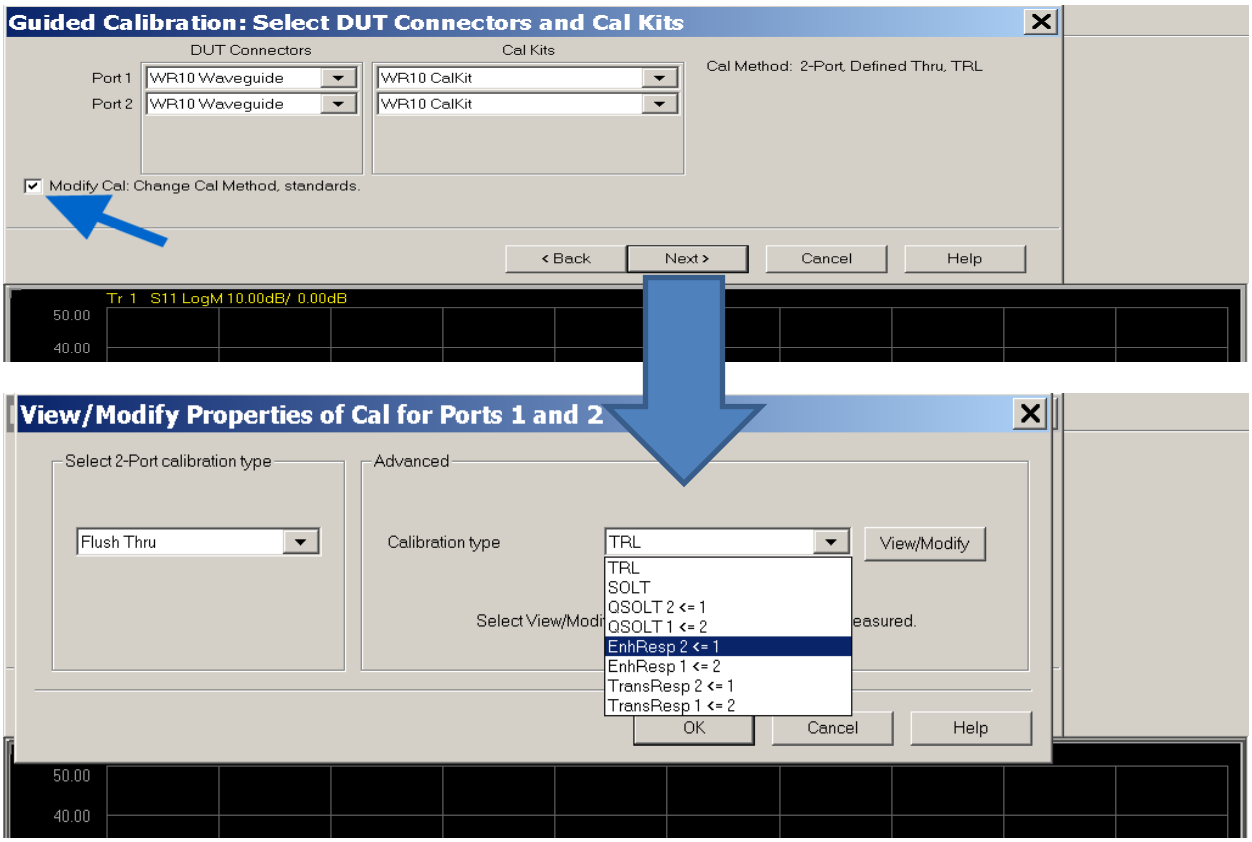
The Calibration Process (Setup Step 2)

Now that we have previously loaded the waveguide calibration kit information, we can continue the calibration setup process by specifying the DUT Connectors for Port 1 and Port 2. As shown in the following screen capture, select the appropriate waveguide interface from the pull-down menus (the Cal Kits field will automatically populate with the corresponding values).



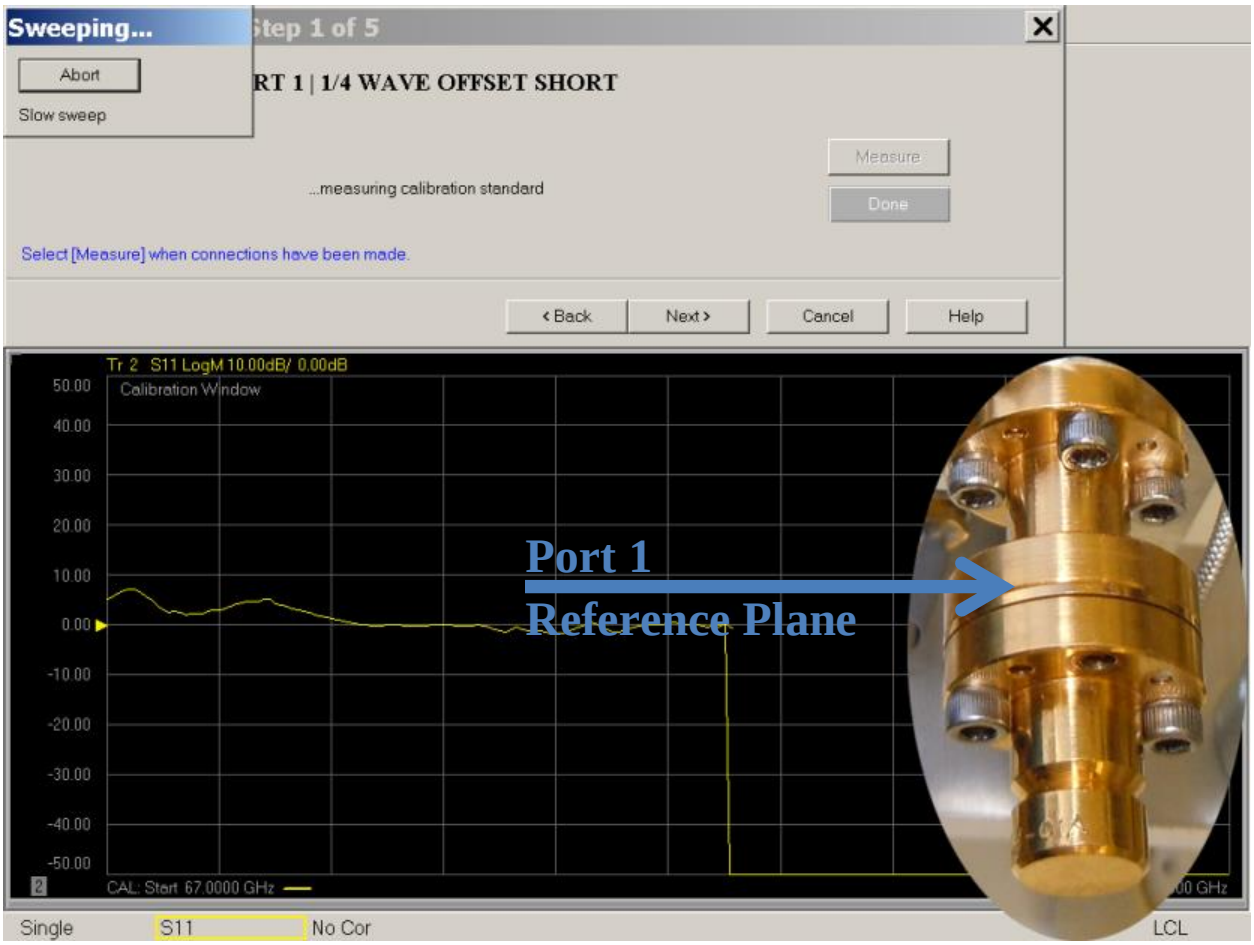
The Calibration Process (Setup Step 3)

