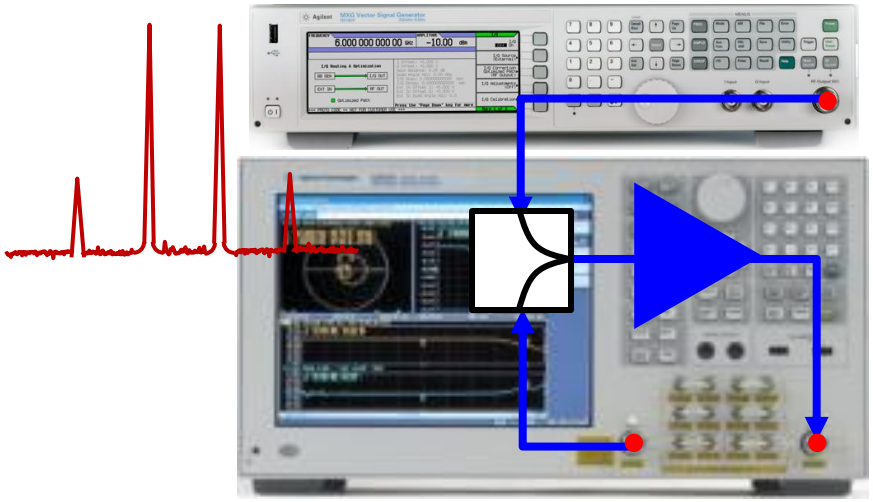
IMD Measurement Wizard for the E5072A ENA Series Network Analyzer

Operation Manual



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June 2012

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Notices

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Sample Program

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Contents

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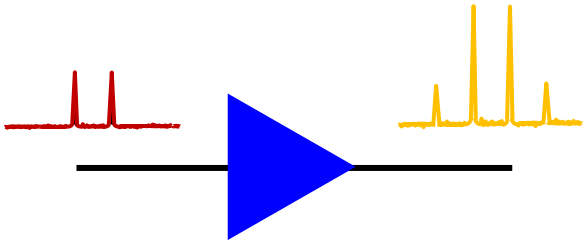
  - What is intermodulation distortion (IMD)?
  - IMD measurement solution
  - IMD measurement wizard for the E5072A
- Operation Manual
- Measurement Examples
- Summary

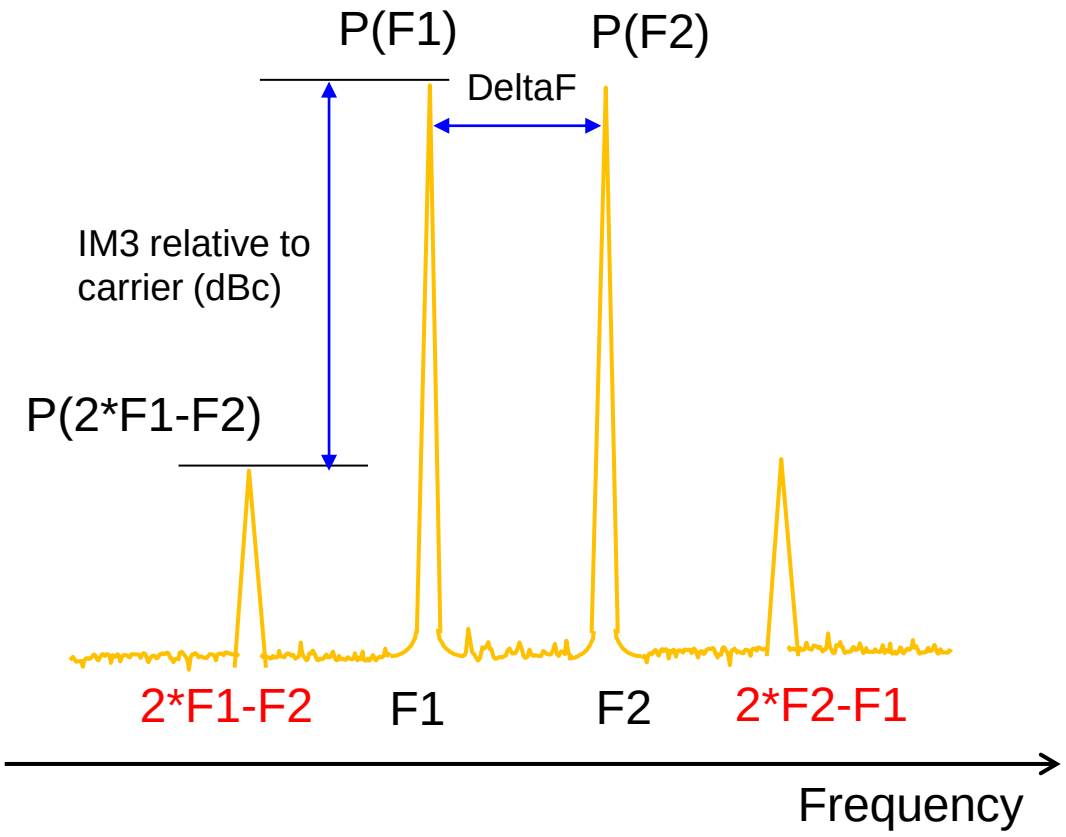
What is intermodulation distortion (IMD)?

- A measure of nonlinearity of amplifiers.
- Two or more tones applied to an amplifier and produce additional intermodulation products.
- The DUT's output will contain signals at the frequencies: n*F1 +m *F2.



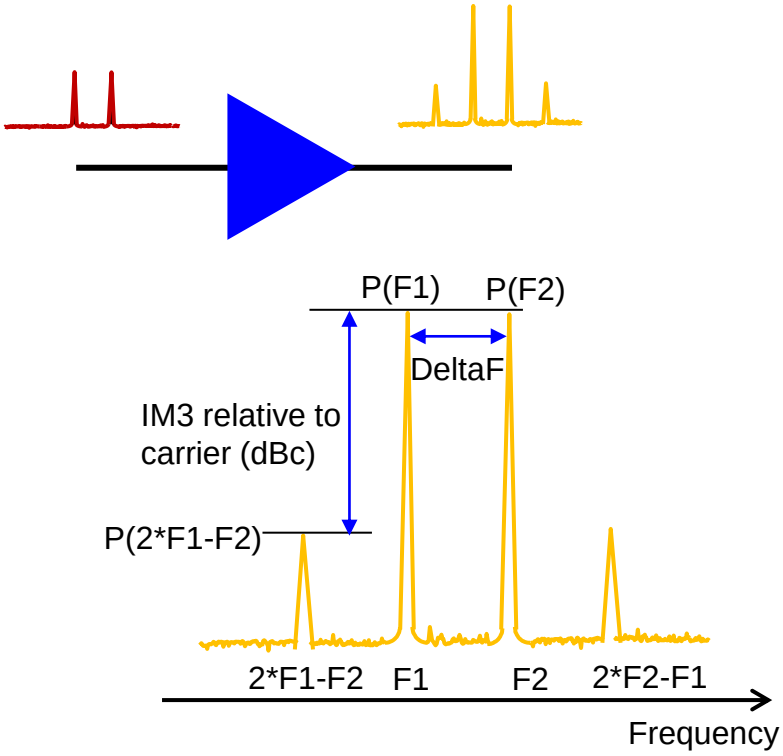
F_IMD = n * F1 + m * F2

ex.)
- Lo F_IM3 = **2 * F1 - F2**
- Hi F_IM3 = **2 * F2 - F1**
- Lo F_IM5 = **3 * F1 - 2 * F2**
- Hi F_IM5 = **3 * F2 - 2 * F1**
- Lo F_IM7 = **4 * F1 - 3 * F2**
- Hi F_IM7 = **4 * F2 - 3 * F1**

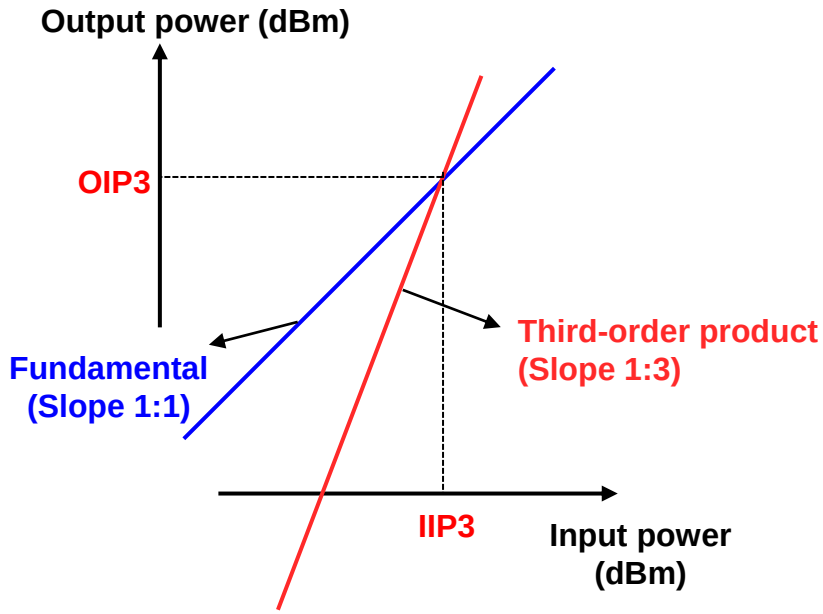


Third-order Intercept Point (IP3)

• The third-order intercept point (**IP3**) or the third-order intercept (**TOI**) are often used as figures of merit for IMD.



P(F1): Power level of low tone
P(F2): Power level of high tone
P(2*F1-F2): Power level of low-side IM3 signal
P(2*F2-F1): Power level of high-side IM3 signal



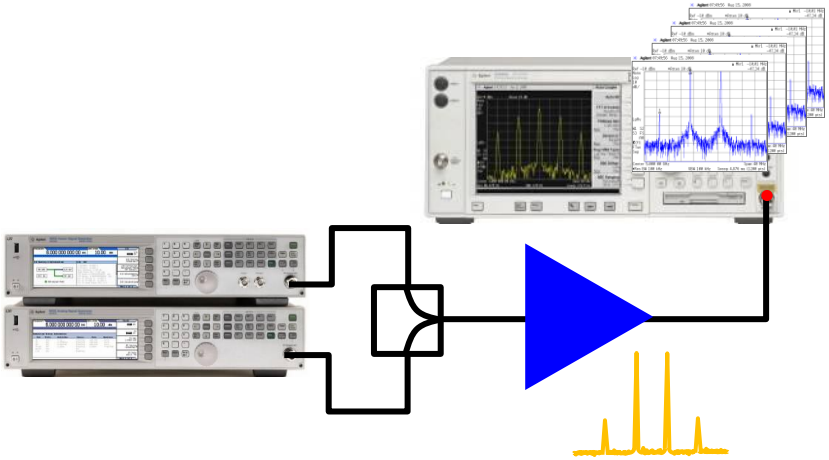
IP3 can be calculated by the equation using low-side IM3:
IP3 (dBm) = P(F1) + (P(F2) - P(2*F1-F2)) / 2

When high-side IM3 is used, the equation is:
IP3 (dBm) = P(F2) + (P(F1) - P(2*F2-F1)) / 2

Intermodulation Distortion

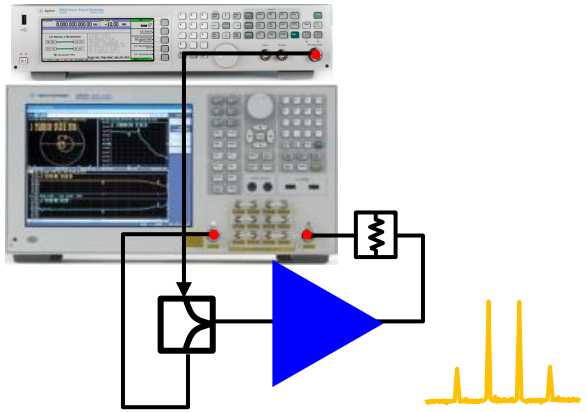
Solution with ENA

2x SG + SA



- Using two SGs and a SA with CW signals.
- It requires a controller to synchronize instruments.
- If many frequencies must be tested, **test time is increased dramatically**.

SG + ENA

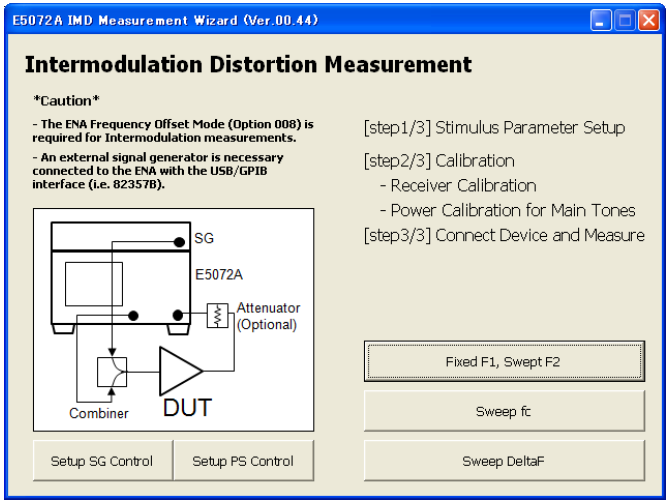


- ENA with **frequency-offset mode (FOM) option** can set different frequencies at the source and receiver.
- **Real-time** swept frequency IMD measurements can be performed.
- Source power calibration and receiver calibration is available with VNA for accurate absolute power measurements.

