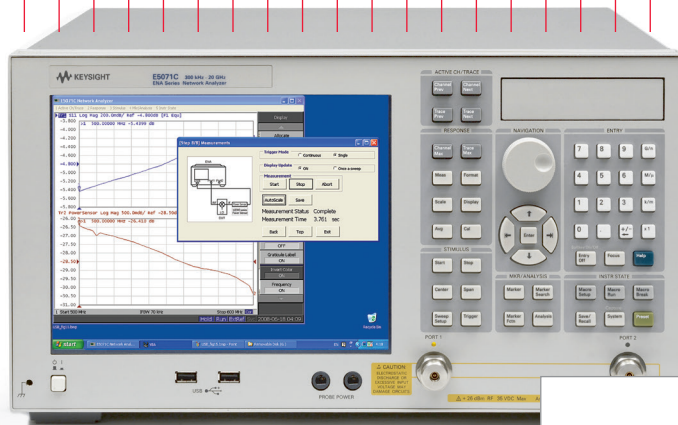# Keysight Technologies
Simple Scalar Network Analysis of Frequency Converter Devices using the U2000 USB Power Sensor Series with the ENA Network Analyzer

Application Note

Introduction

This application note will show how to make easy scalar network analysis or power measurements using the Keysight Technologies, Inc. U2000 series USB power sensor with the Keysight ENA. Controlling this ultra-light and easy-connection USB power sensor with the ENA's built-in VBA macro as a broadband power detector, you can easily make scalar network analysis of frequency converter devices.

Part 1 explains the case that the USB power sensor is useful compared to the normal frequency offset mode (FOM) of the ENA. Part 2 will show a measurement example using a sample VBA Wizard.

Part 1

There are some components that are suitable to be measured with scalar network analysis. For example, frequency converter components with an embedded local oscillator (LO), such as a CATV tuner, low noise block (LNB, down converter of satellite TV parabola antenna) of satellite communications, or similar components. Embedded LO signals of these devices are sometimes not accessible from outside and are difficult to lock the phase between RF and IF signals when measuring.

Note: The USB power sensor control for power calibration of the ENA is not
        yet supported with Firmware version 9.1 or earlier firmware versions
Note: Vector network analysis is not available using power sensors.

Operation of Frequency Offset Mode and Its Limitation

Keysight network analyzers (PNA series and ENA) have a frequency offset mode (FOM) option[1] that allows users to set source or receiver port frequency independently. When using FOM, frequency converter devices can be measured precisely and accurately[2]. The operation requires defining the offset of a source port frequency and a receiver port frequency precisely, and then the receiver port can detect the down-converted or up-converted signals. However, to apply the FOM method properly, the LO signal of a DUT has to be known and locked to the source or the receiver port frequency of a network analyzer. Otherwise the difference between predicted IF signal and actual IF signal directly causes a magnitude error due to the IFBW filter shape implemented in these network analyzers[3]. In general, when the IFBW is set to 1 kHz, the 3 dB bandwidth of the IFBW filter is approximately 1 kHz. That means if an actual output frequency of DUT has 500 Hz offset (=BW/2) from a target frequency, a measured magnitude result has 3 dB error. Also, when the output signal is drifted, measurement results are also changed at the same time.
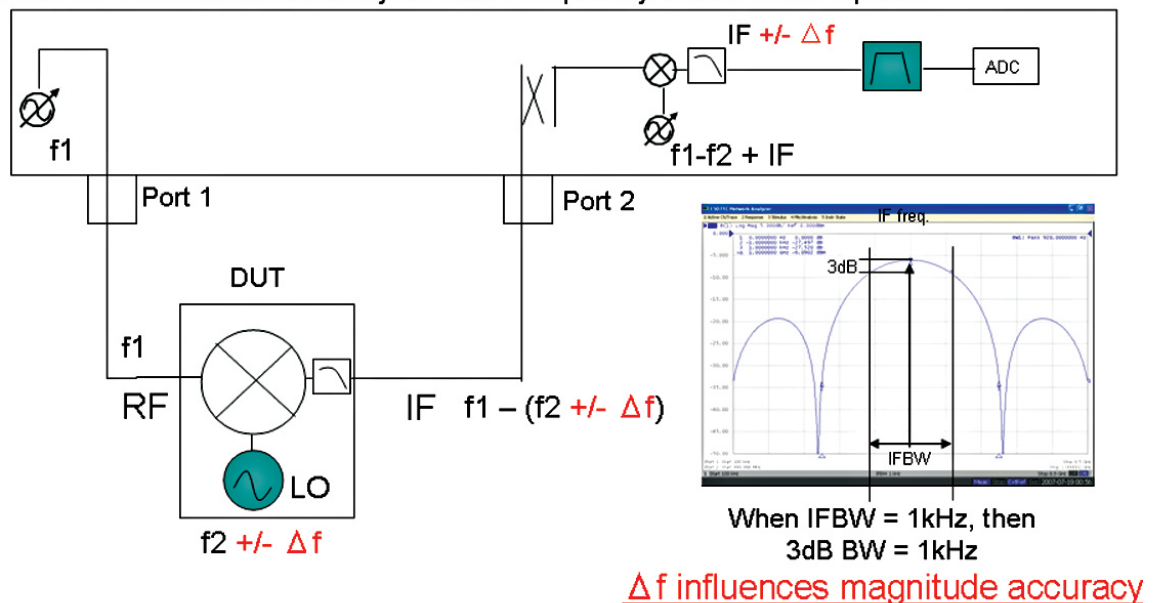