Check the Modify Cal box to specify the desired 2-port calibration type as one-path, two-port. Next, use the Calibration Type pull-down menu to change the default 'TRL' setting to 'EnhResp 2 <= 1.' Finally, click on OK to begin the guided calibration process.



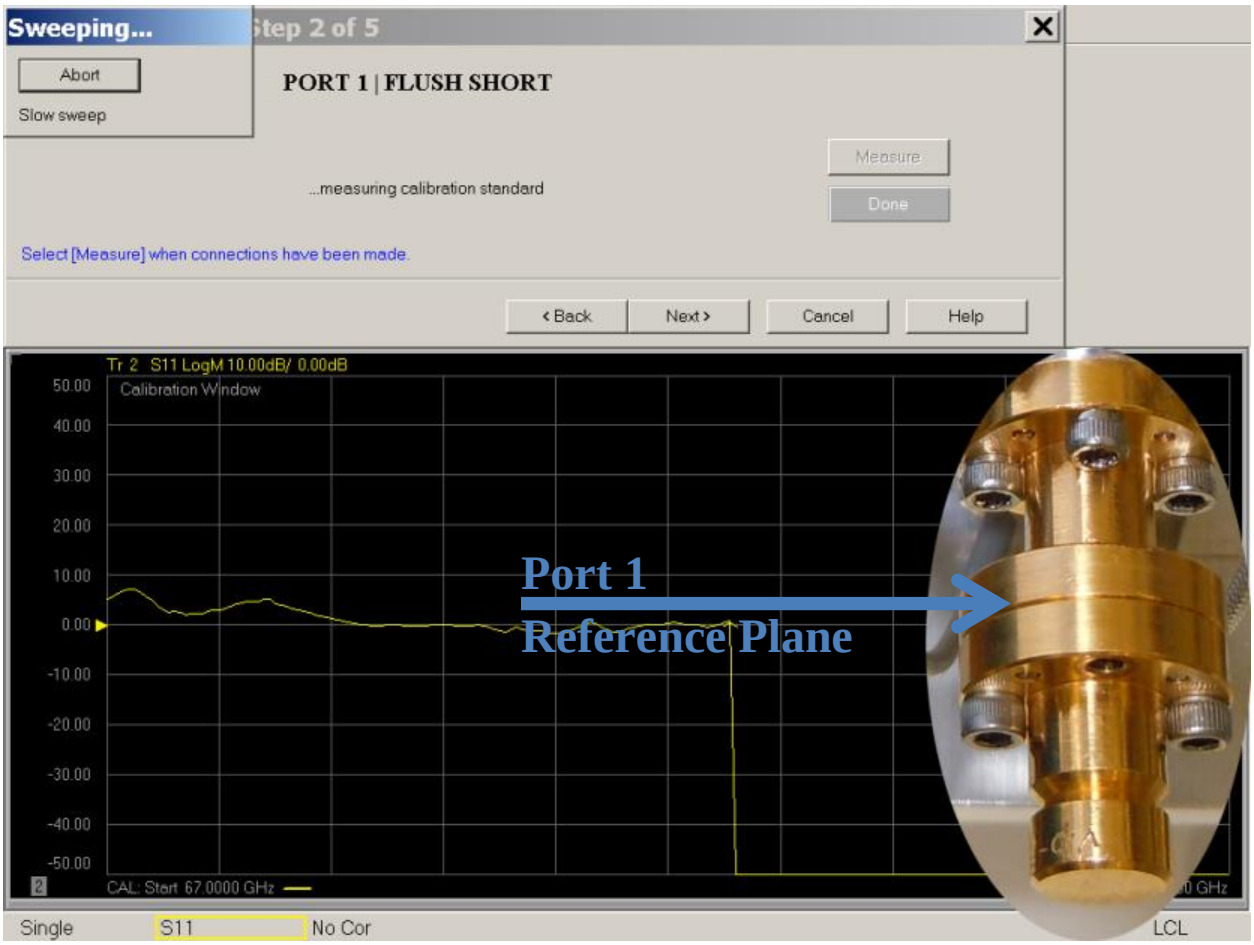
Guided Calibration Step 1: ¼ Wave Offset Short

As prompted, connect the calibration standard and click Next. As shown in the following screen capture with connection overlay, the PNA will then automatically sweep the specified calibration standard.