IMD Measurement Wizard for the E5072A

Key Features:

- Measurement macro running on the E5072A with intuitive GUI
- Quick setup of two-tone IMD measurements
- Control all necessary equipments from E5072A
  - MXG (connected via GPIB/USB interface)
  - Power meter & sensor (connected via GPIB/USB interface)
  - USB power sensor (connected directly to the ENA's USB port)
- Guided calibration wizard
- Various measurement sweep types
  - **Fixed F1 and Swept F2**
  - **Sweep Fc** (center frequency of main tones)
  - **Sweep DeltaF** (delta frequency of main tones)
- Various IMD measurement parameters
  - Absolute power of fundamental tones (in dBm)
  - Power levels of IMD products (absolute in dBm), Low or High-side IM (3rd, 5th, 7th)
  - Calculated third-order intercept point (IP3)

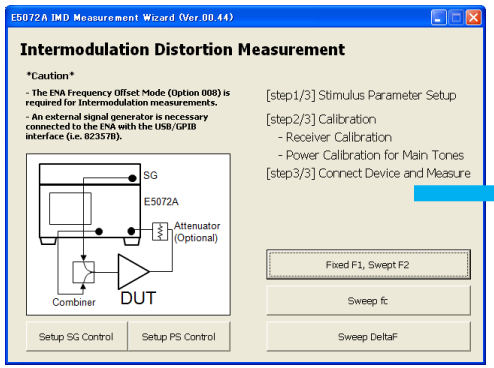


Available at: www.agilent.com/find/enavba

IMD Measurement Wizard

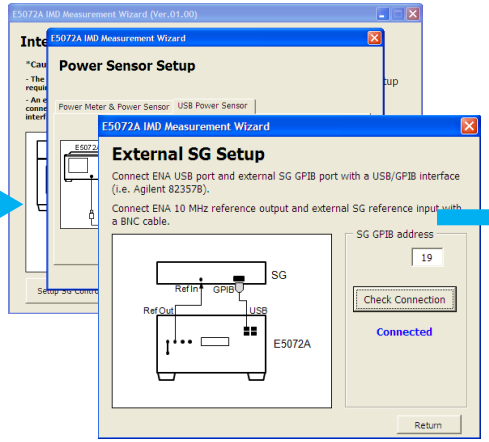
Overview

Introduction



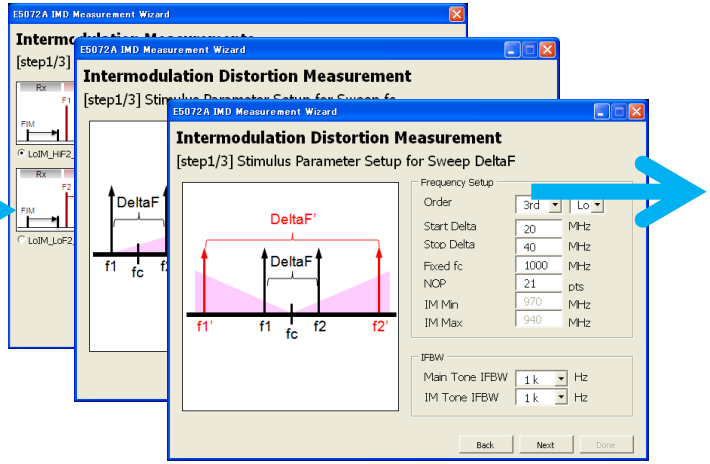
Peripherals Setup

(SG, Power sensor)

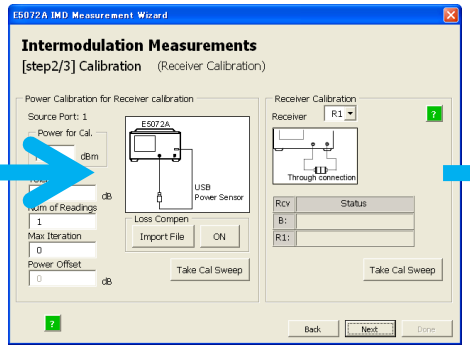


Stimulus Parameter Setup

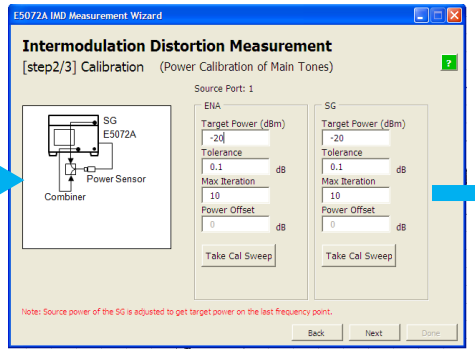
(IM order, frequency, NOP, IFBW etc.)



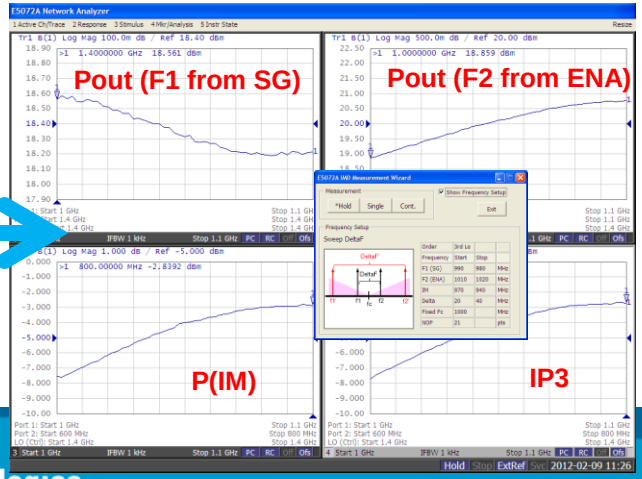
Calibration (Receiver cal)



Calibration (Power Cal)



Measurement Result



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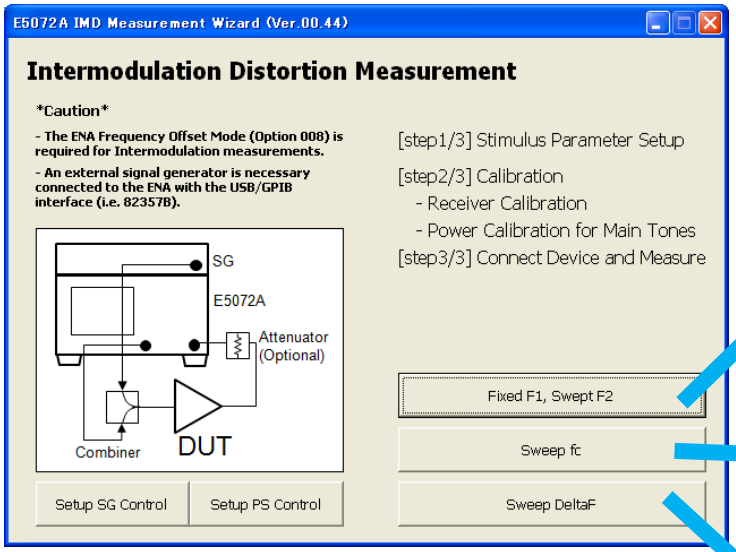
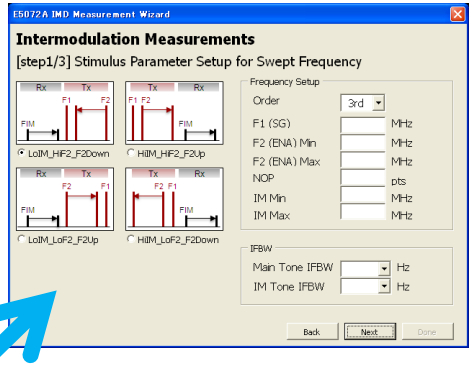
IMD Measurement Wizard

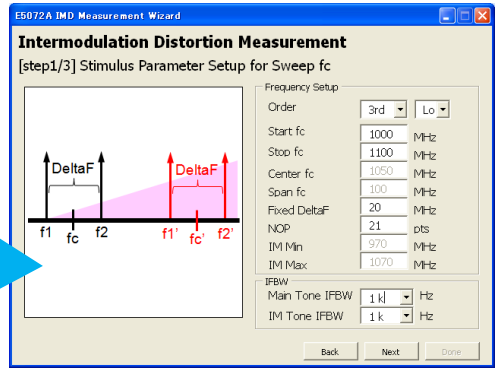
Measurement type

Introduction

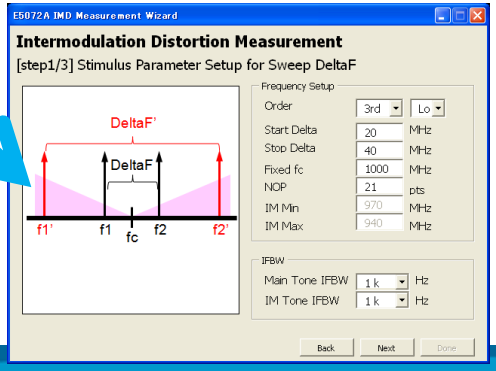




1. Fixed F1, Swept F2



2. Sweep fc
(sweep center frequency between the two main tones)



3. Sweep DeltaF
(sweep delta frequency between the two main tones)

Three different sweep types are available.

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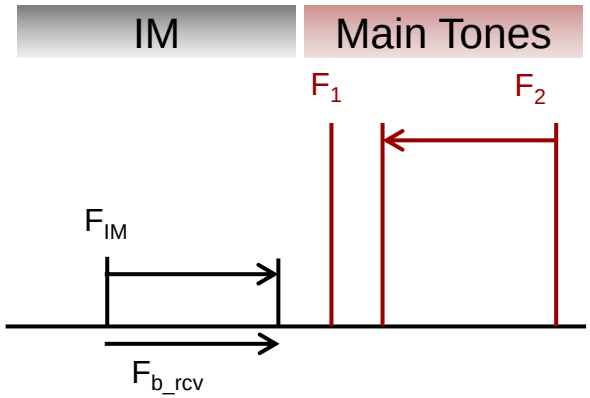
IMD Measurement Type

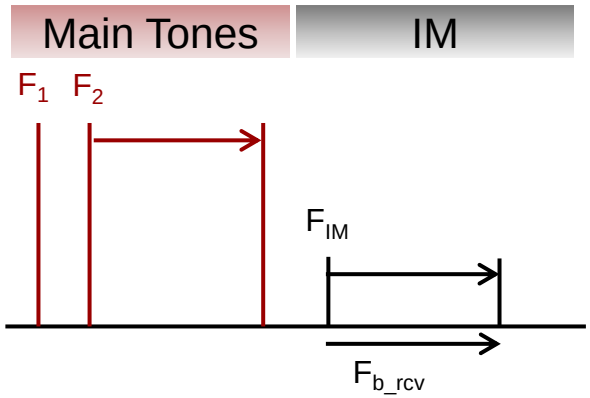
1. Fixed F1, Swept F2

• One of the main tones from the SG is fixed at a certain frequency (F1), while the other F2 from the ENA's source is swept.

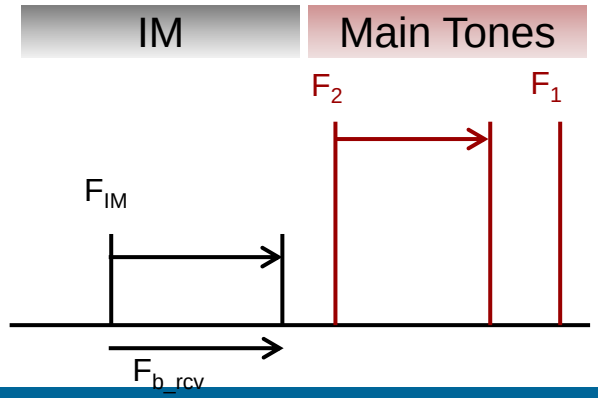
(1-1) Lo IM (Fixed F1, downward-swept F2)



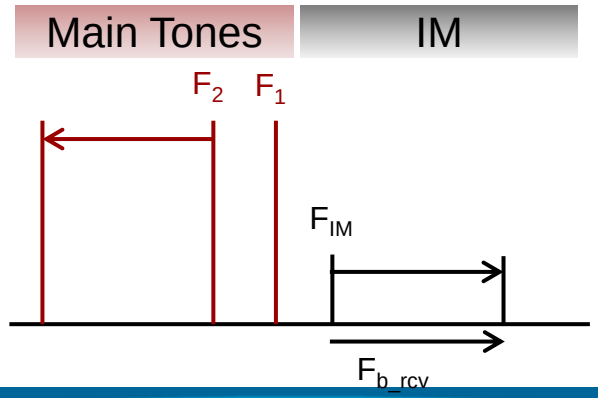
(1-3) Hi IM (Fixed F1, upward-swept F2)



(1-2) Lo IM (Fixed F1, upward-swept F2)



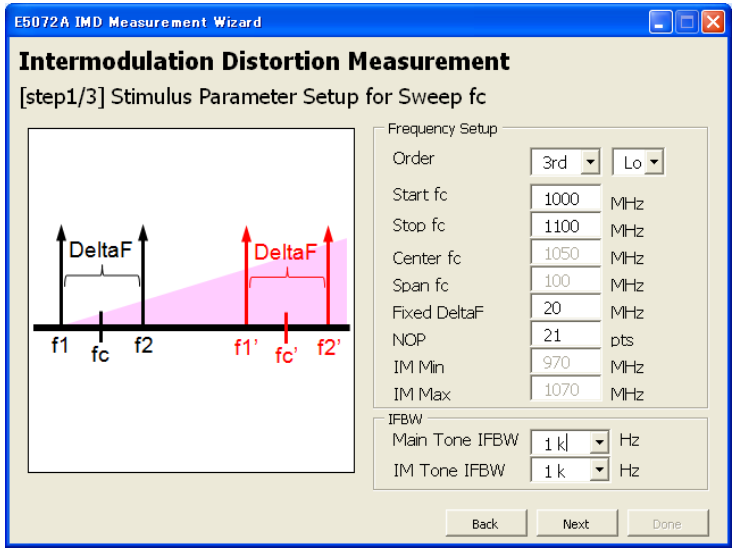
(1-4) Hi IM (Fixed F1, downward-swept F2)



IMD Measurement Type

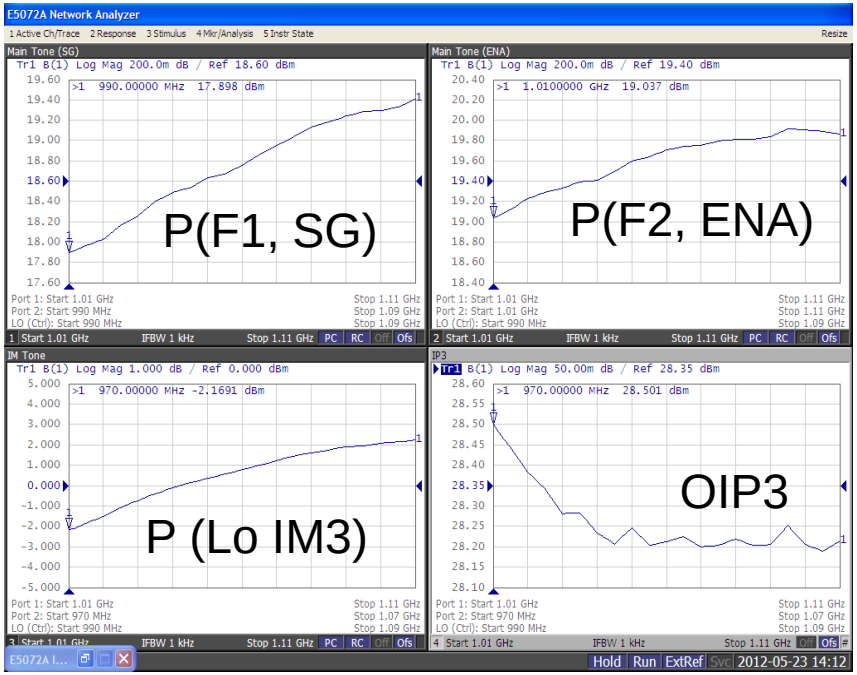
2. Sweep fc

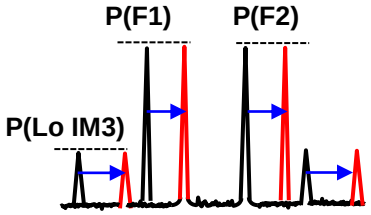
Stimulus setup



- Center frequency of the main tones is swept in the frequency range, while the delta frequency is fixed.
- 3rd, 5th, or 7th-order IM product can be tested for either high-side or low-side.