Figure 1. IFBW vs. LO frequency drift with FOM

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1. For the Keysight E5071C, Option 008 frequency offset mode is necessary to enable the FOM option.
2. The PNA and ENA provide advanced calibration methods to measure absolute group delay using Keysight patented Vector Mixer Calibration (VMC) technique, or matching error corrected measurement using Scalar Mixer Calibration (SMC) technique.
3. The PNA series offers an advanced method Embedded LO Measurement (Option 084) for accurate relative phase and absolute group delay measurement.

Using the USB Power Sensor with the ENA

One reasonable solution for this application is to use a power sensor as a broadband power detector. A power sensor detects all power in its bandwidth. Thus, unless the frequency range of the output signal is within the bandwidth of a power sensor, its measurement result is stable and not influenced by output signal offset or drift as shown Figure 3. The U2000 series USB power sensor is a good solution with its small size, easy connection, controllability, and its affordable price.

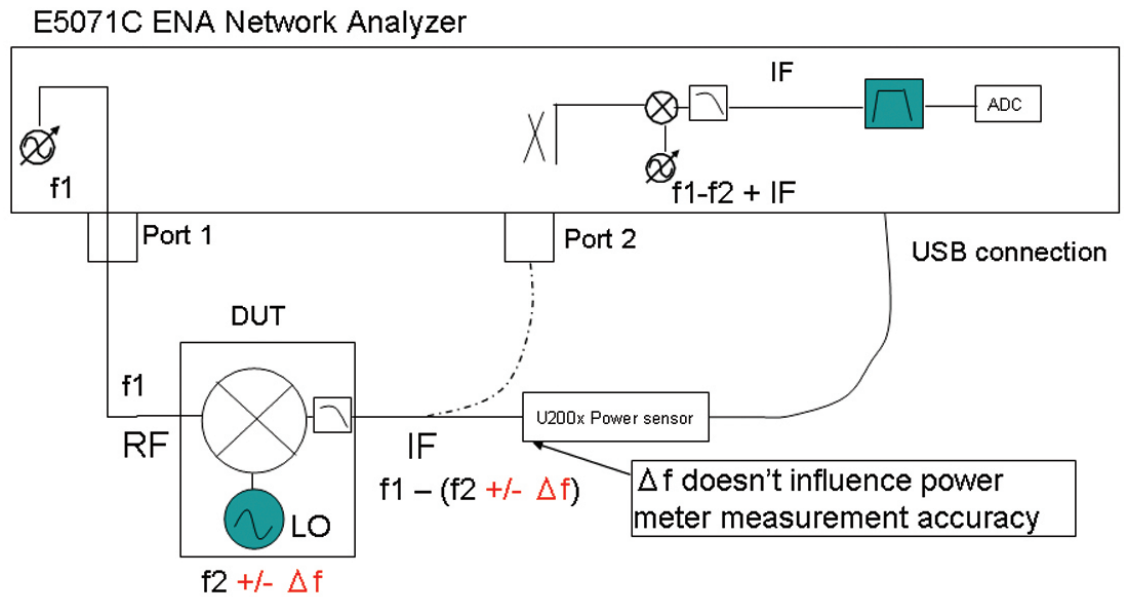E5071C ENA Network Analyzer

Figure 2. Power sensor (broadband detect) vs. LO frequency drift

The next two figures show the result of measuring a mixer with a locked (Figure 3) and drifted (Figure 4) LO signal by FOM (trace 1 in blue) function of the ENA and by the USB power sensor (trace 2 in red). The measurement result of the USB power sensor has good correlation with FOM at locked signal, and is stable with drifted LO signal.
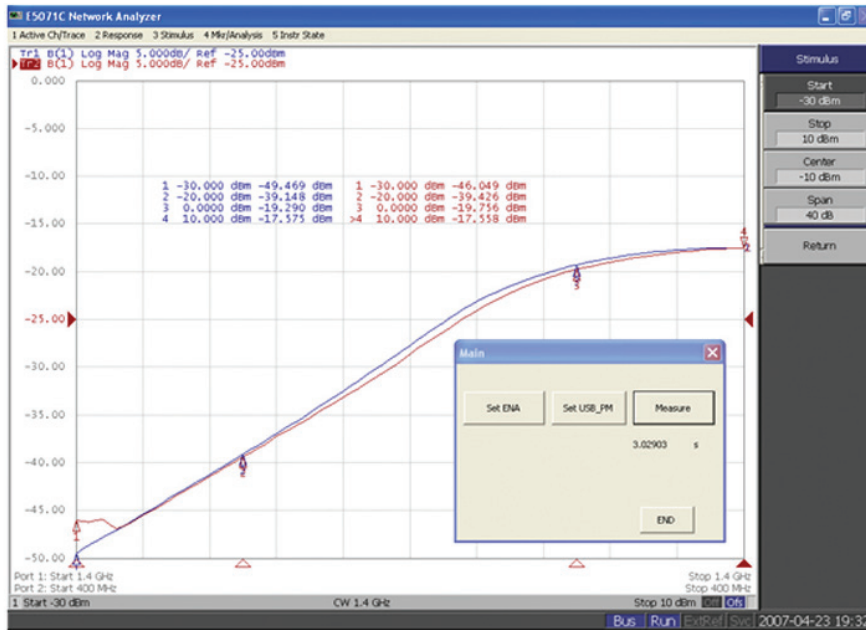
PM result is well correlated to FOM result