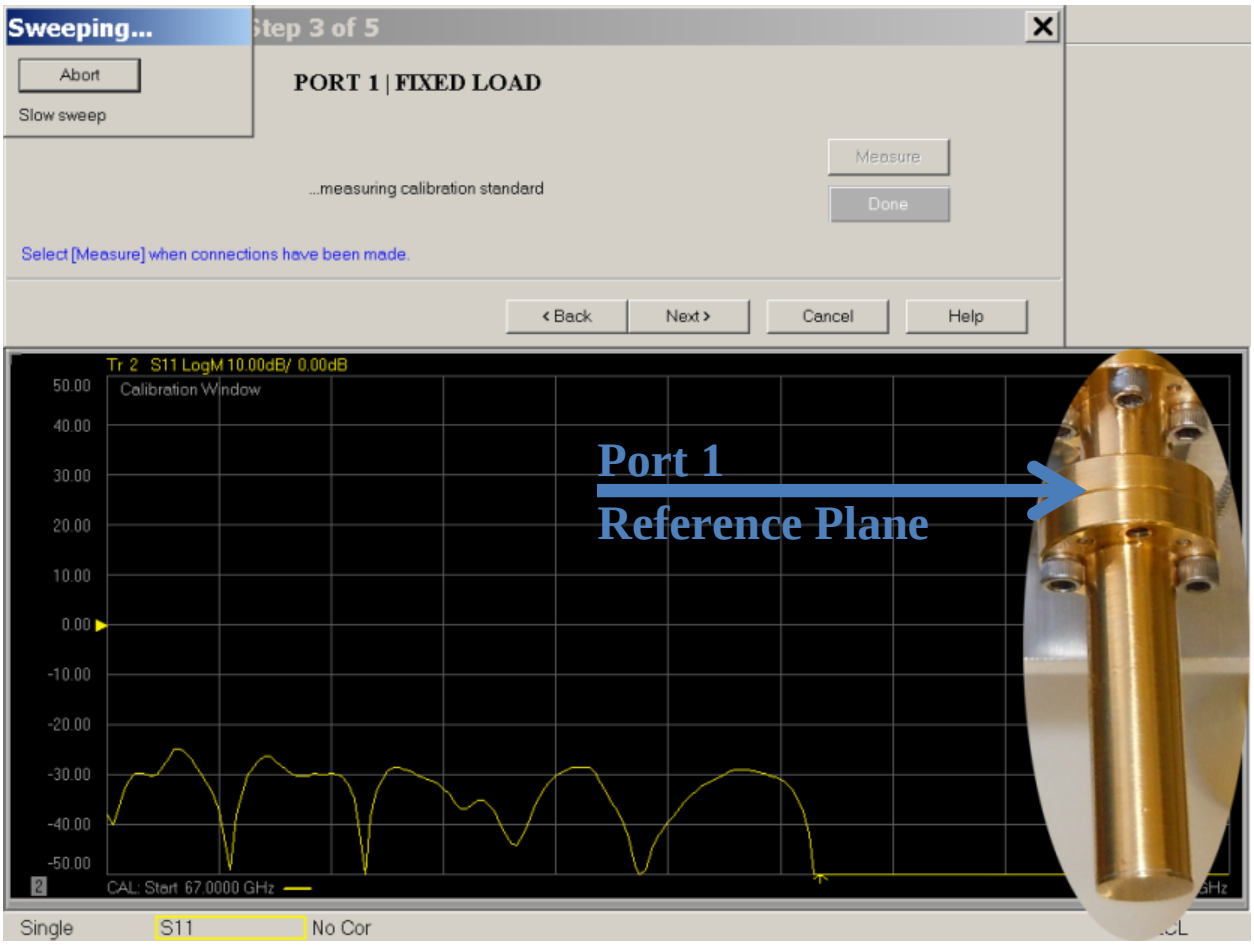
Guided Calibration Step 2: Flush Offset Short

As prompted, connect the calibration standard and click Next. As shown in the following screen capture with connection overlay, the PNA will then automatically sweep the specified calibration standard.