Measurement Result



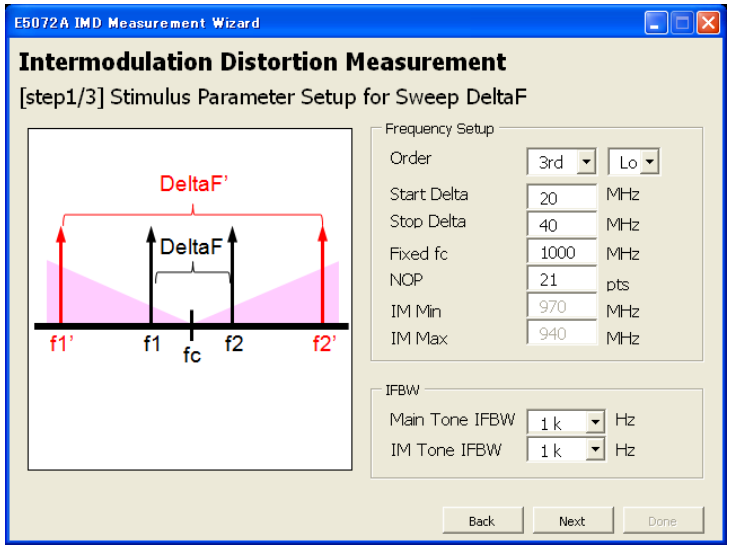


- Output power of the main tones and IM power level is displayed to calculate output IP3 of the DUT.

IMD Measurement Type

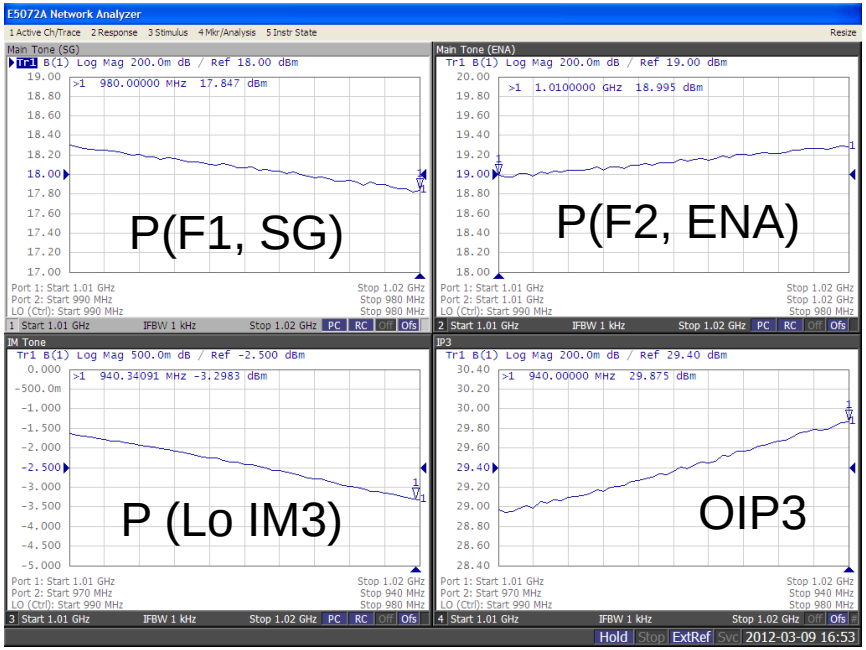
3. Sweep DeltaF

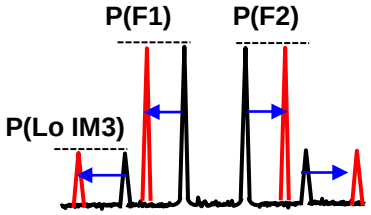
Stimulus setup



- Delta frequency between the main tones is swept in the frequency range, while the center frequency is fixed.
- 3rd, 5th, or 7th-order IM product can be tested for either high-side or low-side.

Measurement Result





- Output power of the main tones and IM power level is displayed to calculate output IP3 of the DUT.

Required Equipments

Model	Description	Note
E5072A	E5072A ENA Series Network Analyzer (with configurable test set)	• **Option 008** (frequency-offset mode) must be installed. (*1) • With the firmware revision 1.01 or later.
N5181A	MXG RF analog signal generator	• An external generator is used as a second source for the main tone.
U200x Series	USB power sensor	• Necessary for accurate absolute measurements using the E5072A's receiver. • Can be directly connected to the E5072A's USB port. • Other power sensors/meters supported for the E5072A are listed in the E5072A's webhelp. (link)
82357B	USB/GPIB interface	• Necessary to control an external SG or power meter over GPIB from the E5072A firmware.

*1: For more details on the E5072A's options, refer to the E5072A configuration guide, part number 5990-8001EN. **(http://cp.literature.agilent.com/litweb/pdf/5990-8001EN.pdf)**

Operation Manual

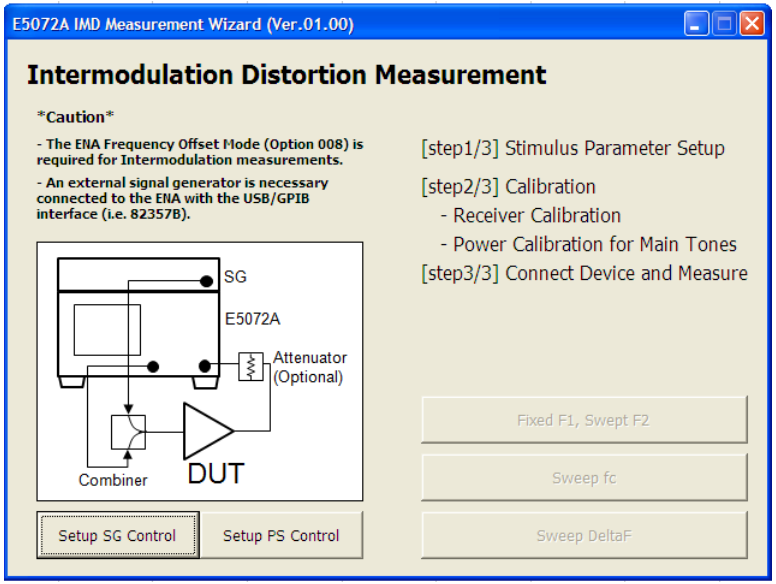
Operation Manual

Launch program

- **Save the wizard program in the E5072A**
  Visit: www.agilent.com/find/enavba
  Go to ENA IMD Measurement Wizard Page
  Download “E5072AIMDWizard_xxxx.zip” and unzip the file.
  Copy “E5072AIMDWizard_xxxx.vba” under “D:/VBA/ “ of the E5072A’s directory.
  Note: xxxx is the revision number of the wizard program.

- **Launch the wizard program**
  [Macro Setup] > Load & Run
  Select “E5072AIMDWizard_xxxx.vba”
  * The main window shows up.

  Note: Be sure to preset the E5072A and SG manually before launching the wizard program.



Operation Manual

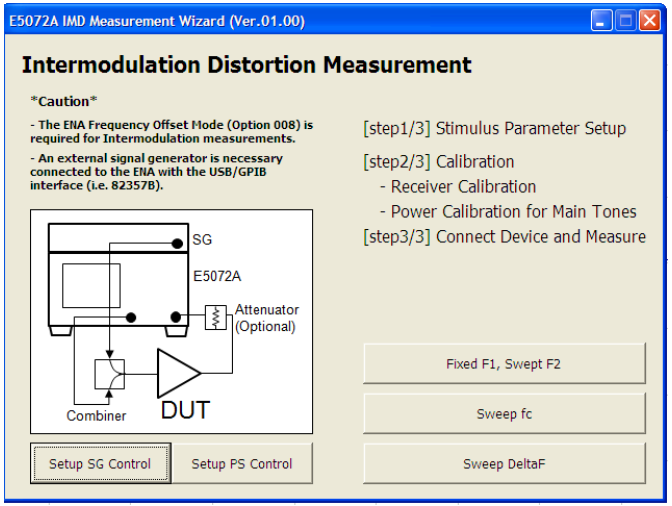
Measurement procedure

1. Setup peripherals
   - Setup SG
   - Setup power meter / sensor (GPIB or USB)

2. Setup measurement parameters
   - Select IMD sweep types
     1. Fixed F1, Swept F2
     2. Sweep fc (center frequency)
     3. Sweep DeltaF (delta frequency)
   - Setup stimulus parameters

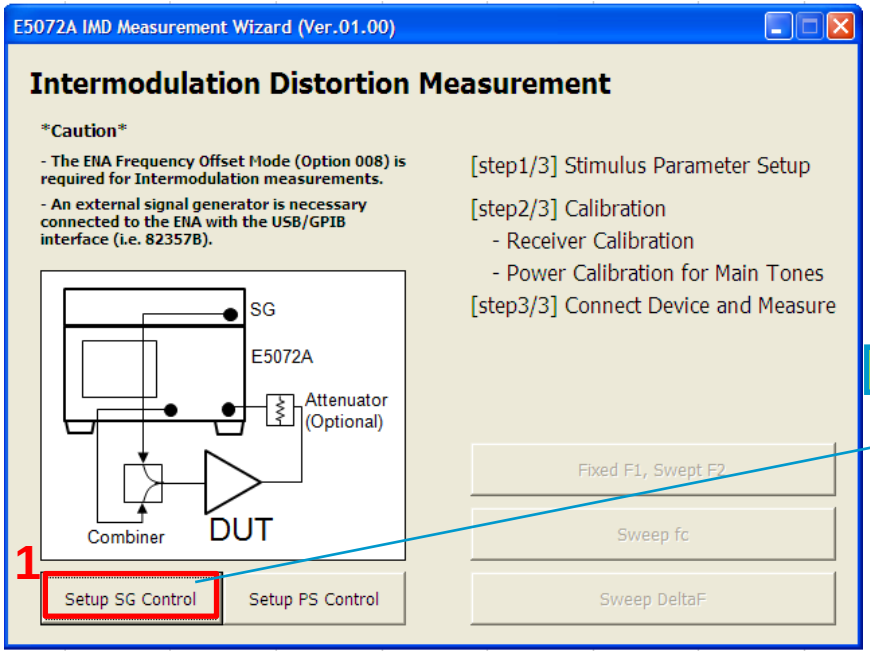
3. Perform calibration
   - Receiver calibration
   - Power calibration for main tones (SG & ENA)

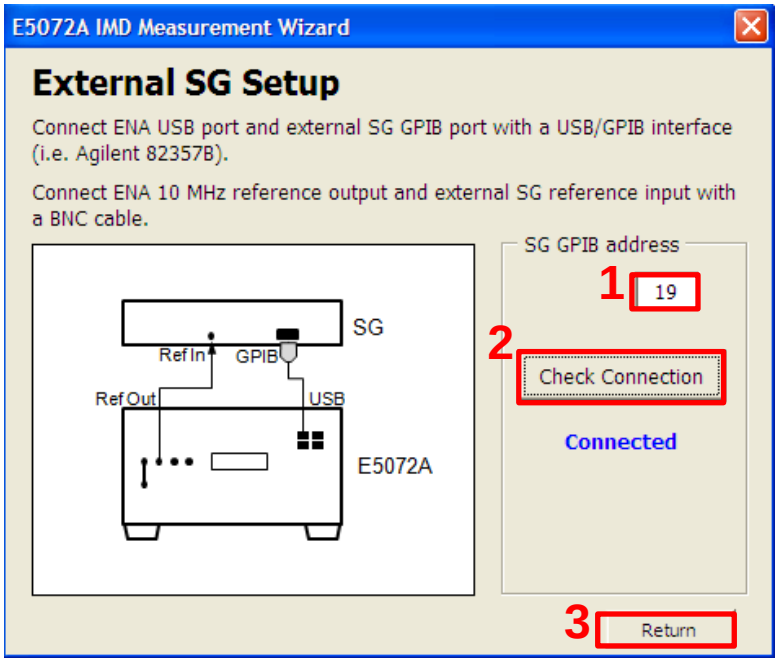
4. Connect DUT and perform measurement



Operation Manual

1. Setup peripherals (SG)



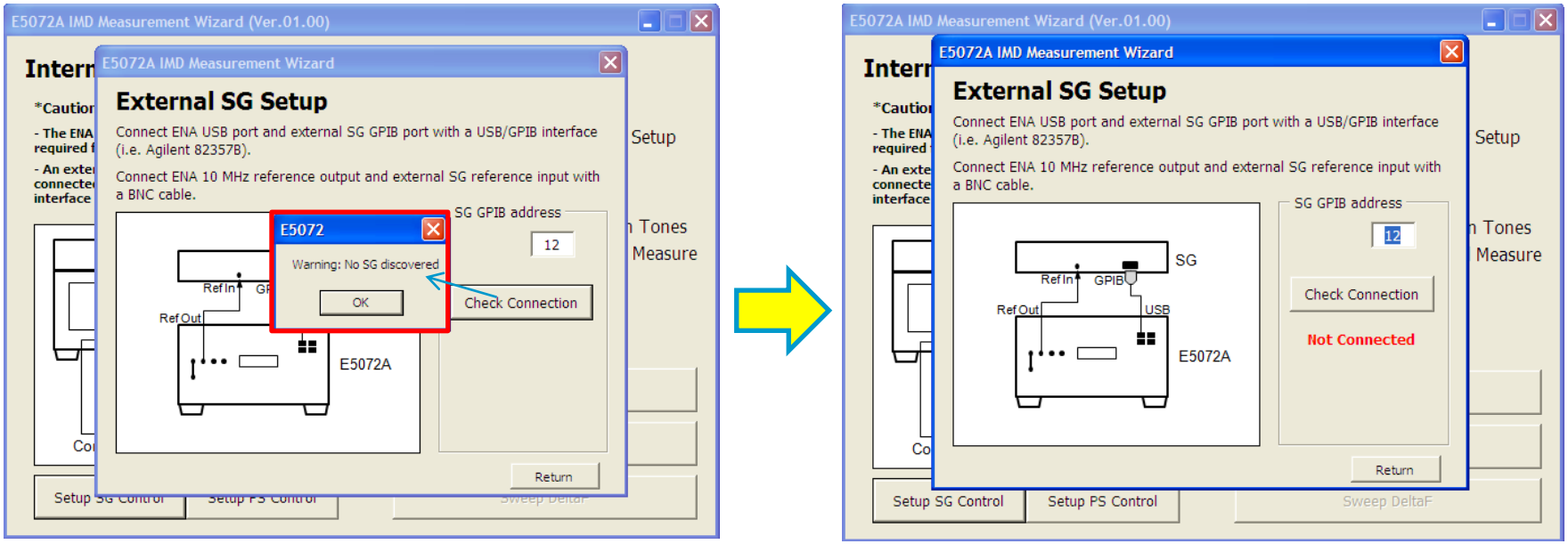


1. Press “Setup SG Control”
   - Necessary to setup an external SG (i.e. Agilent MXG N5181A) which is connected to the ENA via USB/GPIB interface (i.e. 82357B).