Setting:
Power sweep : -30 dBm ~ +10 dBm
IFBW: 1kHz
NOP: 51 points
RF: 1.4GHz
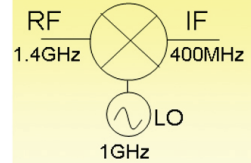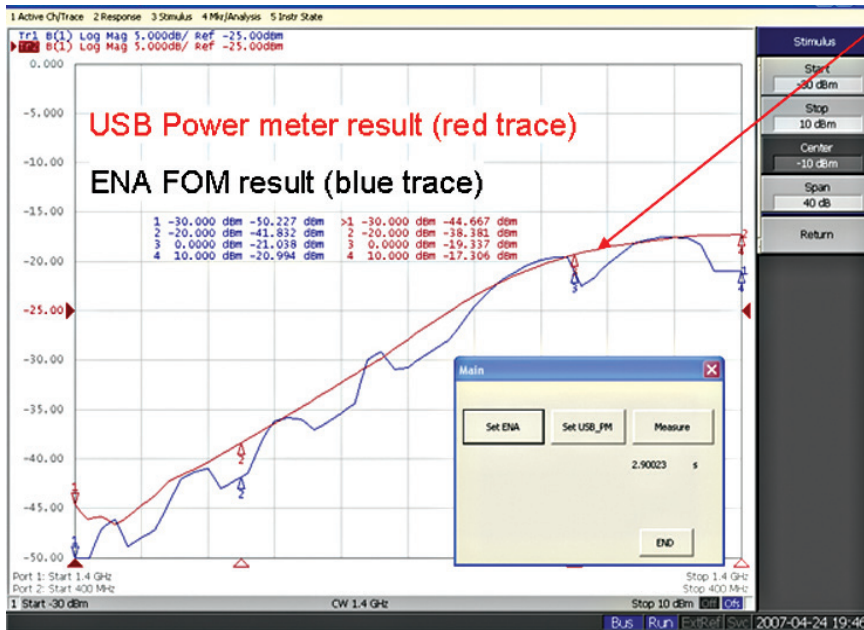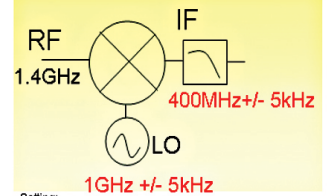LO:1 GHz
ENA FOM port: 400 MHz

Figure 3. Measurement results with Locked LO (RF Power vs. IF Power)

Power Meter catches IF signal well, while FOM mode cannot.

Setting:
Power sweep : -30 dBm ~ +10 dBm
IFBW: 1kHz
NOP: 51 points
RF: 1.4GHz
LO: 1GHz +/- 5kHz
ENA FOM port: 400 MHz

Figure 4. Measurement results with drifted LO (RF Power vs. IF Power)

Part 2

Operation Example with Sample VBA Wizard

Here is an example procedure using a sample VBA program (USB power sensor measurement wizard) using the E5071C ENA network analyzer. The VBA makes scalar power measurements with a U2000 series USB power sensor using port 1 of the ENA as a signal source. S11 reflection measurement is also performed to measure return loss of the DUT.

<Setup>

Connect the U2000 series USB power sensor to the E5071C using a USB cable. Confirm the power sensor is recognized correctly using"Keysight Connection Expert", which can run from Windows Desktop menu [Start] > [All Programs] > [Keysight IO Libraries Suite] > Keysight Connection Expert.