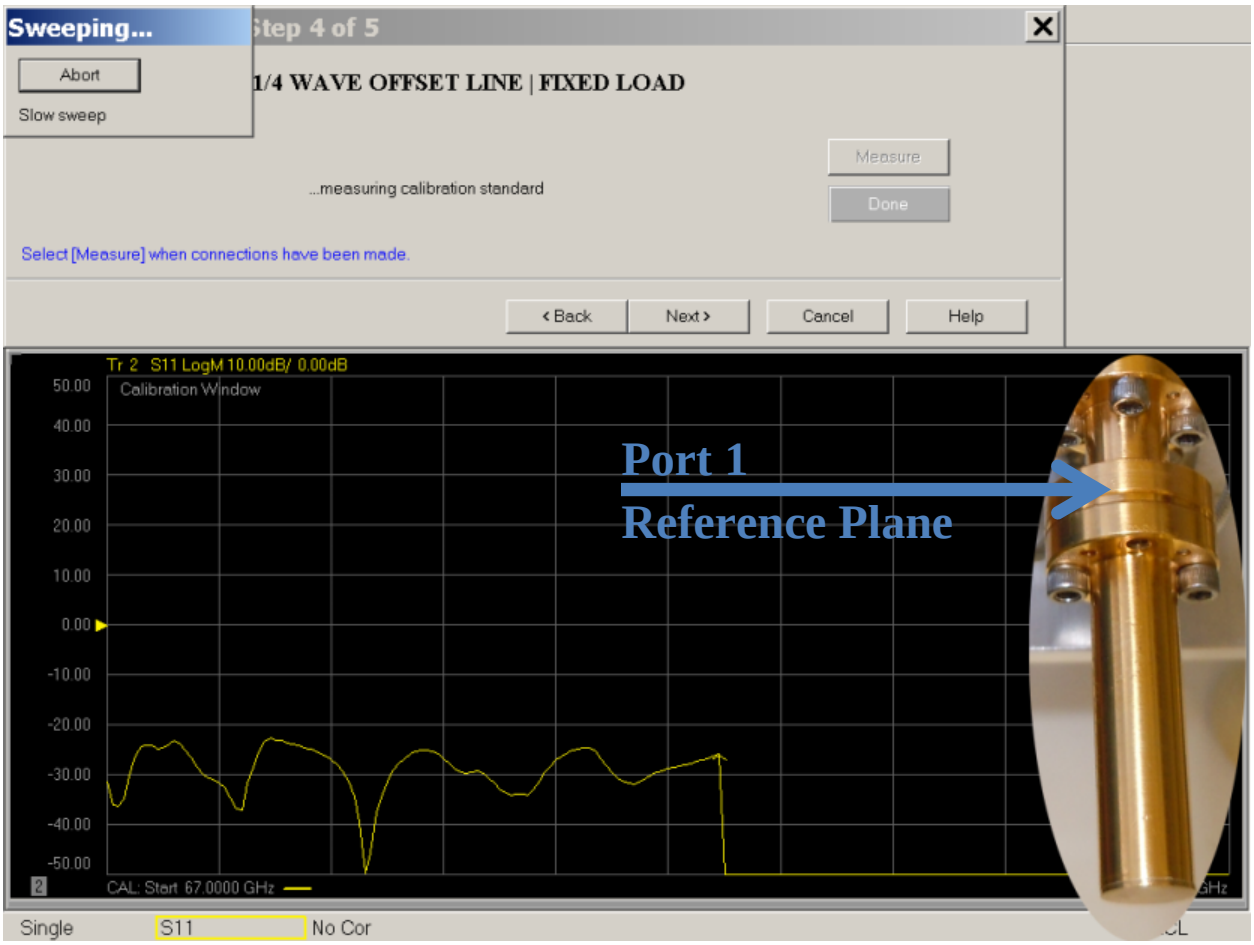
Guided Calibration Step 3: Fixed Load

As prompted, connect the calibration standard and click Next. As shown in the following screen capture with connection overlay, the PNA will then automatically sweep the specified calibration standard.



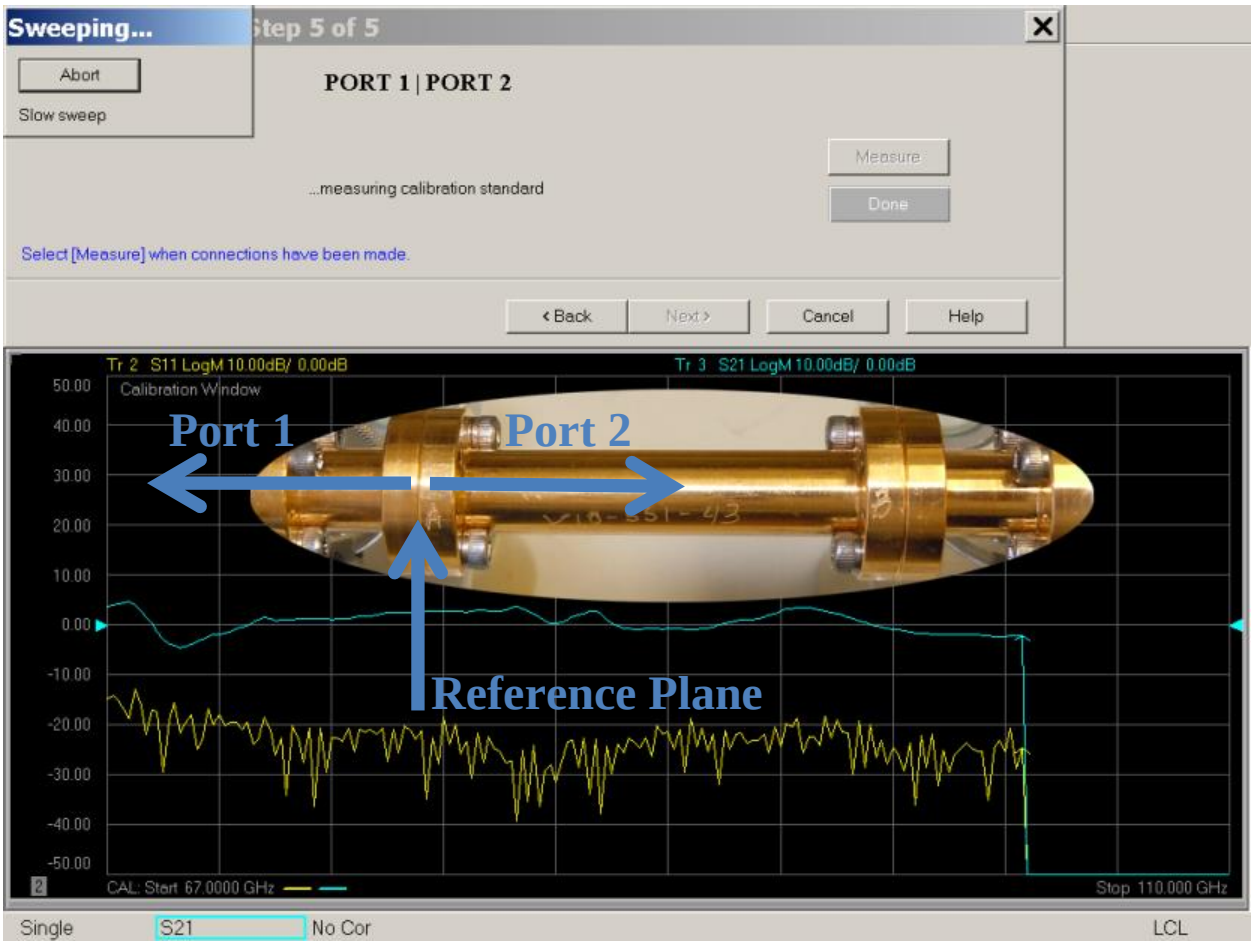
Guided Calibration Step 4: ¼ Wave Offset Load

As prompted, connect the calibration standard and click Next. As shown in the following screen capture with connection overlay, the PNA will then automatically sweep the specified calibration standard.