1. Enter the SG’s GPIB address
2. Press “Check Connection”
   - When the SG is connected to the ENA successfully, “Connected” is displayed.
3. Press “Return”

Operation Manual

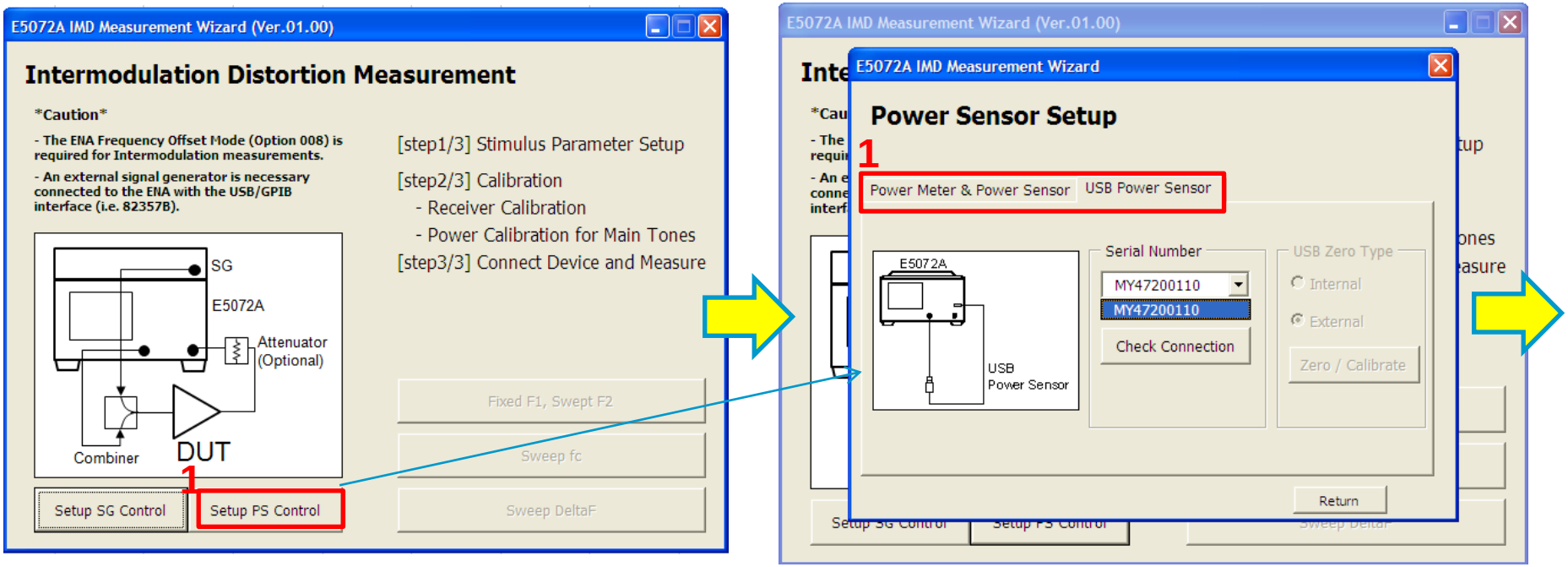
1. Setup peripherals (Error: SG - Not connected)



- When the correct GPIB address of the SG is not entered, the error message is shown “Warning: No SG discovered” after pressing “Check Connection”.
- “Not connected” is displayed in the SG setup window.

Operation Manual

1. Setup peripherals (Power sensor via GPIB or USB)



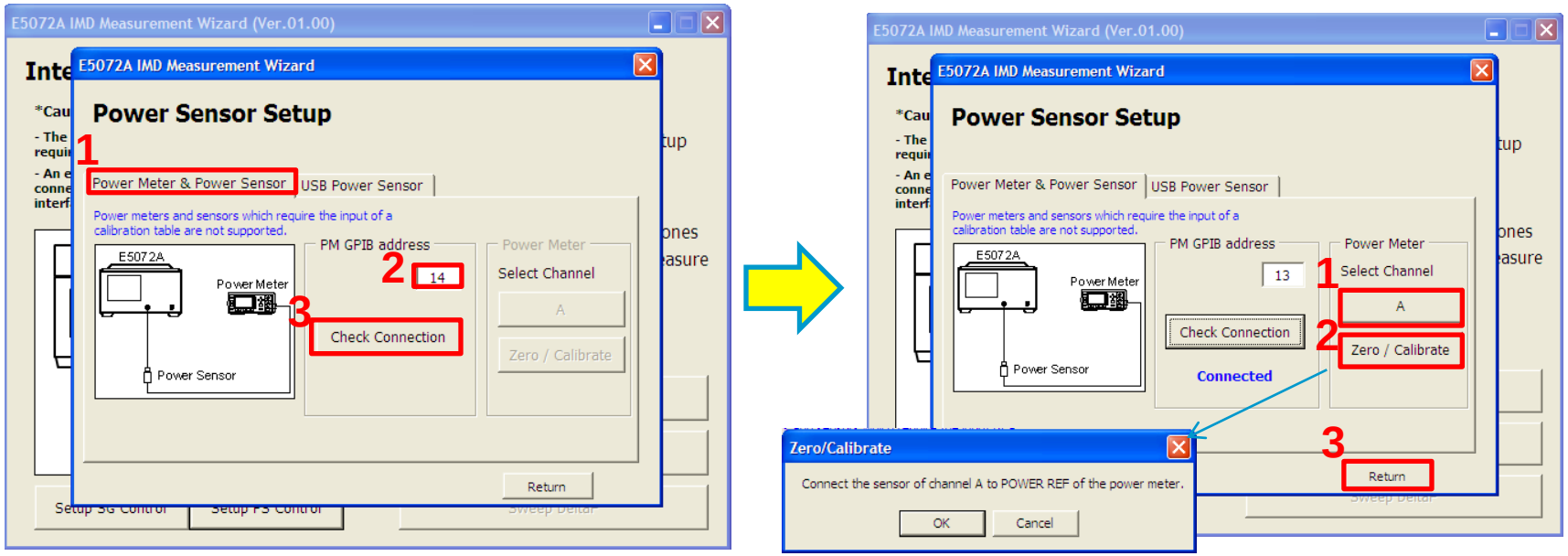
1. Press “Setup PS Control”
   - Necessary to setup a power sensor which is connected to the ENA by either the USB/GPIB interface (i.e. 82357B) or the ENA’s USB port.

1. Select tab, “Power Meter & Power Sensor” (GPIB) or “USB Power Sensor” (USB)

Operation Manual

1. Setup peripherals (Power sensor via GPIB)

Setup for power meter connected via GPIB/USB interface (i.e. Agilent 82357B)

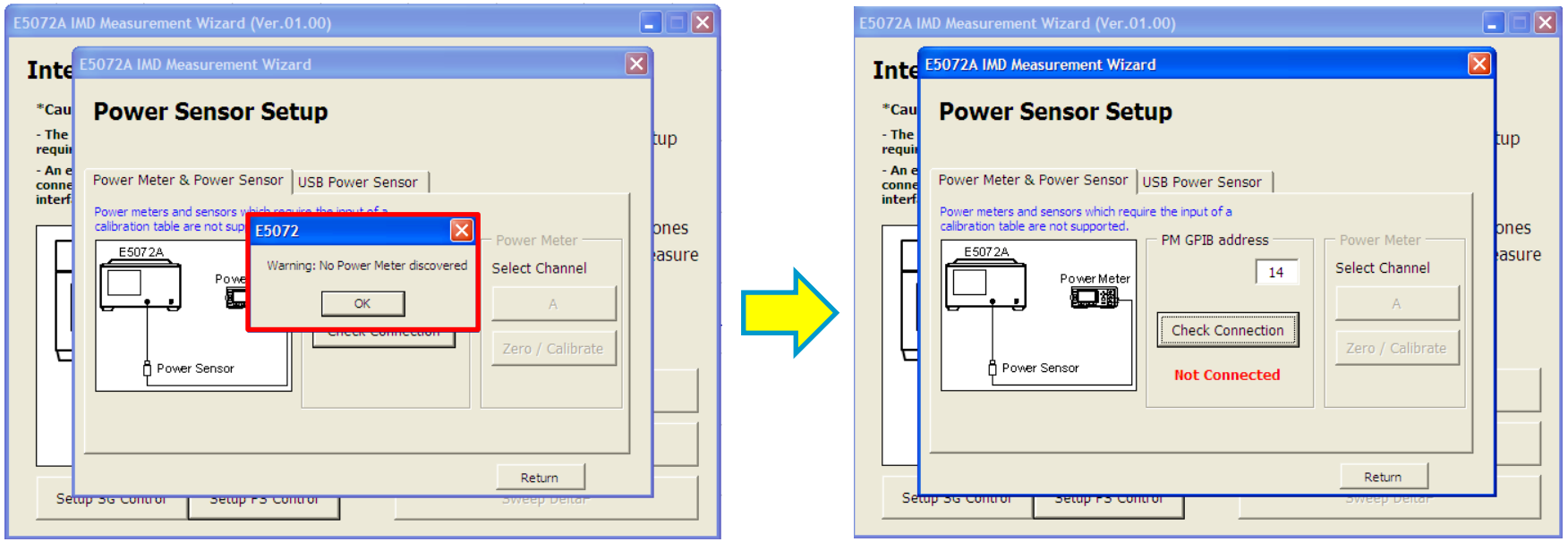


1. Select tab, “Power Meter & Power Sensor”
2. Enter the GPIB address of the power meter
3. Press “Check Connection”
   - When the power meter is connected to the ENA successfully, “Connected” is displayed.

1. Select Channel
2. Perform zeroing of the sensor (optional)
3. Press “Return”

Operation Manual

1. Setup peripherals (Error: Power Meter - Not connected)

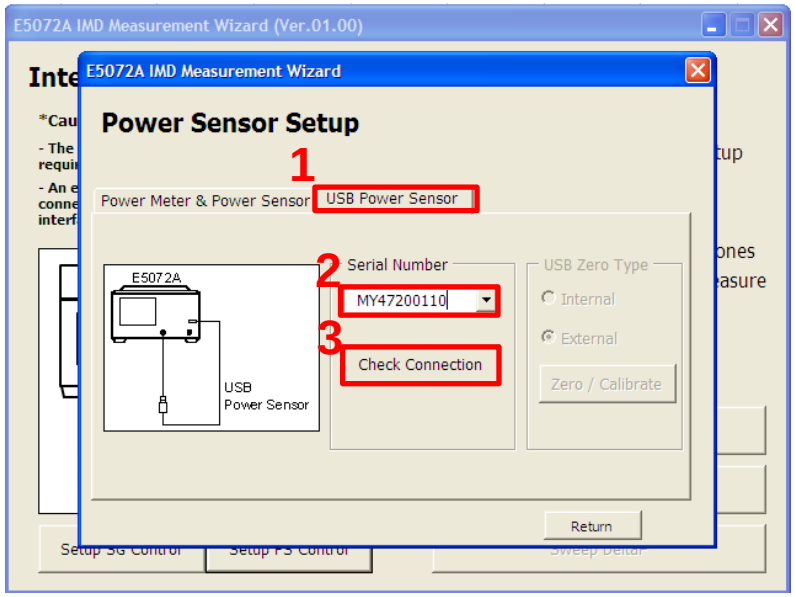


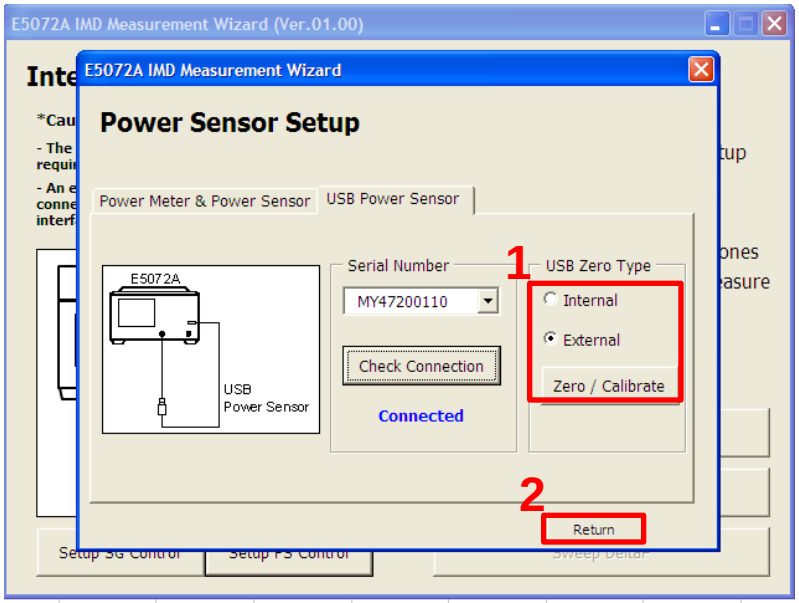
- When the power meter is not connected or correct GPIB address of the power meter is not entered, the error message is shown “Warning: No Power Meter discovered” after pressing “Check Connection”.
- “Not connected” is displayed in the setup window.