The USB connected instruments has to be listed with the correct serial number and a VISA alias. If the VISA alias is missing, add it by right-clicking the U200xA model icon, then select "Add VISA Alias" to be recognized by the sample VBA.
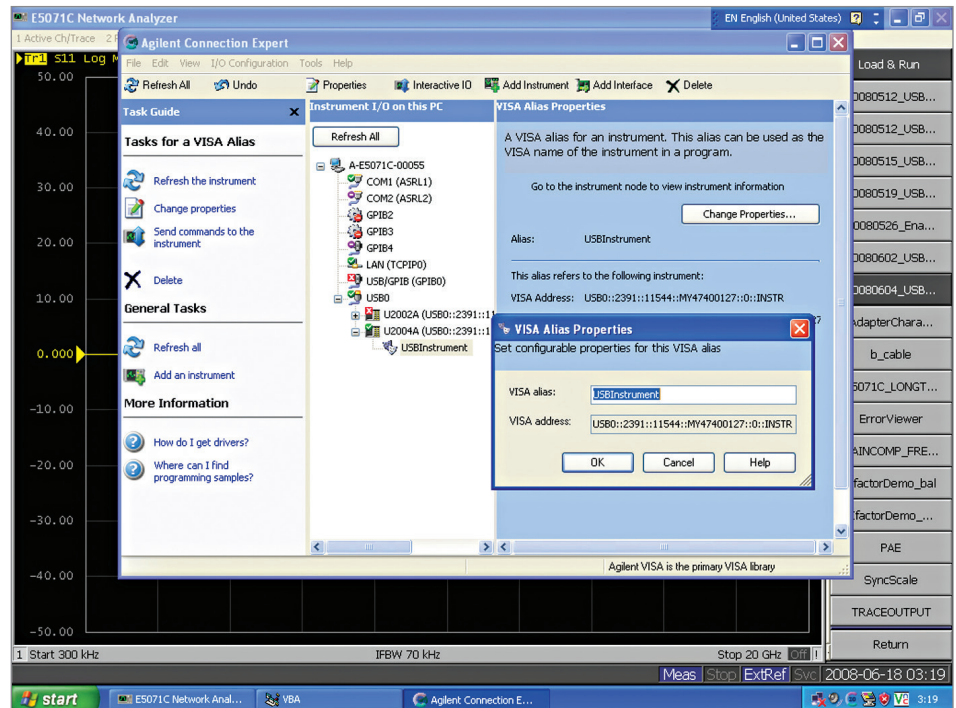

Figure 5. Keysight Connection Expert

<Operation>

After confirming the USB power sensor connection, run the program on the ENA menu from [Macro setup] > {Load Project} > and select "E5071C_USB-PSmeasWizard_xxxx.vba", then press [Macro Run] button or select {Select Macro} > {Module1 main} by softkey.

► Start. Program running with USB recognition

The first page of the wizard is shown in Figure 6. This sample wizard consists of eight steps to complete the measurement process. Press [Next] button to select the USB power sensor.
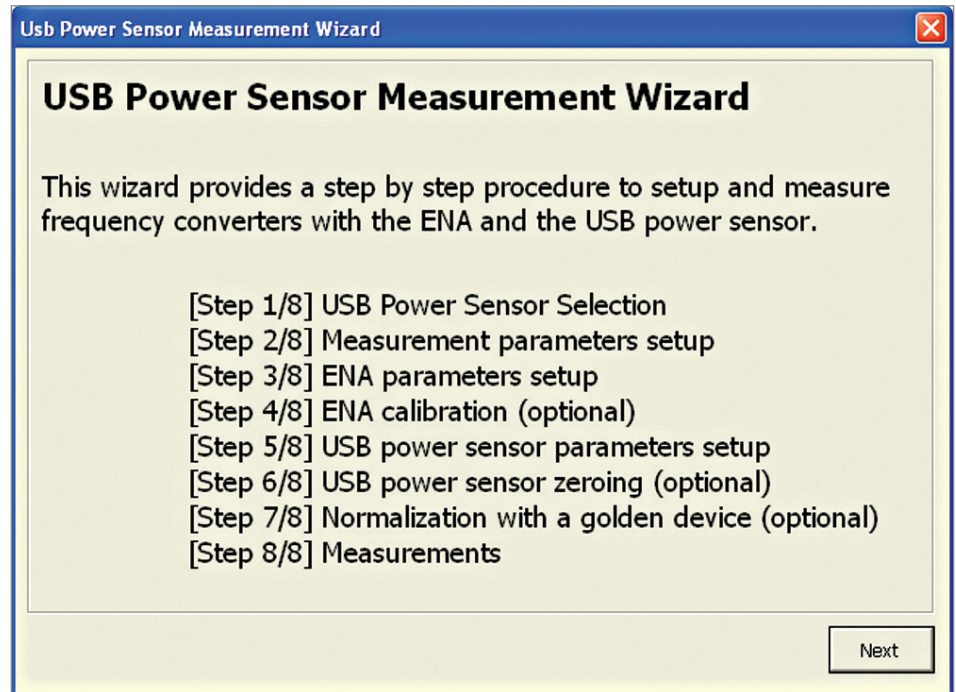