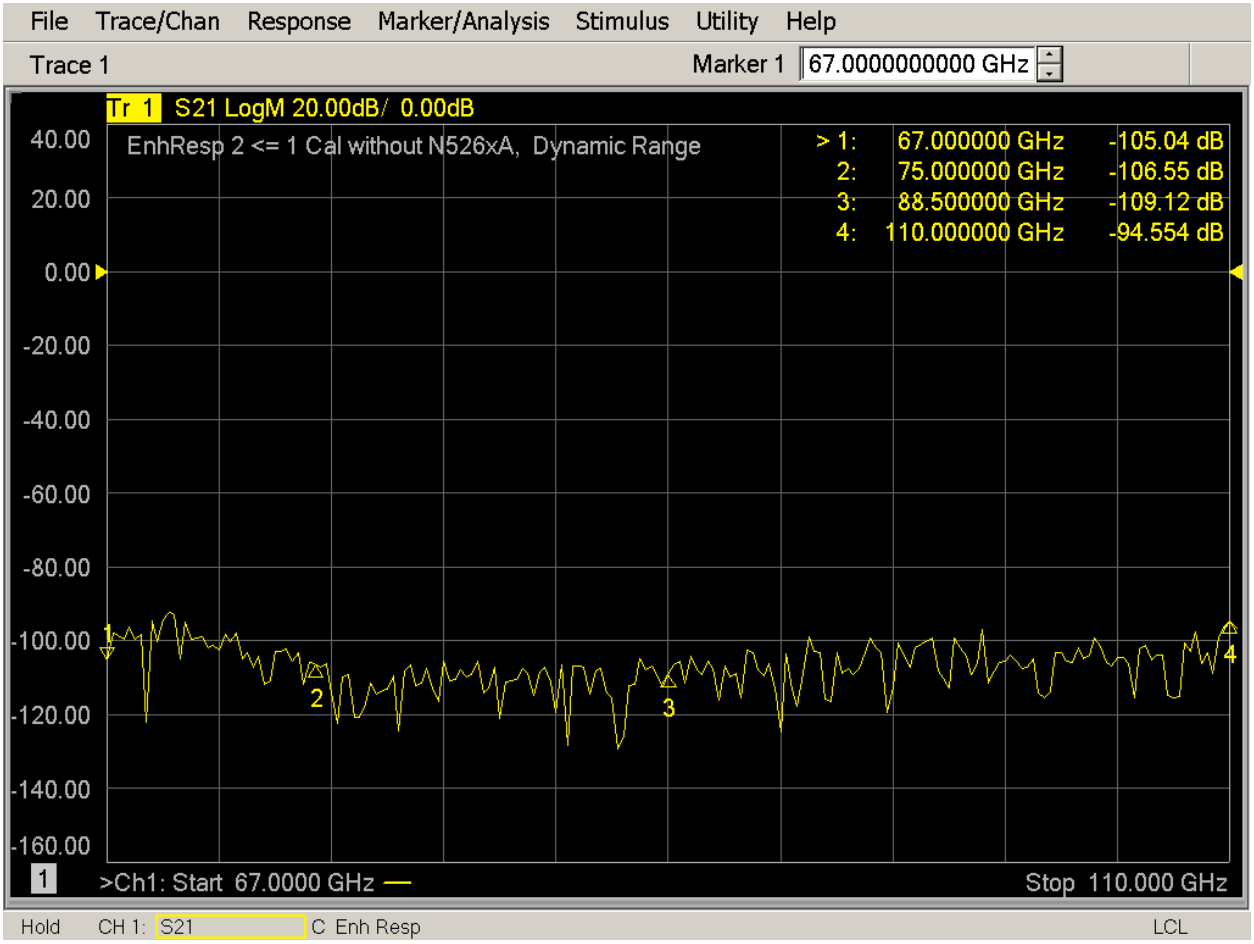
Guided Calibration Step 5: Through Connection

As prompted, connect the calibration standard and click Next. As shown in the following screen capture with connection overlay, the PNA will then automatically sweep the specified calibration standard.



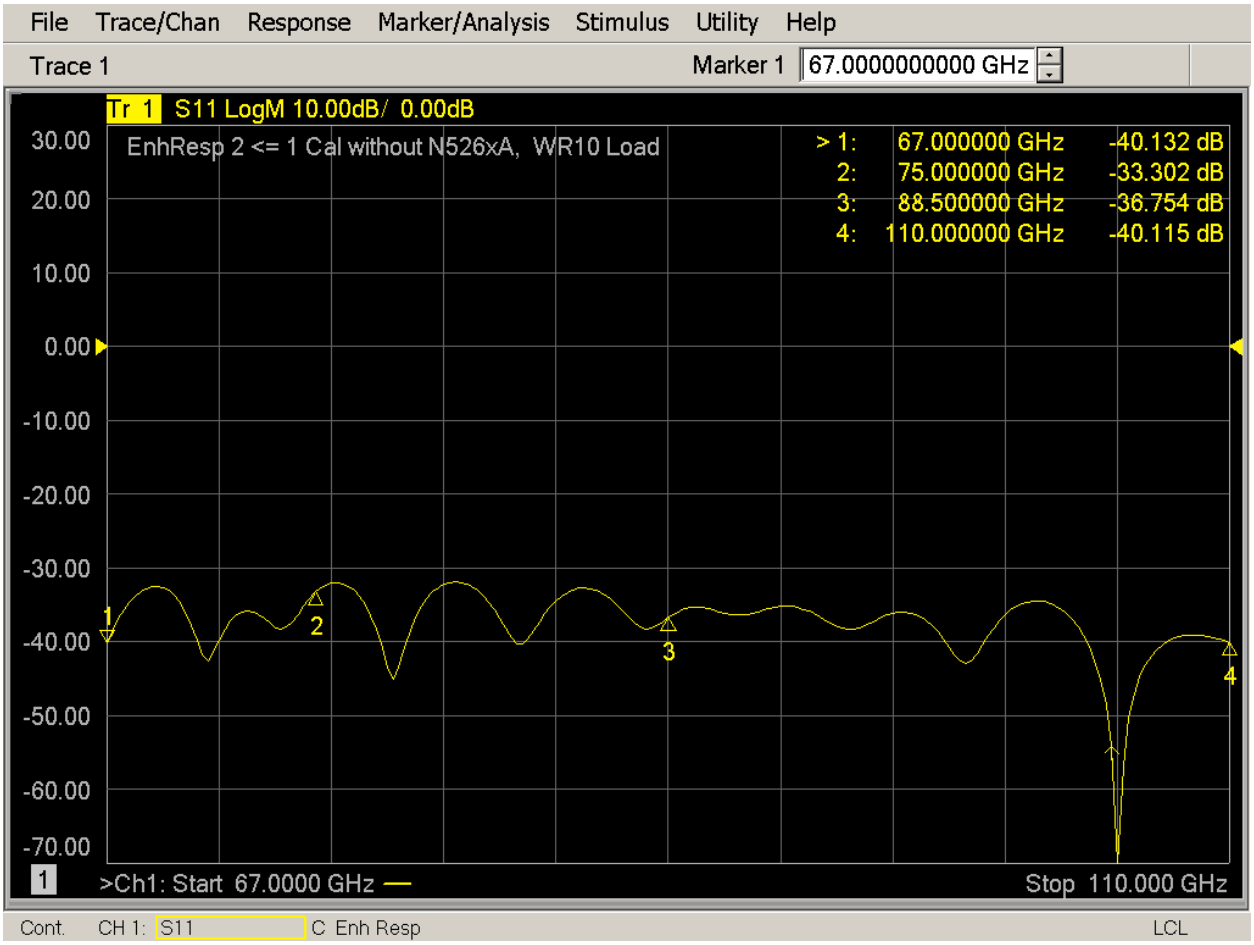
Typical Performance: Dynamic Range (S21) Using Shorts