Operation Manual

1. Setup peripherals (Power sensor via USB)

Setup for USB power sensor (i.e. Agilent U2000 series)



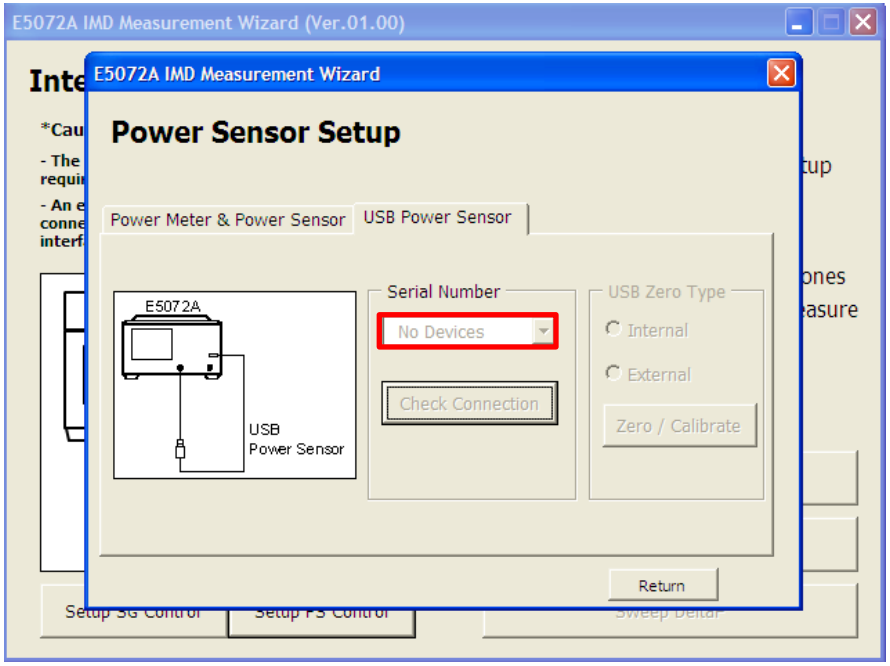


1. Select tab, “USB Power Sensor”
2. Select the serial number of the connected USB power sensor
3. Press “Check Connection”
   - When the power sensor is connected to the ENA successfully, “Connected” is displayed in the setup window.

1. Perform zeroing of the sensor (optional)
2. Press “Return”

Operation Manual

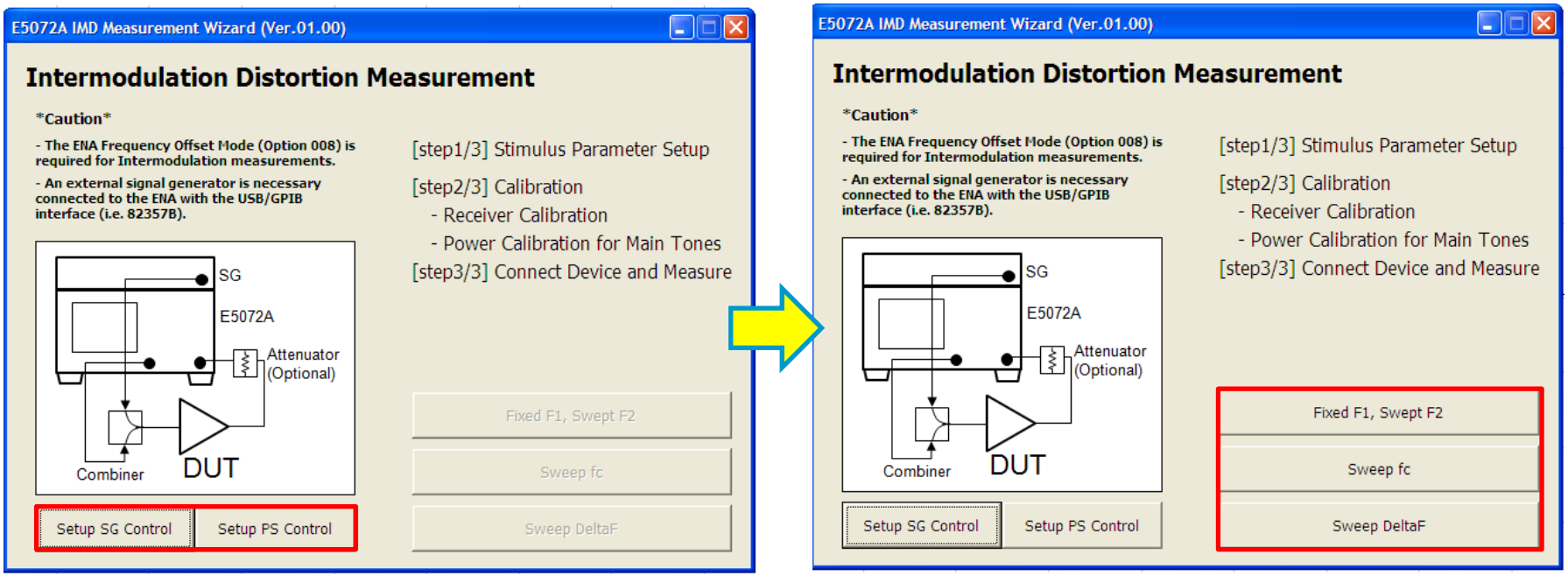
1. Setup peripherals (Error: Power Sensor - No Devices)



- If the USB power sensor is not connected to the E5072A, the serial number is not displayed in the pull-down menu.

Operation Manual

1. Setup peripherals

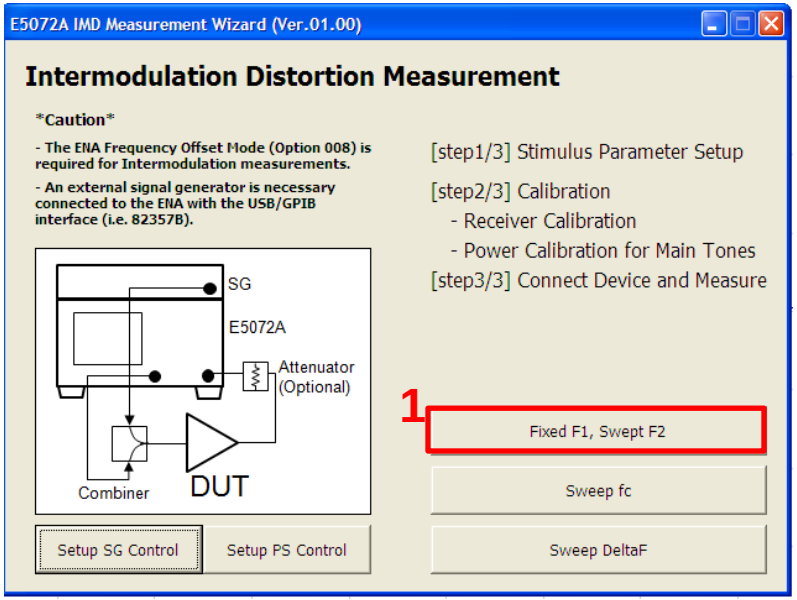


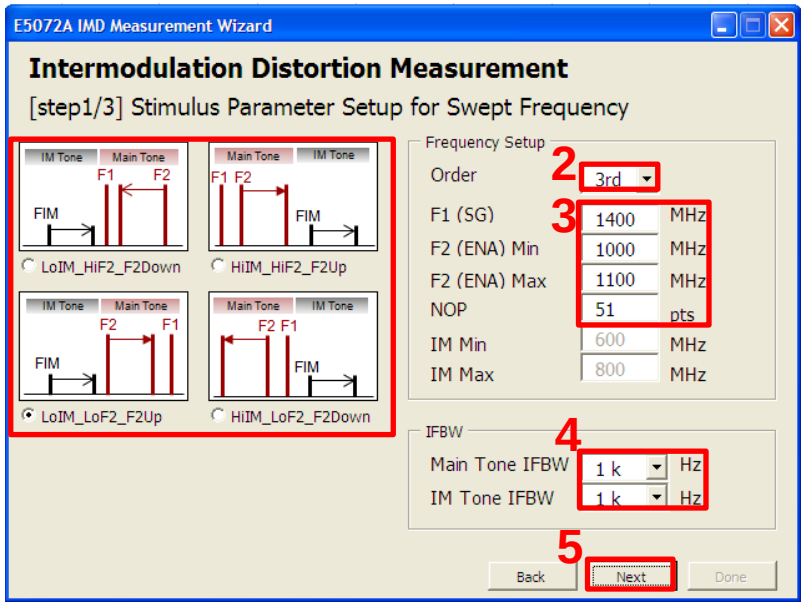
- When the both SG and power sensor are connected to the E5072A successfully, the measurement sweep types can be selected.

Operation Manual

2. Setup measurement parameters

1. Fixed F1, Swept F2





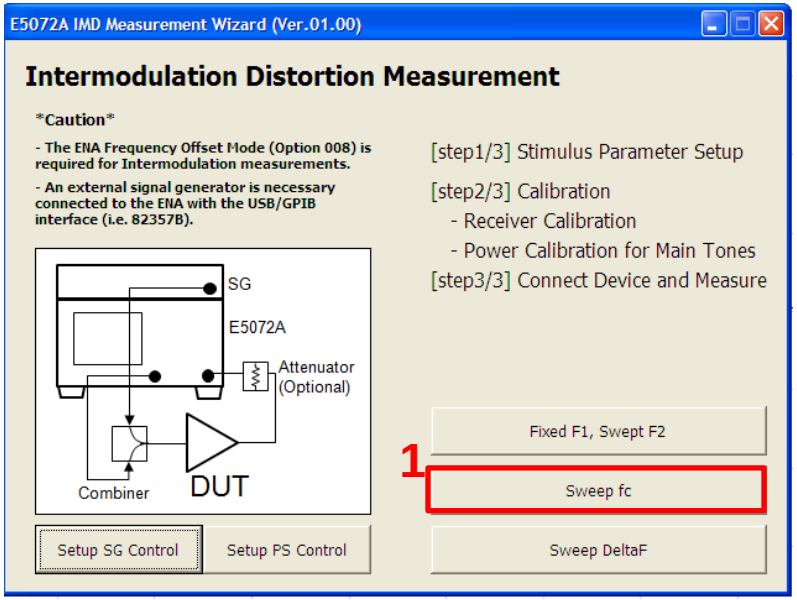
1. Press “**Fixed F1, Swept F2**”
   - One of the main tones is fixed at a specific frequency, while the other main tone is swept in the frequency range.

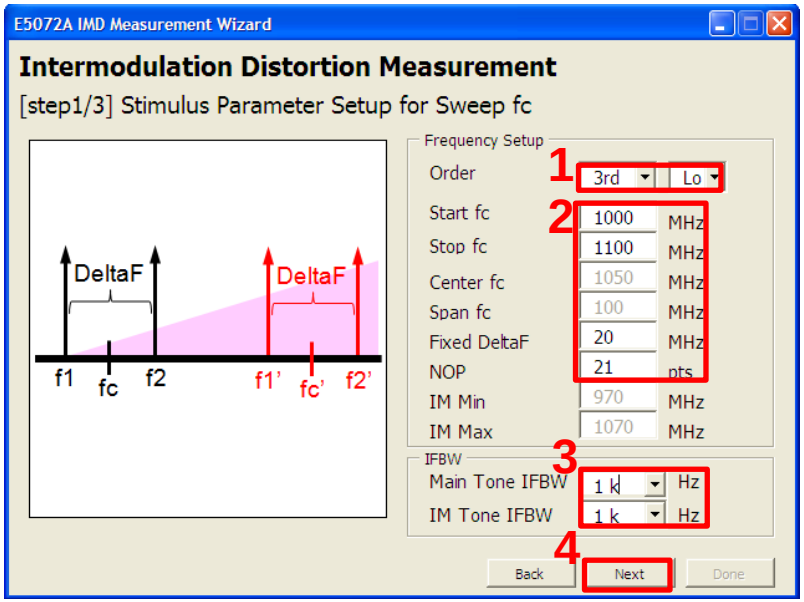
1. Select sweep type
2. Select IM order (3rd, 5th, or 7th)
3. Enter main tones’ frequency, NOP
4. Select IFBW for main tones & IM tone
5. Press “Next”

Operation Manual

2. Setup measurement parameters

2. Sweep fc





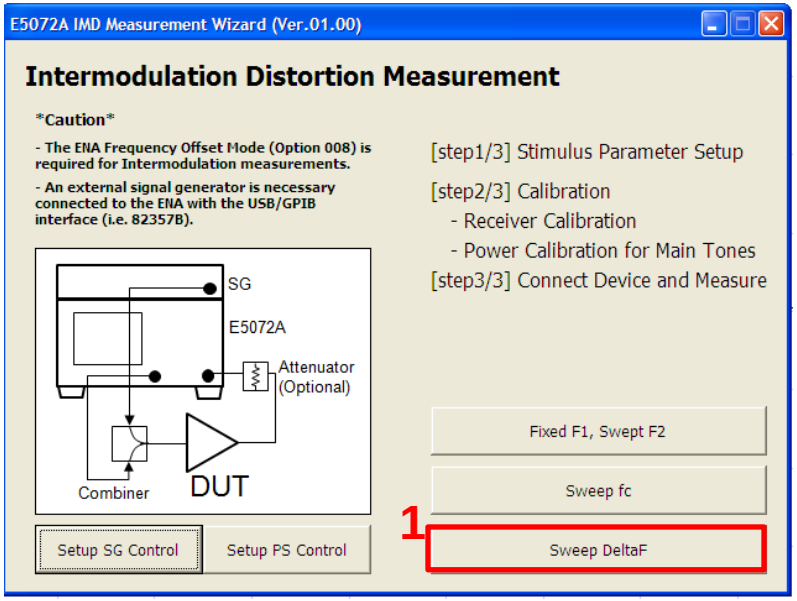
1. Press "**Sweep fc**"
   - Center frequency of the main tones is swept in the frequency range, while the delta frequency is fixed.