Figure 6. Top page

► Step 1. USB Power Sensor Selection

Select the USB power sensor that is connected to the ENA. The serial numbers of the USB power sensor connected to the ENA are displayed in this menu. If you don't see the proper serial number, check the USB power sensor connection by returning to Setup.
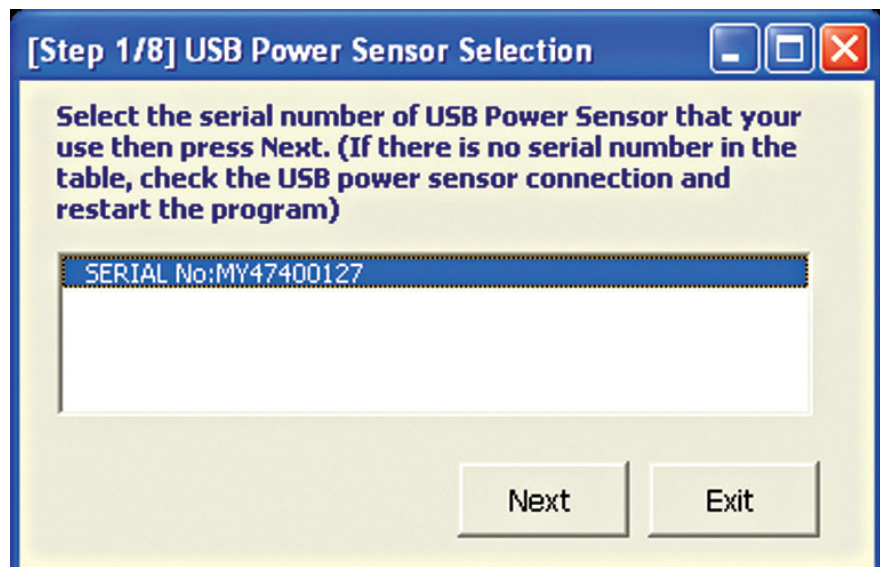

Figure 7. USB power sensor selection page

▶ Step 2. Measurement parameters setup

Select pre-defined parameters and trace locations for three cases.
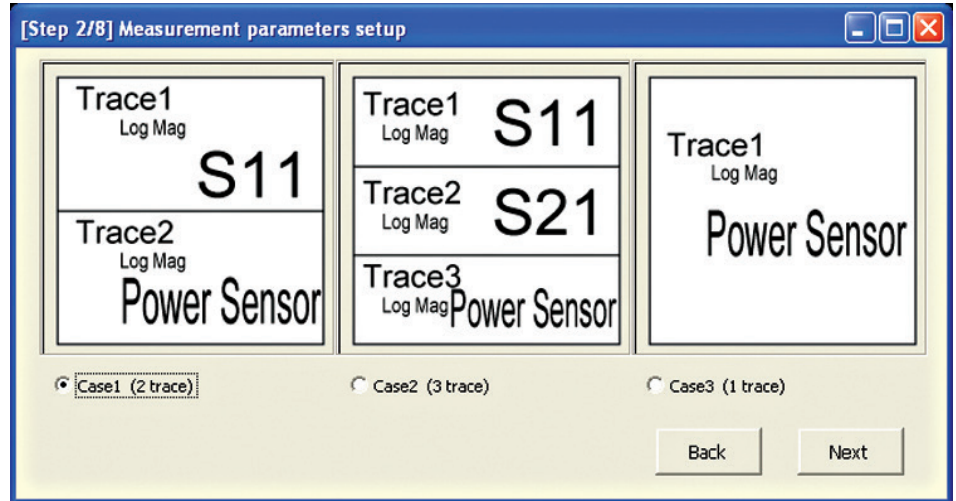

Figure 8. Measurement parameters setup

▶ Step 3. Parameters setup

Set the ENA's stimulus and sweep parameter setting. Also, you can check the USB power sensor's measurement range in the lower right hand side.
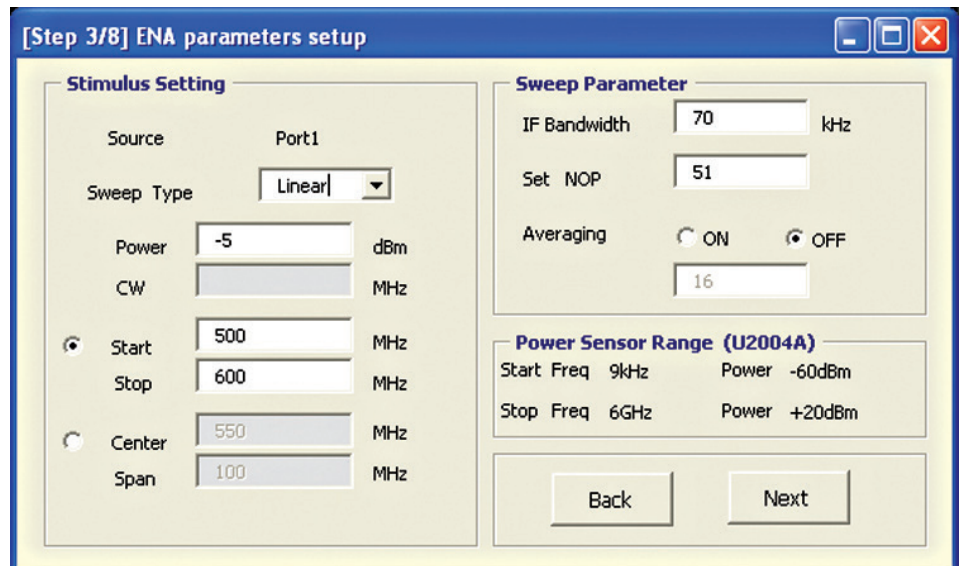