Connect Shorts to Port 1 and Port 2 to measure dynamic range. For WR-10, the following screen capture shows typical dynamic range after a 1-path, 2-port calibration.



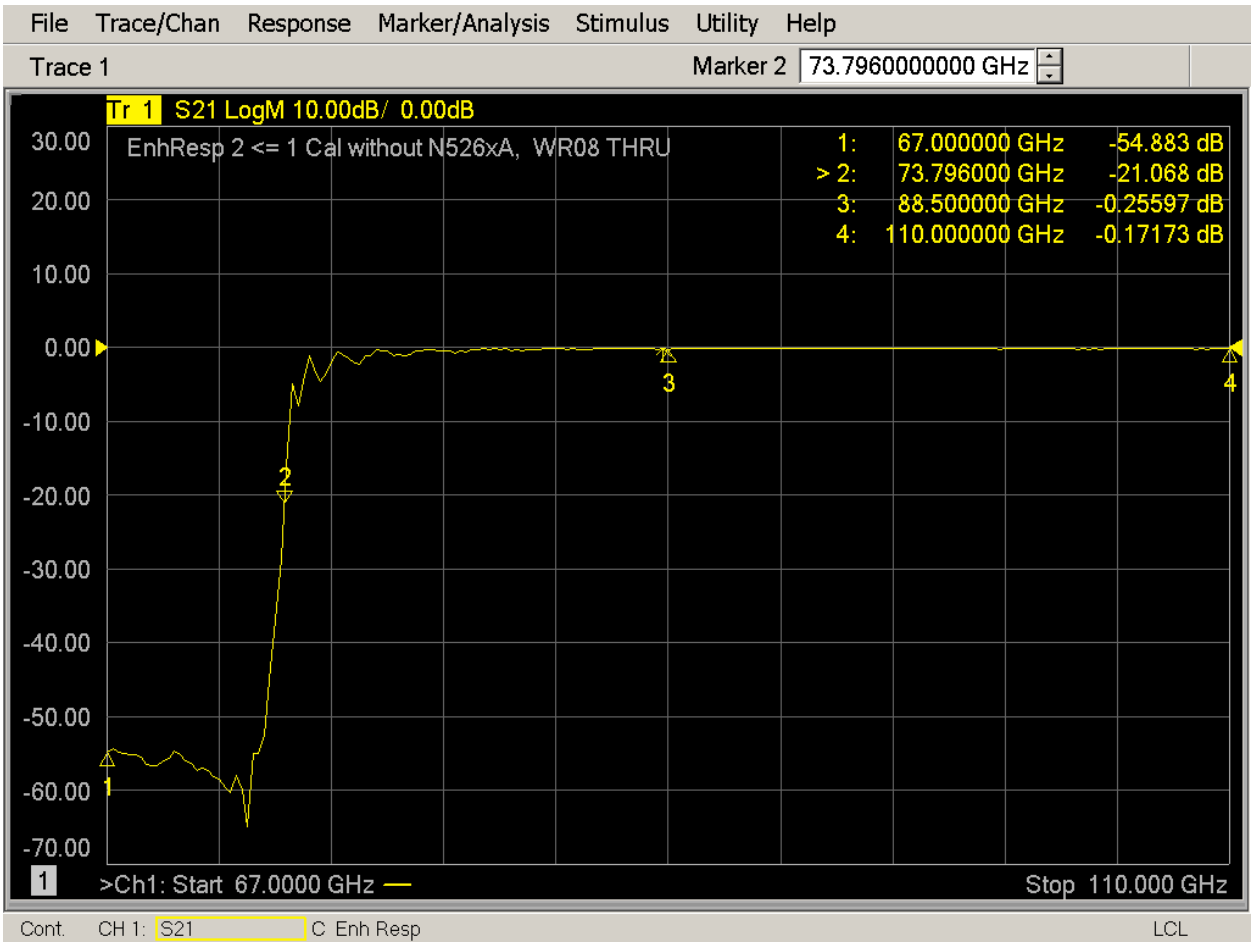
Typical Performance: Return Loss (S11) of Load

Connect Load to Port 1 to measure return loss. For WR-10, the following screen capture shows typical return loss of the load after a 1-path, 2-port calibration.



Typical Performance: Insertion Loss (S21) of WR-08 (1” Section)