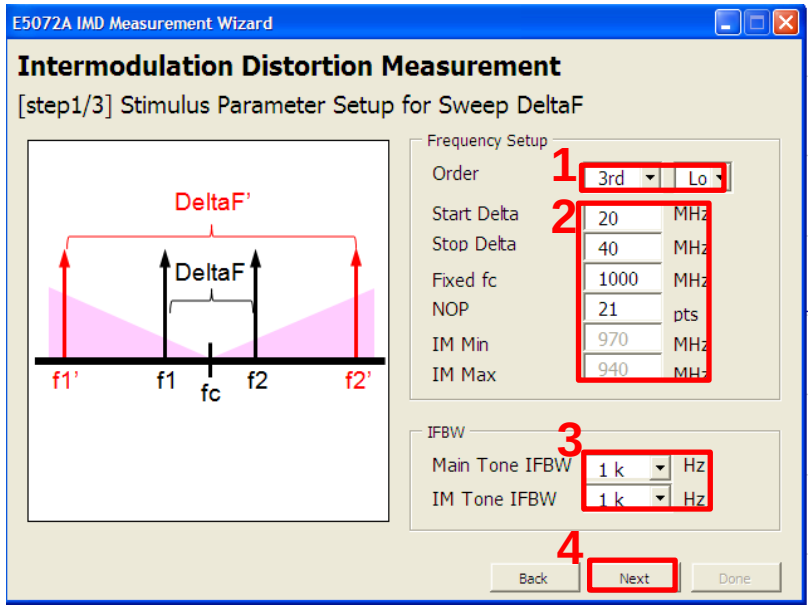
1. Select IM order (3rd, 5th, or 7th), Hi-side or Low-side.
2. Enter center frequency (fc), delta frequency (DeltaF), and NOP
3. Select IFBW for main tones & IM tone
4. Press "Next"

Operation Manual

2. Setup measurement parameters

3. Sweep DeltaF



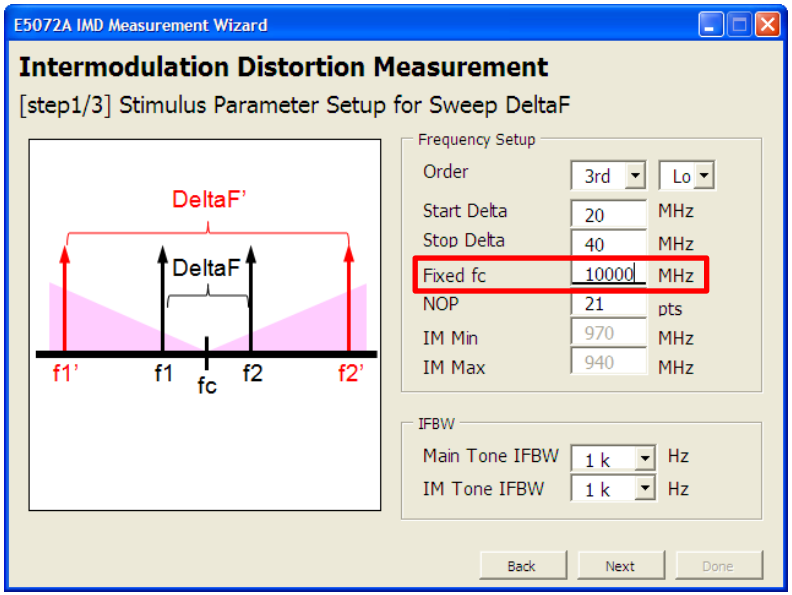


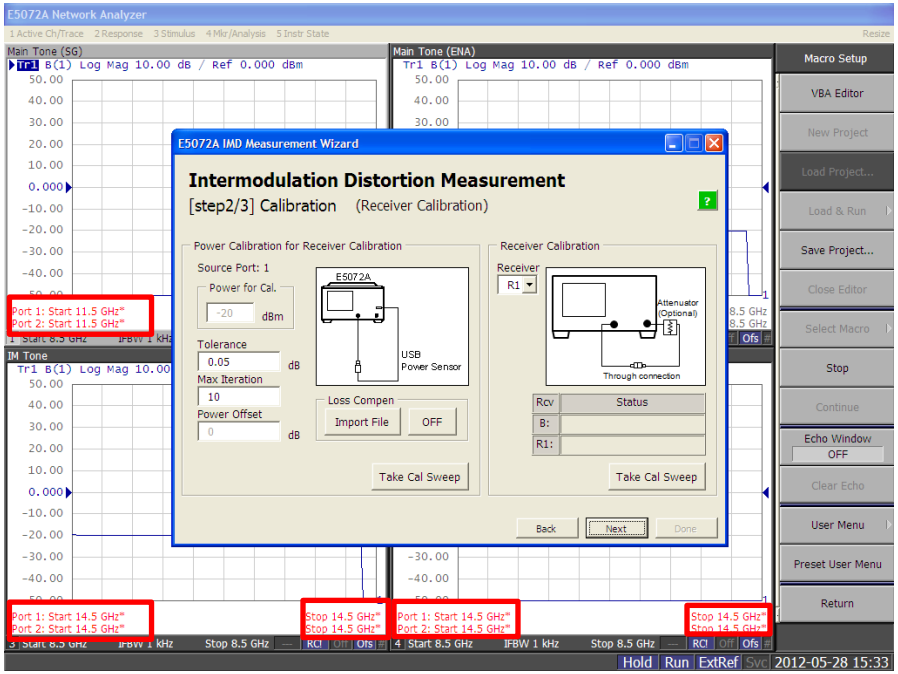
1. Press "**Sweep DeltaF**"
   - Delta frequency between the two main tones is swept in the frequency range, while the center frequency is fixed.

1. Select IM order (3rd, 5th, or 7th), Hi-side or Low-side.
2. Enter center frequency (fc), delta frequency (DeltaF), and NOP
3. Select IFBW for main tones & IM tone.
4. Press "Next"

Operation Manual

2. Setup measurement parameters (Error: Frequency out of range)



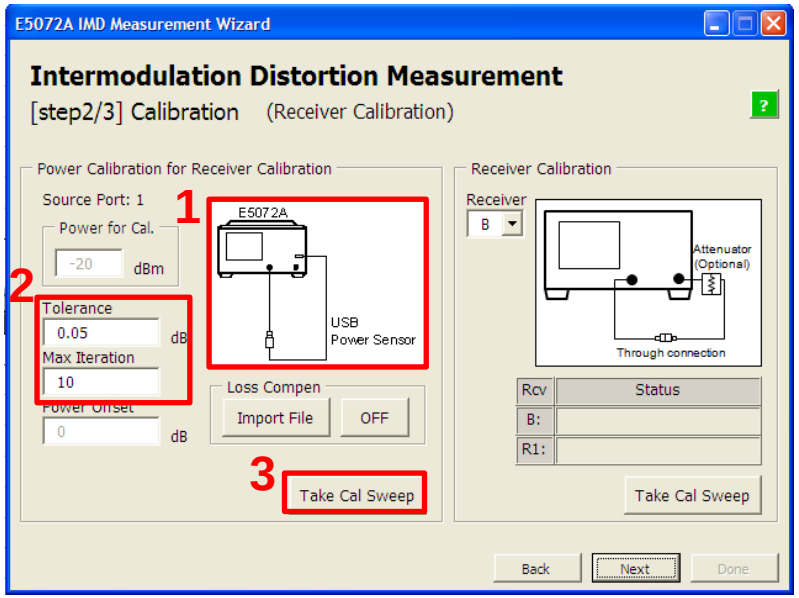


- When the entered frequency value is out of the specification of the E5072A, the frequency is highlighted in red in the measurement channels.
- In this case, it is necessary to reenter the correct frequency range in the stimulus parameter setup.

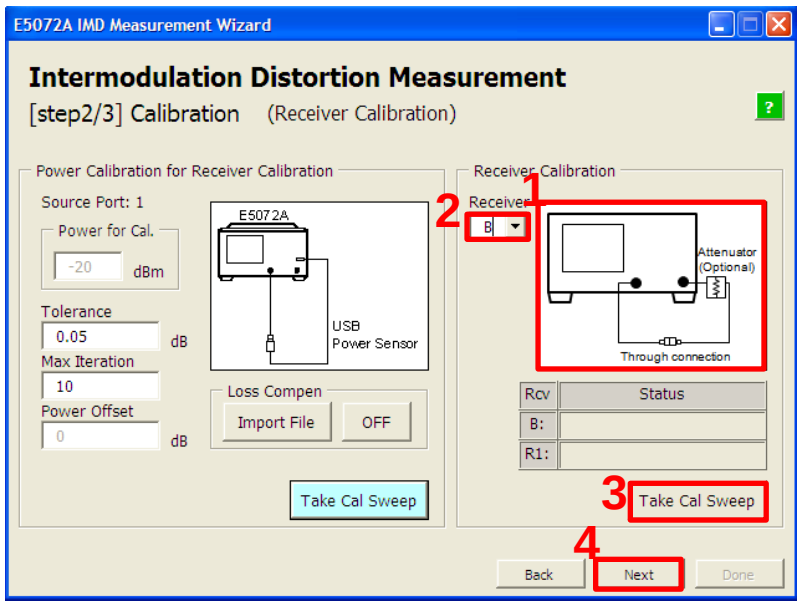
Operation Manual

3. Perform calibration (Receiver cal)

Note: Power calibration is recommended before receiver calibration to characterize the E5072A's receivers with calibrated source power for accurate absolute measurements.



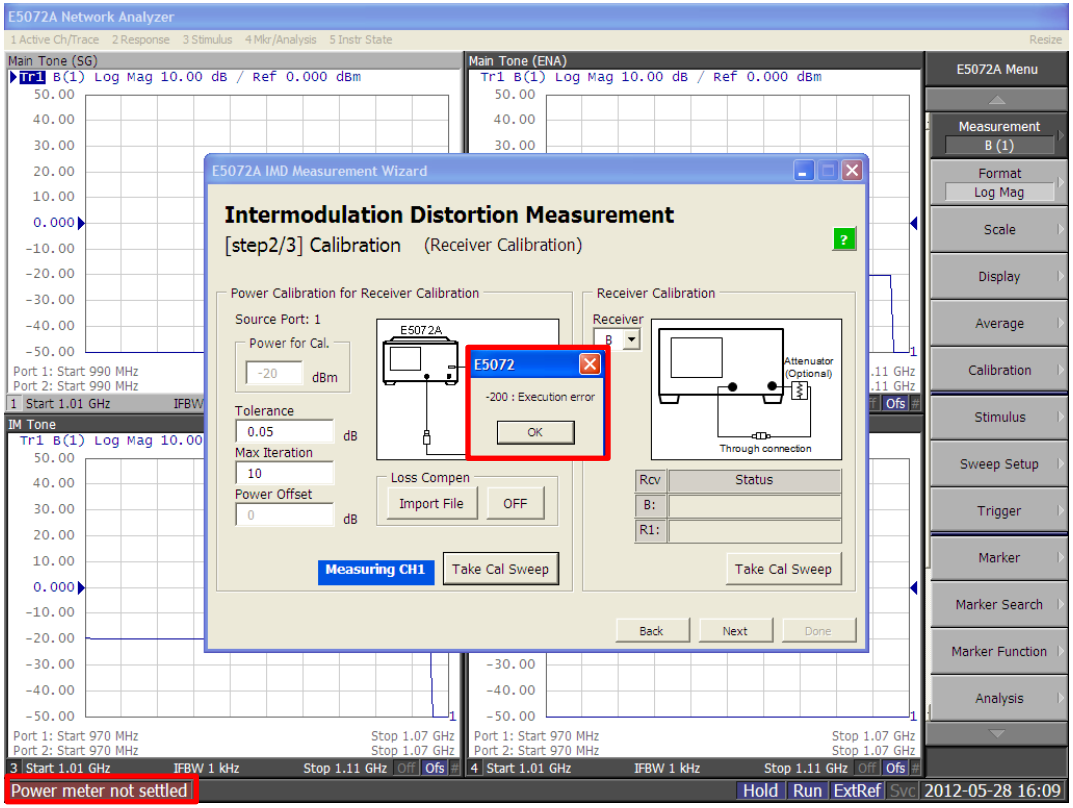
1. Connect the power sensor to the E5072A's port 1
2. Enter Tolerance and Max Iteration for power calibration
   - Measurement sweep of power calibration is continued until the power is adjusted within the accuracy tolerance or maximum iteration is met.
3. Press "Take Cal Sweep"
   - Power calibration is performed for the channel 1,2 and 3 respectively. The button is highlighted in blue after the calibration is completed.



1. Connect the E5072A's port 1 and port 2 with a thru adapter
2. Select Receiver "B"
3. Press "Take Cal Sweep"
   - The button is highlighted in blue and "Corrected" is shown in the status cell after the calibration is completed.
4. Press "Next"

Operation Manual

3. Perform calibration (Error: Power meter not settled)

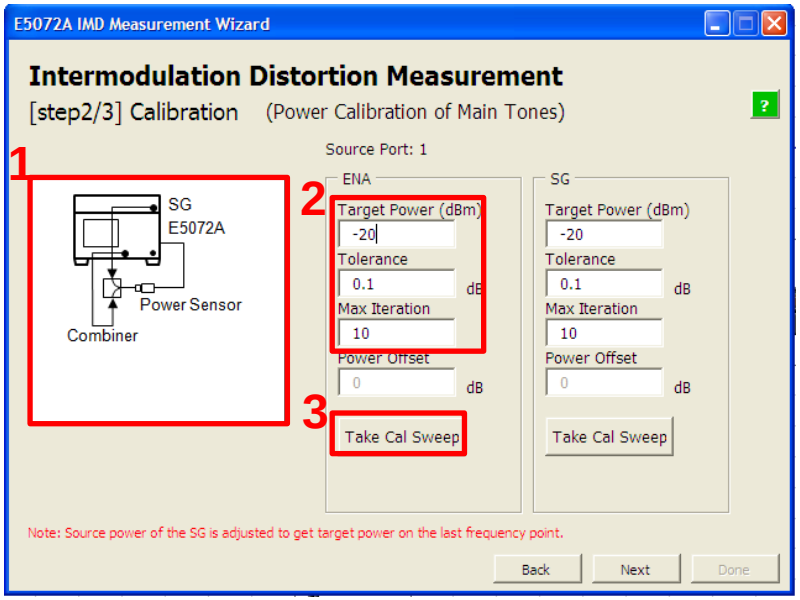


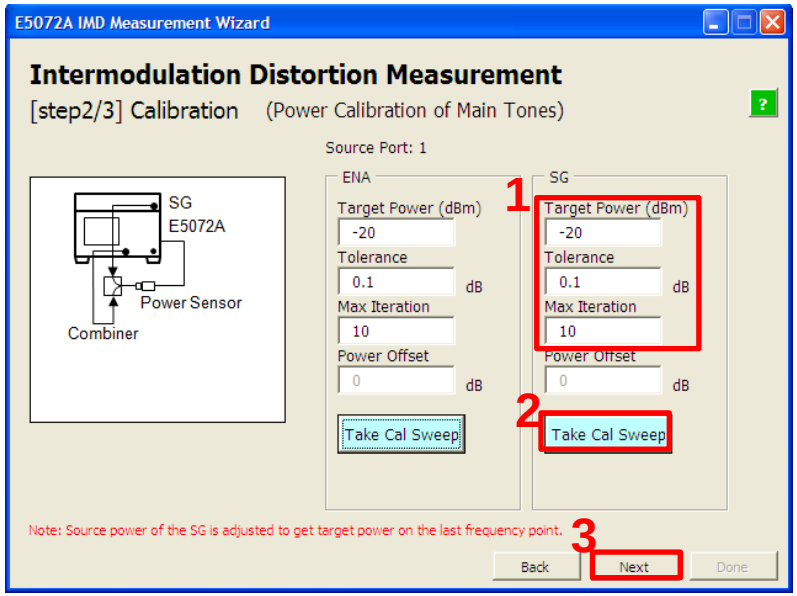
- When the power sensor is NOT connected to the E5072A's port 1, the error message, "-200: Execution error" and "Power meter not settled" are displayed. The power calibration is aborted automatically.