Figure 9. ENA parameter setup

► Step 4. ENA calibration (optional)

Take the full 1-port SOLT calibration to the port 1 of ENA that is valid for S11 measurement.
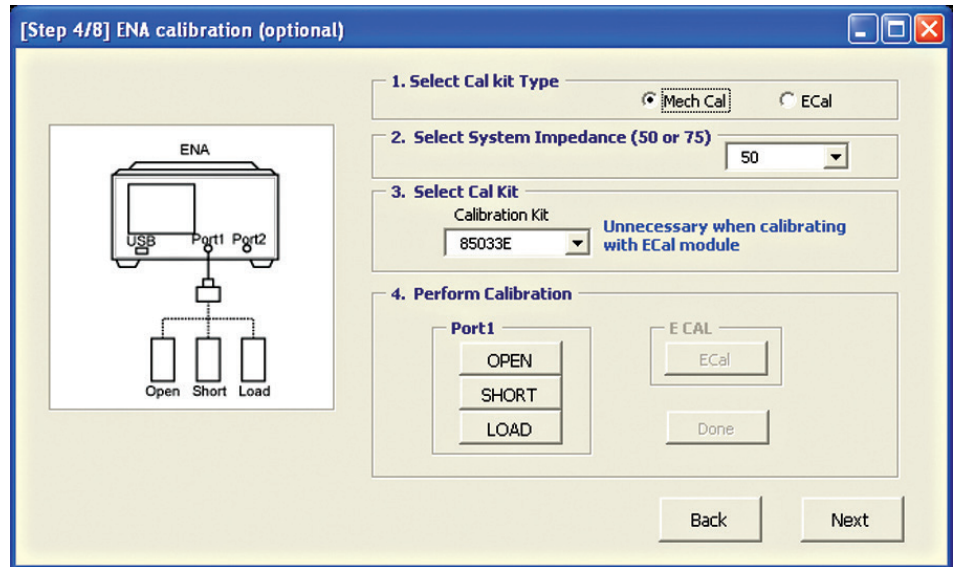

Figure 10. ENA port 1 calibration

Select the ENA's system impedance between 50 ohm and 75 ohm based-on the impedance of the DUT. When selecting 75 ohm, connect 11852B 50 ohm / 75 ohm minimum loss pads to the test cable and power sensor. Loss value of the 11852B can be set in this form.
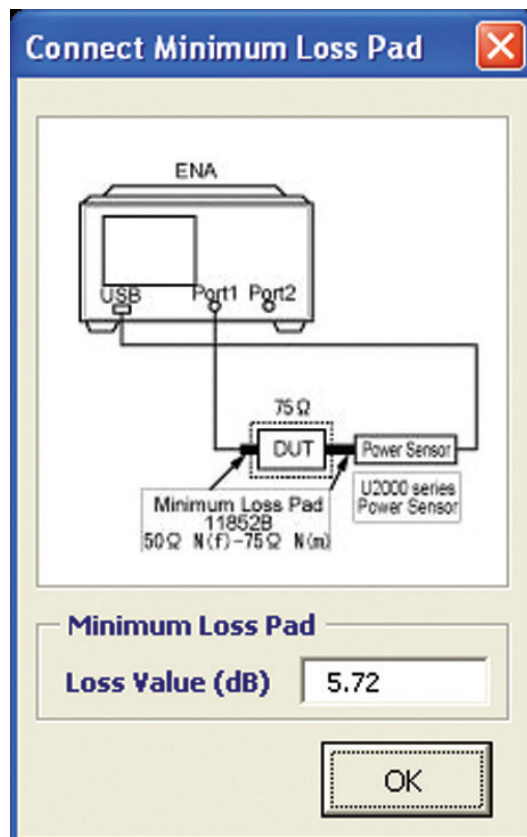

Figure 11. Connecting minimum loss pad when 75 ohm system is selected

► Step 5. USB power sensor parameters setup

Set the power sensor's target power and target frequency. If the RF signal of the ENA is from 500 MHz to 600 MHz and the DUT's LO signal is 400 MHz, then set the target frequency as RF + LO (900 MHz to 1000 MHz) or RF – LO (100 MHz to 200 MHz) depending on the setting.
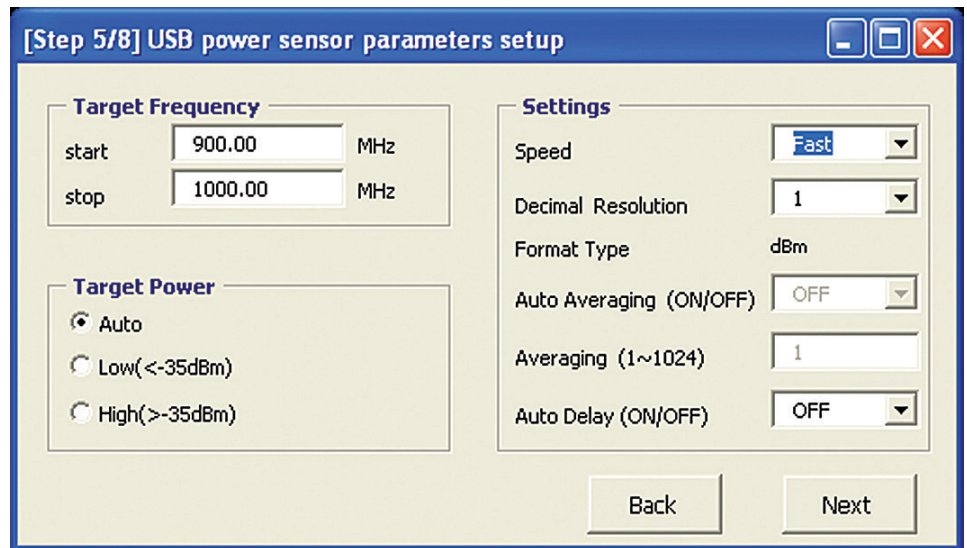