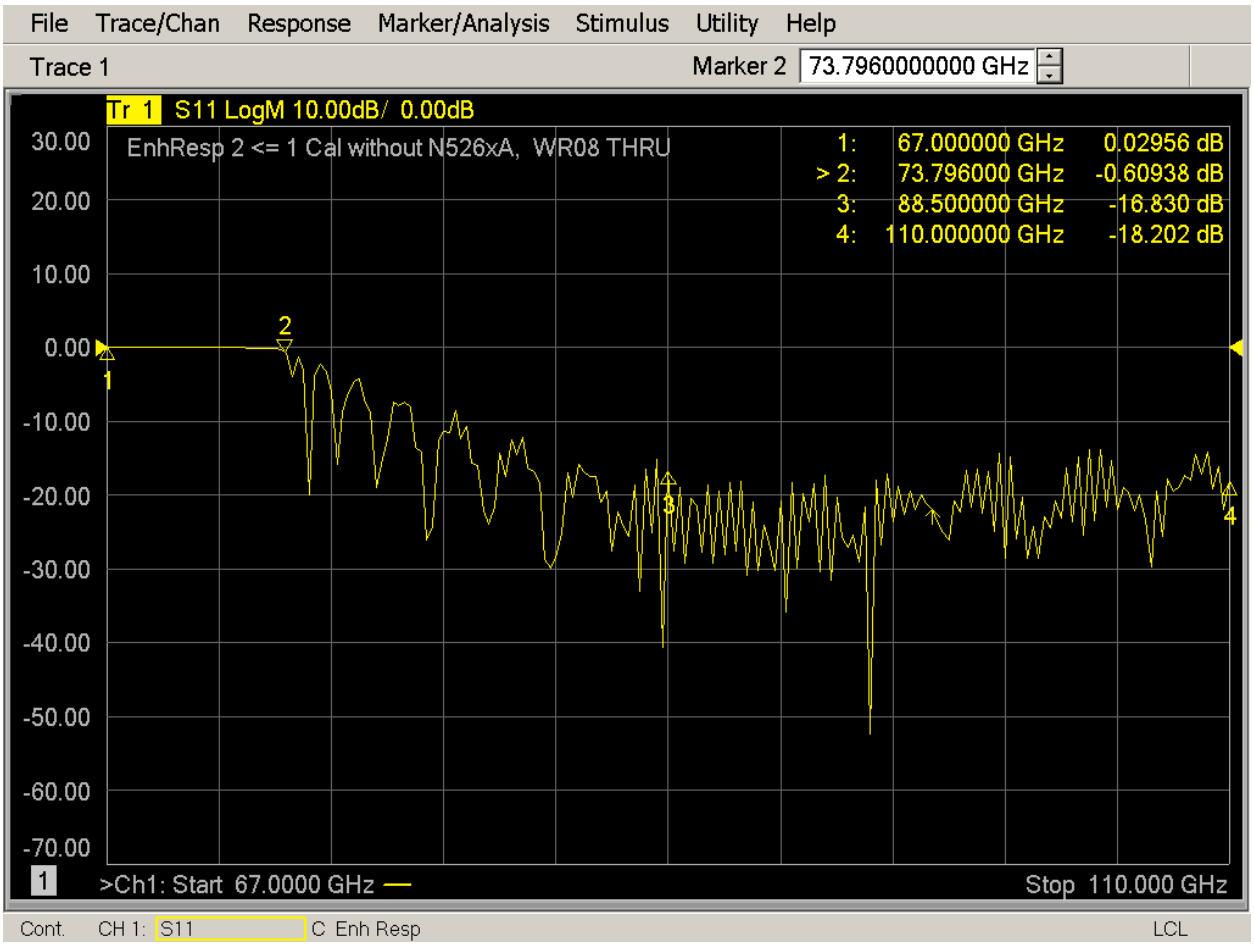
Connect a WR-08 waveguide section between Port 1 and Port 2. We should observe the waveguide cut-off frequency: low insertion loss above and high insertion loss below the cut-off frequency. For WR-08 waveguide section, the following screen capture shows typical insertion loss after a 1-path, 2-port calibration.



For reference, the WR-08 cut-off frequency is 73.8 GHz. Note that readout of Marker #2 confirms the cut-off frequency of this band.

Typical Performance: Return Loss (S11) of WR-08 (1” Section)

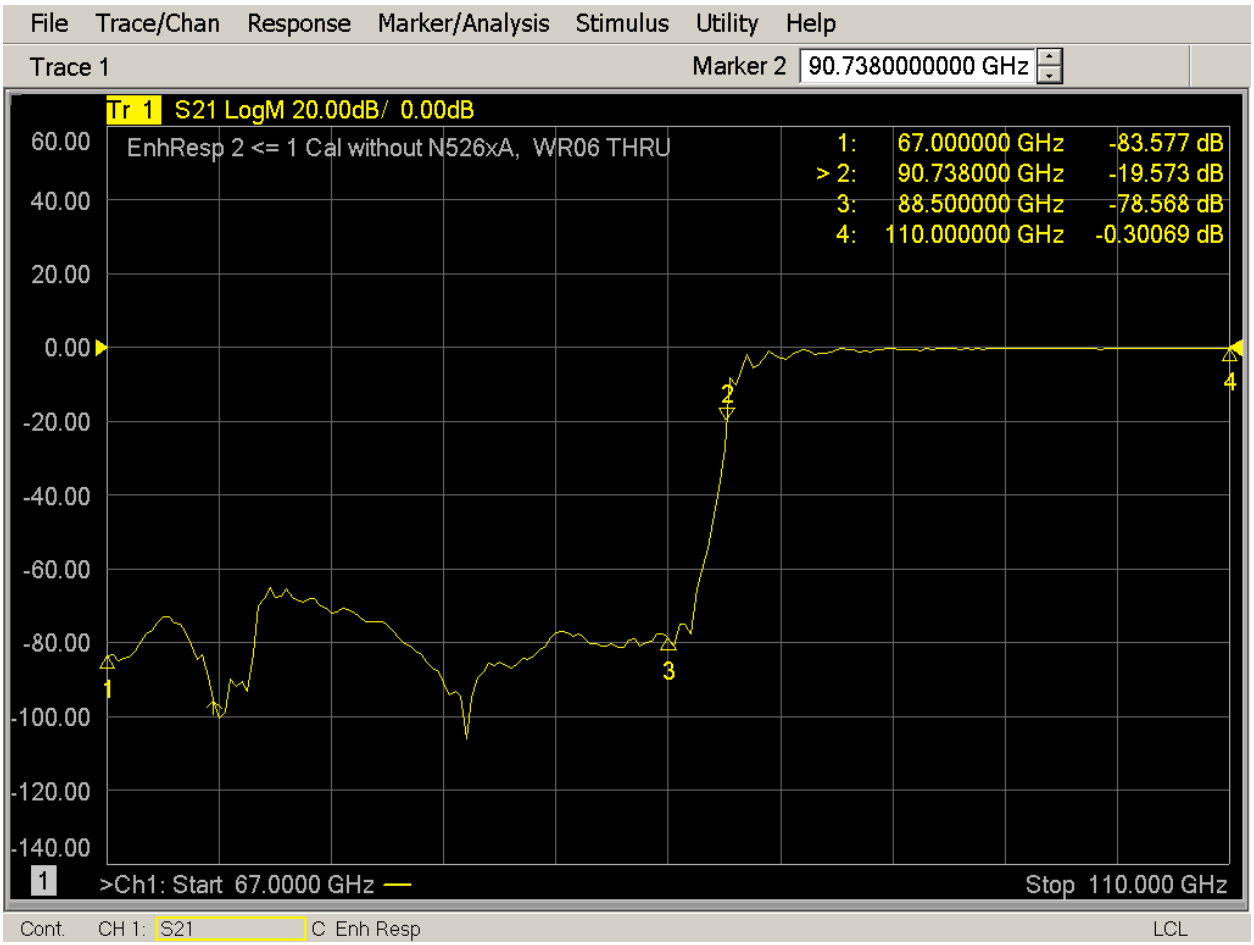
Connect a WR-08 waveguide section between Port 1 and Port 2. We should observe the waveguide cut-off frequency: high return loss below and low return loss below the cut-off frequency. For WR-08 waveguide section, the following screen capture shows typical return loss after a 1-path, 2-port calibration.