Operation Manual

3. Perform calibration (Power cal for main tones)

Power calibration is performed for the main tones from the ENA and SG to ensure accurate power levels at the DUT's input. Different power levels can be set for the frequency ranges.



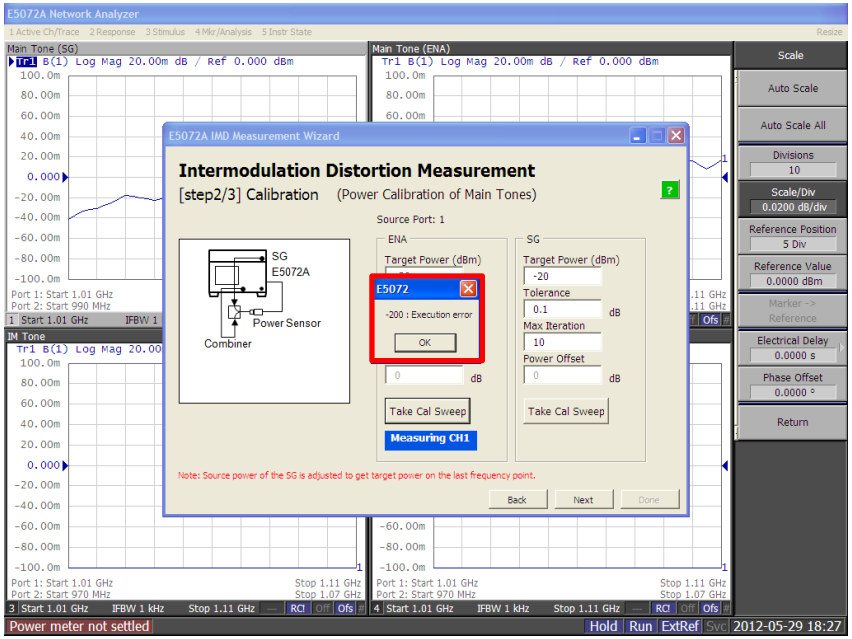


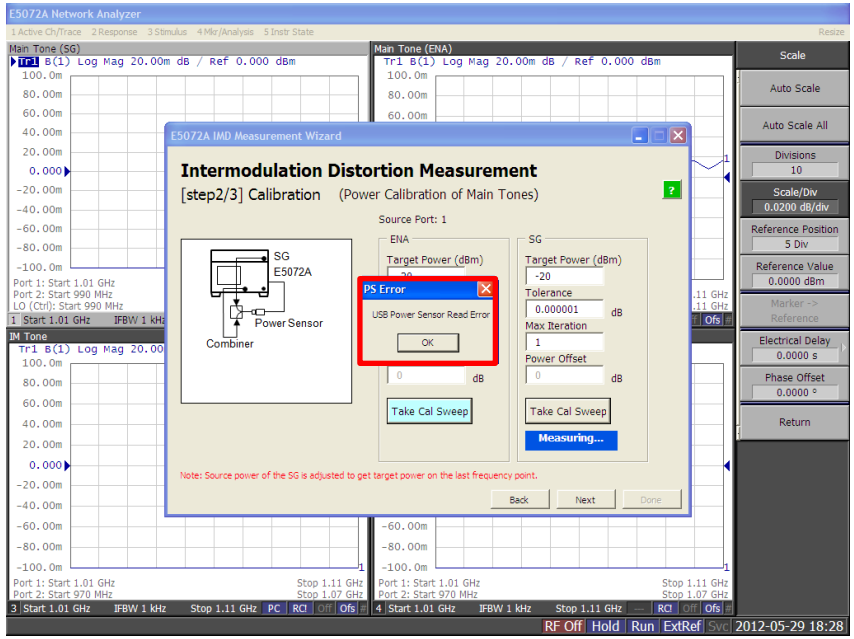
1. Connect the combiner / E5072A / SG / power sensor
2. Enter Target power, Tolerance, and Max Iteration for power calibration of the main tone from the E5072A
3. Press "Take Cal Sweep"
   - The button is highlighted in blue after the calibration is completed.

1. Enter Target power, Tolerance, and Max Iteration for power calibration of the main tone from the SG
2. Press "Take Cal Sweep"
   - Note power calibration for the SG is performed only for the last frequency point.
   - The button is highlighted in blue after the calibration is completed.
3. Press "Next"

Operation Manual

3. Perform calibration (Error - Power can not be adjusted)

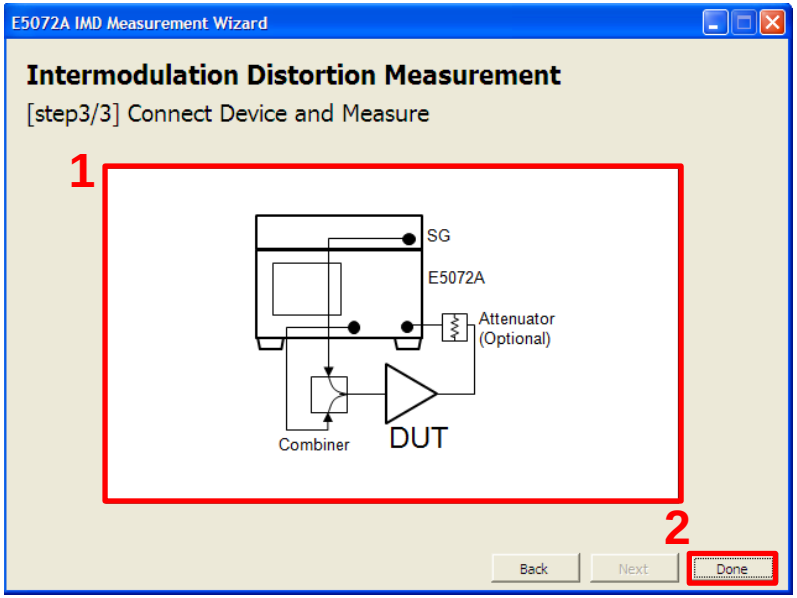




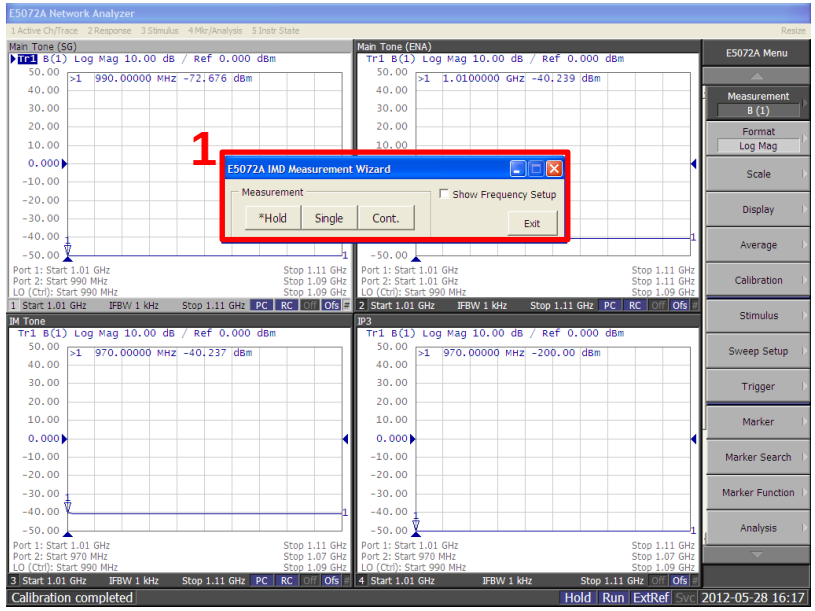
- When the power level can not be adjusted within the accuracy tolerance during power calibration, the error message will be displayed. In this case, it is necessary to set the wider tolerance for the target power level.

Operation Manual

4. Connect DUT and perform measurement



1. Connect the DUT
2. Press “Done”
   - All the necessary setup is done and ready to measure IMD of the DUT.



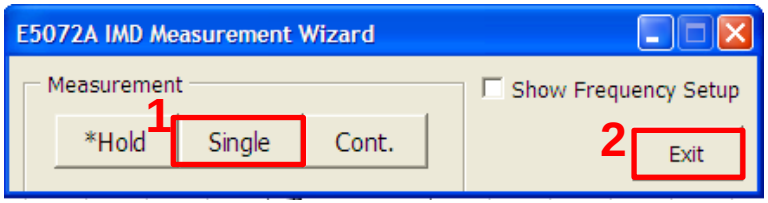
1. Measurement window is displayed on the E5072A screen.

Agilent Technologies

Operation Manual

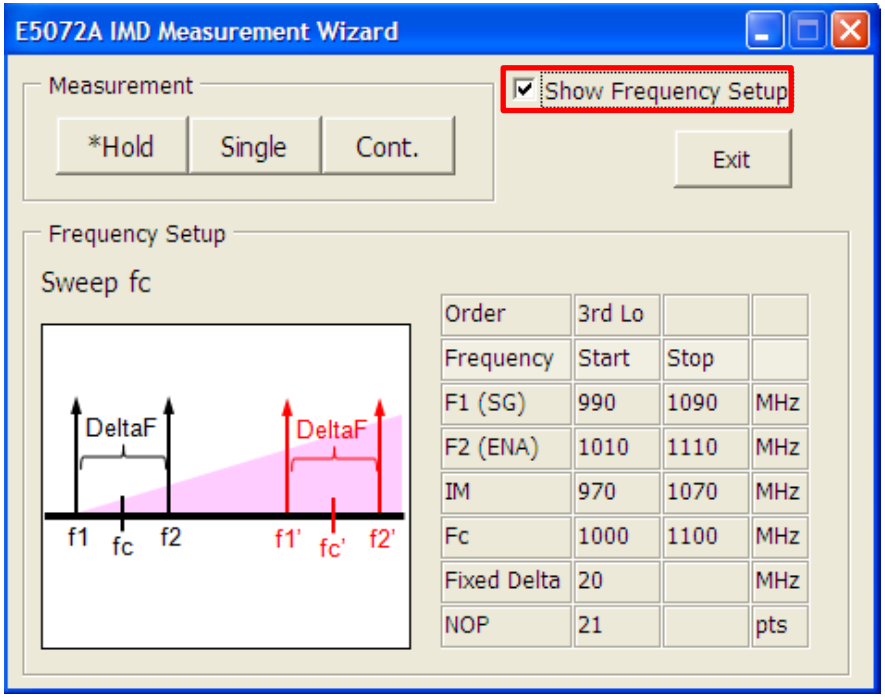
4. Connect DUT and perform measurement

Measurement window



1. Press “Single” to trigger measurement once
   - Press “Cont.” to perform continuous sweep measurements and press “*Hold” to hold measurements.
2. Press “Exit” to exit the program

Measurement window (with frequency information)

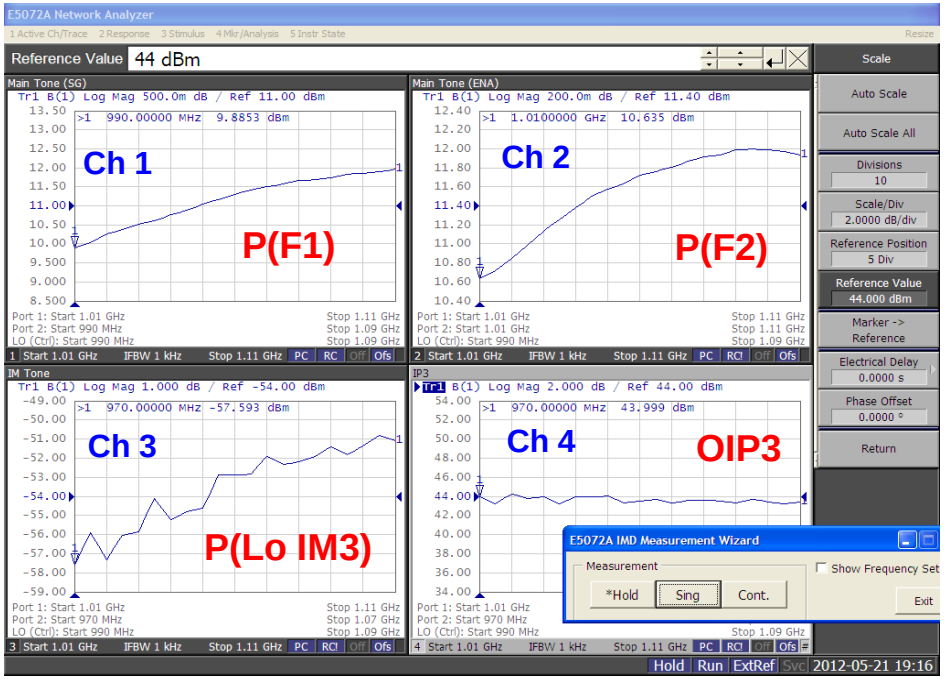


- When “Show Frequency Setup” box is checked, the frequency range of main tones and IM product is displayed.