Figure 12. USB power sensor parameters setup

► Step 6. USB power sensor zeroing (optional)

The USB power sensor supports both internal and external zeroing function. When input power to the sensor is >-30 dBm, you can choose to use "Internal Zeroing" or "External Zeroing". Internal Zeroing can be performed without removing the RF input signal from the sensor thus simplifying the zeroing procedures. When the input power to sensor is </= -30 dBm, zeroing must be performed with "External Zeroing", whereby the RF input signal has to be switched off or the DUT has to be disconnected from the power sensor.
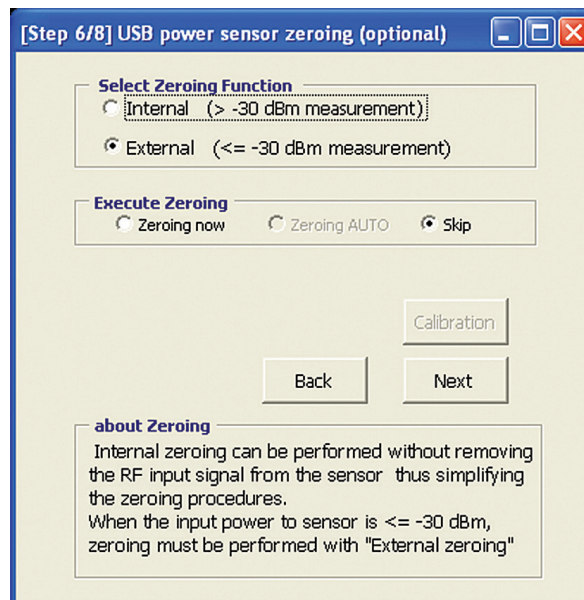

Figure 13. Power sensor zeroing

► Step 7. Normalizing with a golden device (optional)

If you would like to measure normalized output power measurement result refer to a golden device at DUT measurement, select YES at this step, and measure the golden device output level, by connecting the USB power sensor as shown in Figure 14. The result is used in Step 8 (DUT measurement page) to divide measured power of DUT, and display a result normalized by the golden device.
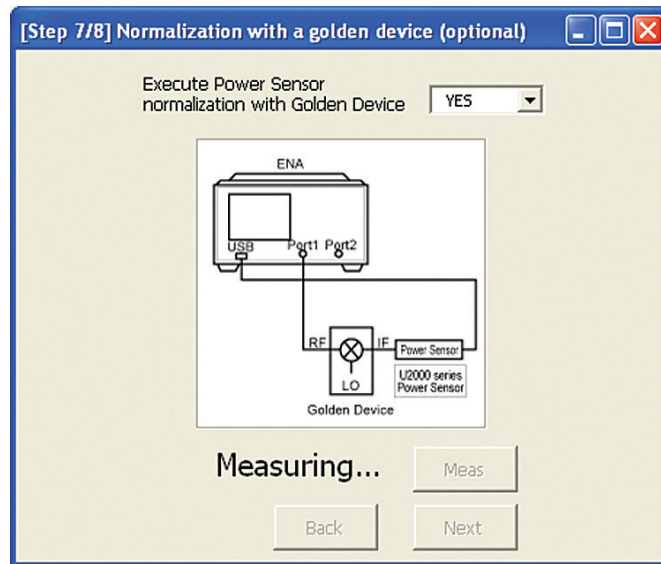

Figure 14. Normalization using golden device

► Step 8. Measurements

Measure the DUT continuously or once by selecting trigger mode. Select trigger mode and display mode, then press "Start" to begin the measurement. For faster measurement speed, select display update as once a sweep. To finish the measurement in continuous mode, press "Stop", the measurement will end after the current sweep is complete. You can save the data as .csv format by pressing the "Save" button.

If you would like to change the measurement setting, the "Top" button takes you back to the Step 1 or you can use the "Back" button to return to the previous page.