For reference, the WR-08 cut-off frequency is 73.8 GHz. Note that Marker #2 is located at the cut-off frequency of this band.

Typical Performance: Insertion Loss (S21) of WR-06 (1” Section)

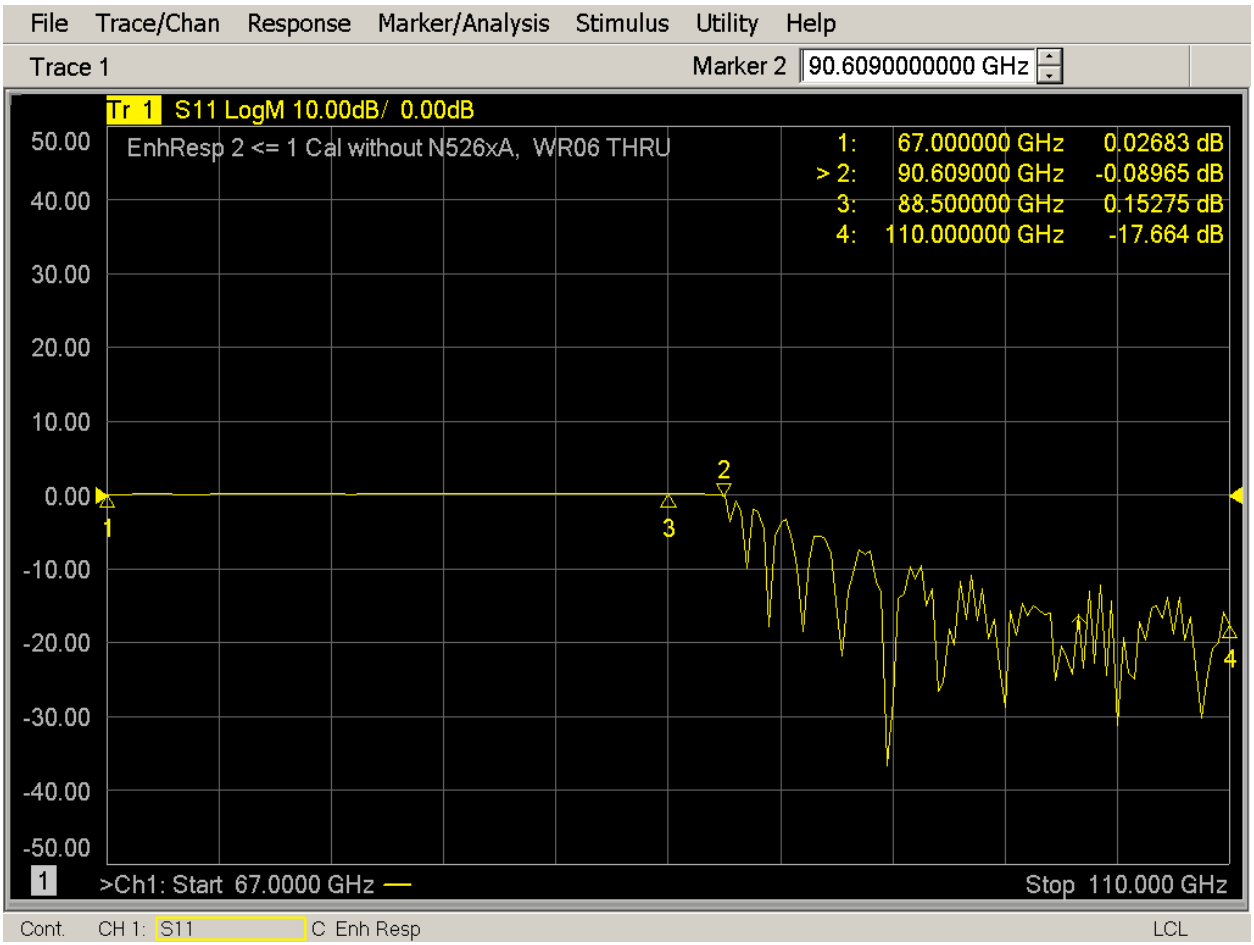
Connect a WR-06 waveguide section between Port 1 and Port 2. We should observe the waveguide cut-off frequency: low insertion loss above and high insertion loss below the cut-off frequency. For WR-06 waveguide section, the following screen capture shows typical insertion loss after a 1-path, 2-port calibration.



For reference, the WR-06 cut-off frequency is 90.8 GHz. Note that readout of Marker #2 confirms the cut-off frequency of this band.

Typical Performance: Return Loss (S11) of WR-06 (1” Section)

Connect a WR-08 waveguide section between Port 1 and Port 2. We should observe the waveguide cut-off frequency: high return loss below and low return loss below the cut-off frequency. For WR-08 waveguide section, the following screen capture shows typical return loss after a 1-path, 2-port calibration.



For reference, the WR-06 cut-off frequency is 90.8 GHz. Note that Marker #2 is located at the cut-off frequency of this band.