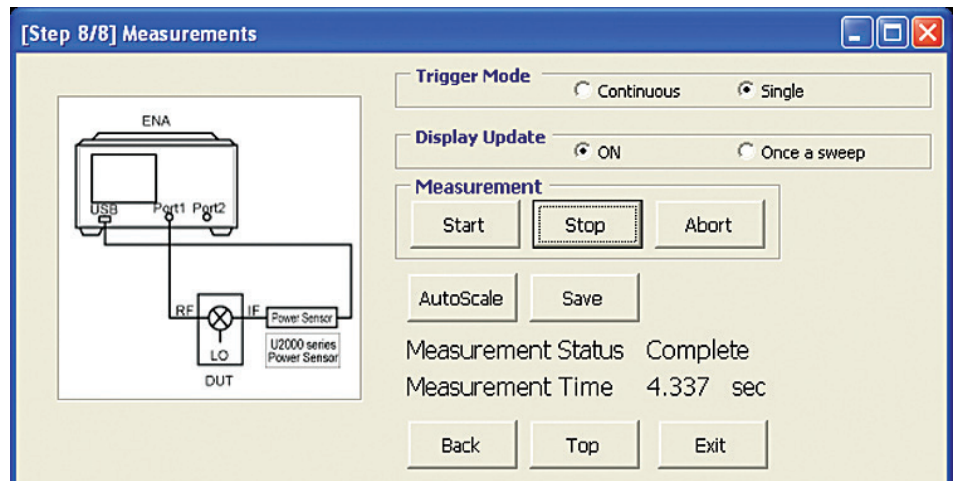Press "Exit" button to end the program.

Figure 15. Measurement window

Figure 16 shows a measurement example using this macro. Trace 1 in blue is the S11 trace and Trace 2 in red is the IF power measurement result by U2002A USB power sensor.
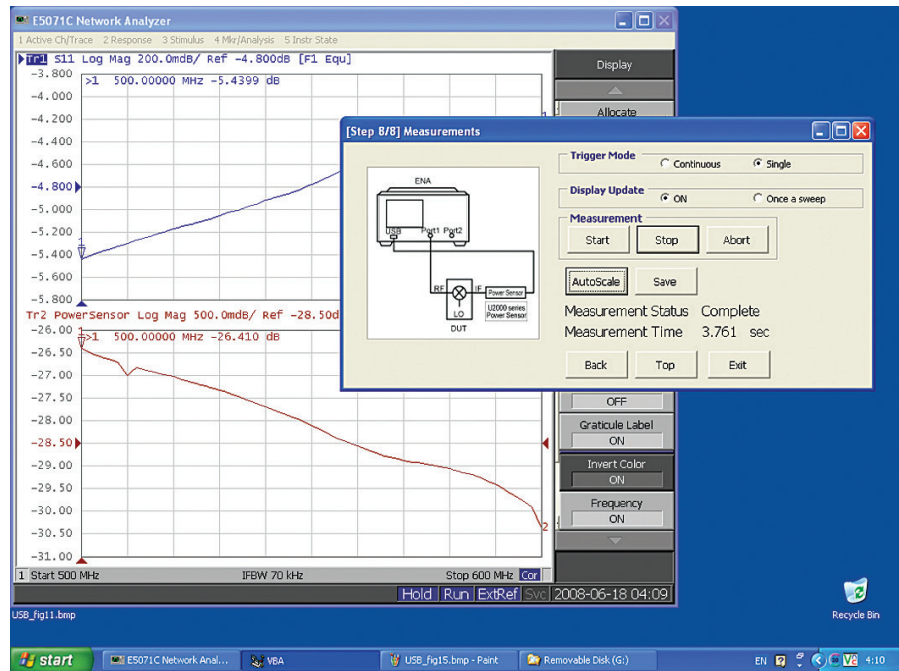

Figure 16. S11 (Trace 1 in blue) and power meter (Trace 2 in red) frequency sweep

Typical Cycle Time

Typical cycle time for 1 trace measurement using this VBA Macro is as follows:

E5071C ENA network ananlyzer

RF input setting	ENA setting	Power sensor setting	Number of points	Cycle time [sec]
CW frequency (3 GHz)	IFBW 70 kHz	fast	51	1.1
1 GHz to 8 GHz	IFBW 70 kHz	fast	201	3.8
Power sweep (–15 dBm to 0 dBm)	IFBW 70 kHz	fast	51	0.9

Sytem Requirements

E5071C ENA Network Analyzer
U2000 series USB power sensors
U2000A 10 MHz - 18 GHz USB Power Sensor
U2001A 10 MHz - 6 GHz USB Power Sensor
U2002A 50 MHz - 24 GHz USB Power Sensor
U2004A 9 kHz - 6 GHz USB Power Sensor

VBA program:
E5071C_USB-PSmeasWizard_0100.vba or later
URL: www.keysight.com/find/enavba

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Related Literature

E5071C ENA network analyzer:
Accurate Mixer Measurements Using the Frequency-Offset Mode,
Application note, literature number 5989-1420EN
ENA Series Brochure, literature number 5989-5478EN
ENA Series Data Sheet, literature number 5989-5479EN
ENA Series Configuration Guide, literature number 5989-5480EN

U2000 series USB power sensor:
Keysight U2000 Series USB Power Sensors, Technical Overview,
literature number 5989-6279EN
Compatibility of the U2000 Series USB Power Sensor with Keysight Instruments: Application note, literature number 5989-8743EN

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