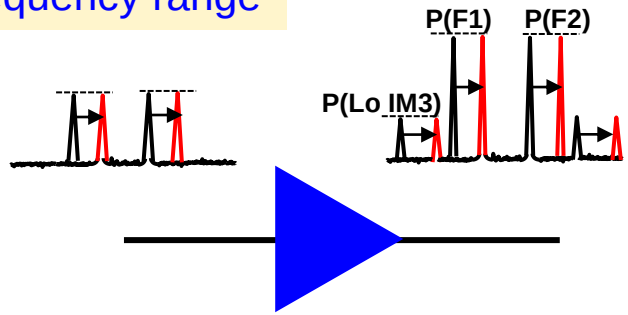
Operation Manual

4. Connect DUT and perform measurement

Measurement result (Sweep fc)

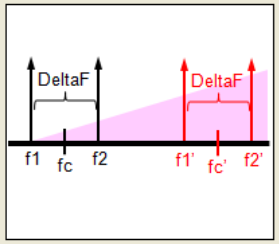


Frequency range



Frequency Setup

Sweep fc



Order	3rd Lo		
Frequency	Start	Stop	
F1 (SG)	990	1090	MHz
F2 (ENA)	1010	1110	MHz
IM	970	1070	MHz
Fc	1000	1100	MHz
Fixed Delta	20		MHz
NOP	21		pts

Ch 1: P(F1) Output power of main tone frequency from SG (in dBm)
Ch 2: P(F2) Output power of main tone frequency from E5072A (in dBm)
Ch 3: P(IM) Power of IM product (in dBm)
Ch 4: OIP3 Calculated OIP3 (in dBm)

IP3 (dBm) = P(F1) + (P(F2) - P(2*F1-F2)) / 2
IP3 (dBm) = P(F2) + (P(F1) - P(2*F2-F1)) / 2

•Output power of main tones and IM product is measured by the absolute measurement using the E5072A's receiver B.
• Output-referred IP3 (OIP3) is calculated and displayed in the channel 4 of the E5072A.

Measurement Examples

DUT for Demo

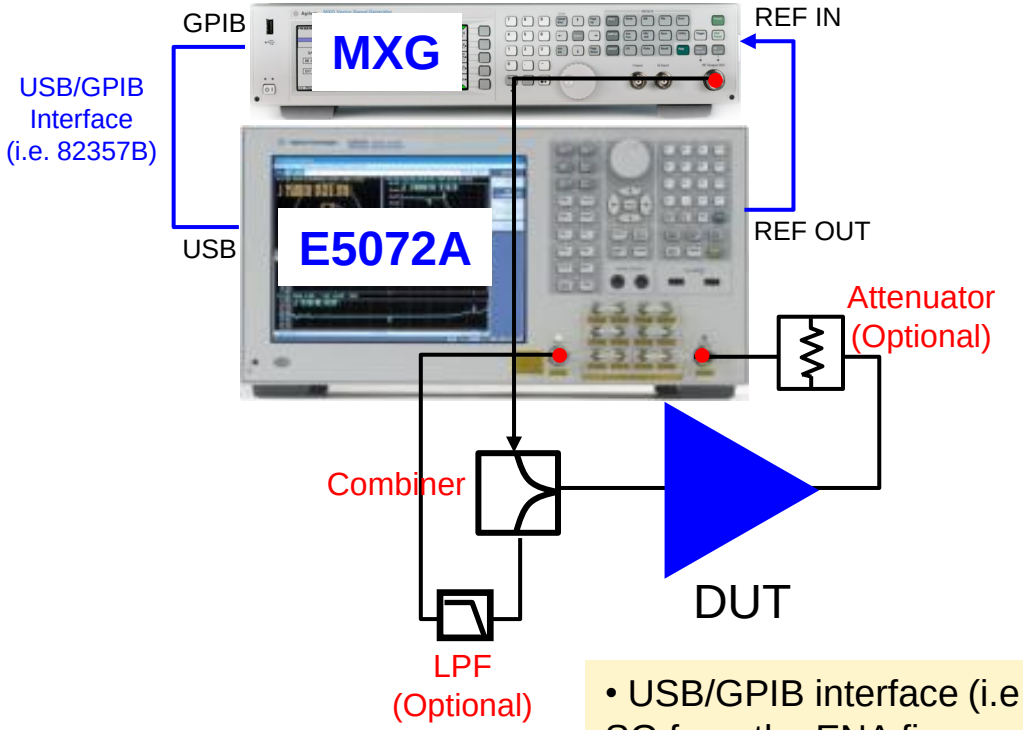
- DUT: The amplifier included in the E5072A's demo kit is used for measurements.
  Mini-Circuits: ZRL-2400LN+ (Agilent P/N: 0955-2330)
  *Data sheet is available at: http://www.minicircuits.com/pdfs/ZRL-2400LN.pdf

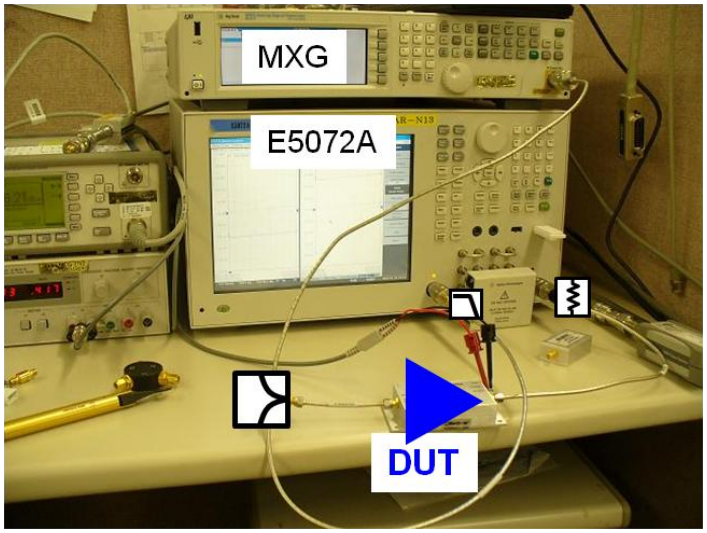
S-parameters:
500 M to 6 GHz, IFBW = 1 kHz, Power level = -30 dBm, Full 2-port Cal

Test Configuration 1

Using the external combiner

Configuration - Test setup

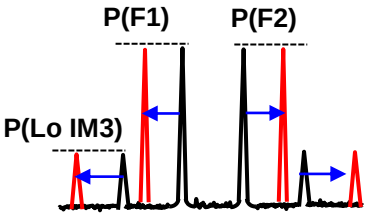




- USB/GPIB interface (i.e. Agilent 82357B) is necessary to control the SG from the ENA firmware.
- 10 MHz reference is connected between the instruments.
- A low-loss and high-isolation combiner is recommended.
- An optional LPF is needed to eliminate source harmonics from the ENA.
- An optional attenuator is needed to protect ENA's receiver.

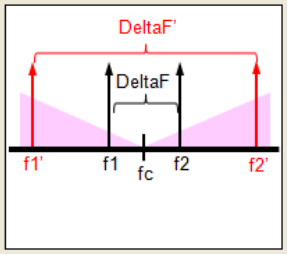
Measurement Example

E5072A Receiver IP3



Frequency Setup

Sweep DeltaF

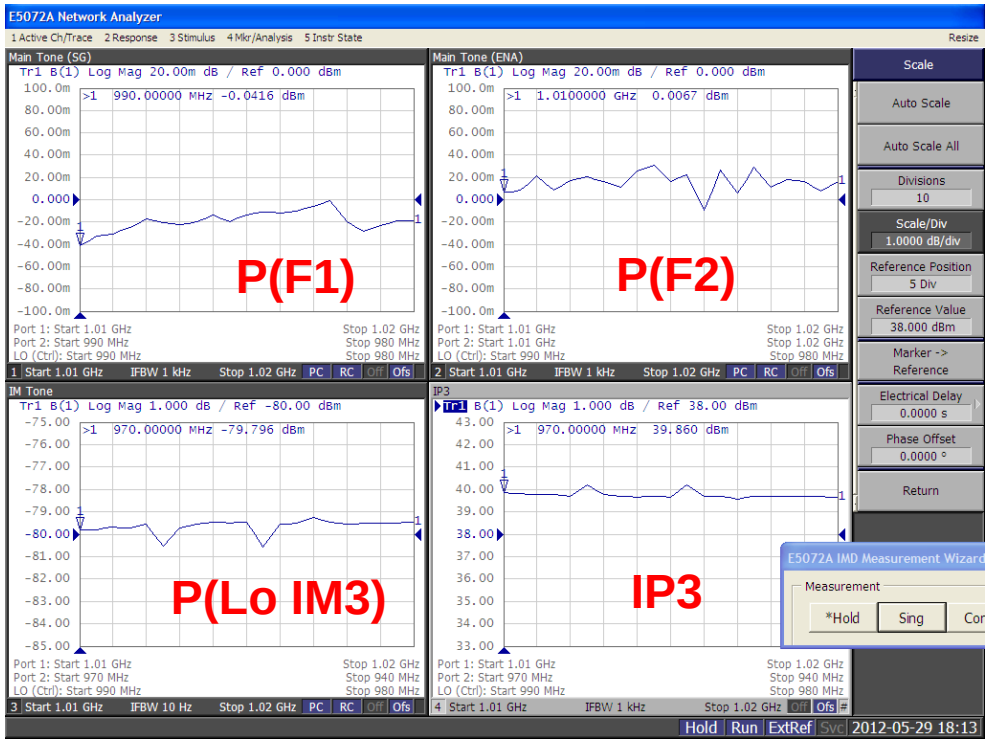


Order	3rd Lo		
Frequency	Start	Stop	
F1 (SG)	990	980	MHz
F2 (ENA)	1010	1020	MHz
IM	970	940	MHz
Delta	20	40	MHz
Fixed Fc	1000		MHz
NOP	21		pts

Measurement result (Sweep DeltaF)

DUT: Thru. Pin (F1) = Pin (F2) = 0 dBm, IFBW = 10 Hz

Ch 1:
Pout (@ Main tone frequency from SG, in dBm)



Ch 2:
Pout (@ Main tone frequency from ENA, in dBm)

Ch 3:
Power of IM product (@ Lo IM3, in dBm)

Ch 4:
Calculated IP3 (in dBm)

IP3 (dBm) = P(F1) + (P(F2) - P(2*F1-F2)) / 2

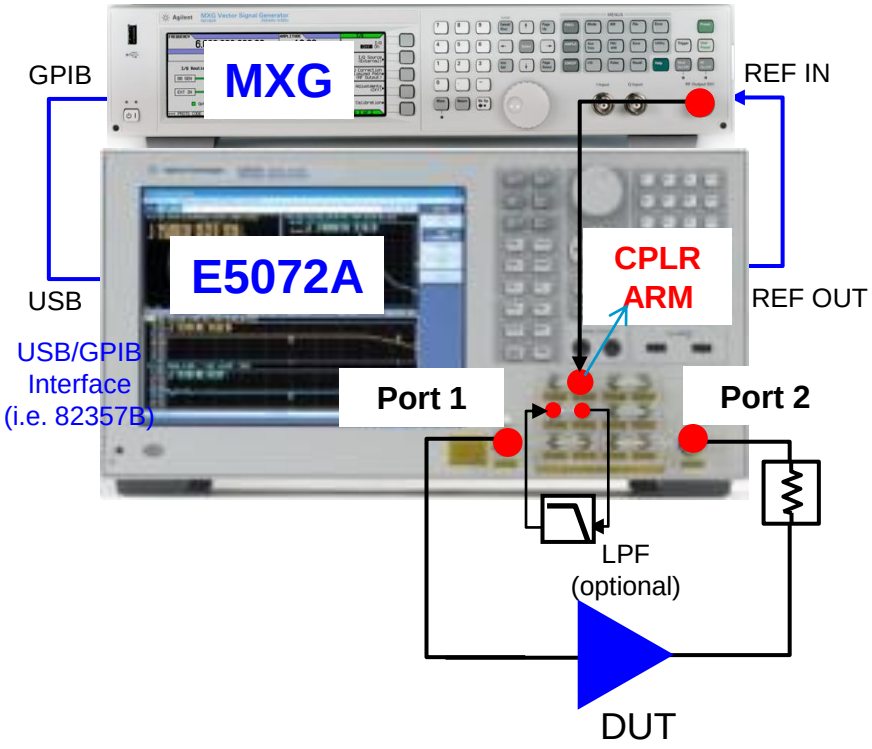
- The E5072A receiver's IP3 can be determined by connecting a thru adapter between the port 1 and port 2, injecting a two-tone stimulus and measuring the power of the two tones and the 3rd IM product.
- The receiver IP3 is approx. +40 dBm in the frequency range.

Test Configuration 2

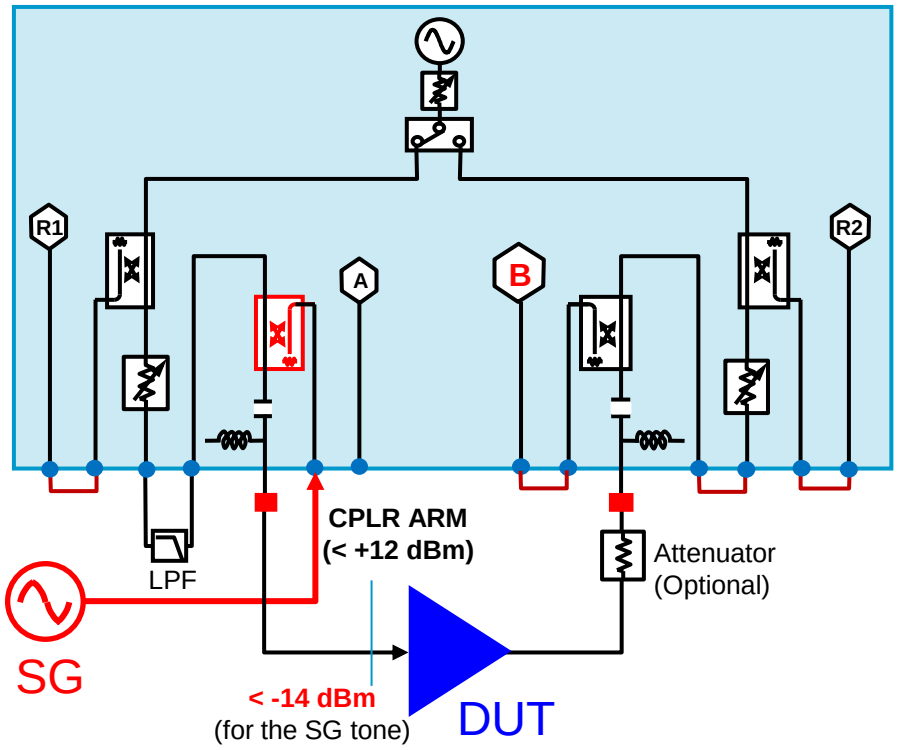
Using the internal bridge as a combiner

- The E5072A's internal bridge can be used as a combiner for two-tones.
- No external combiner is required in the test setup.

Configuration - Test setup

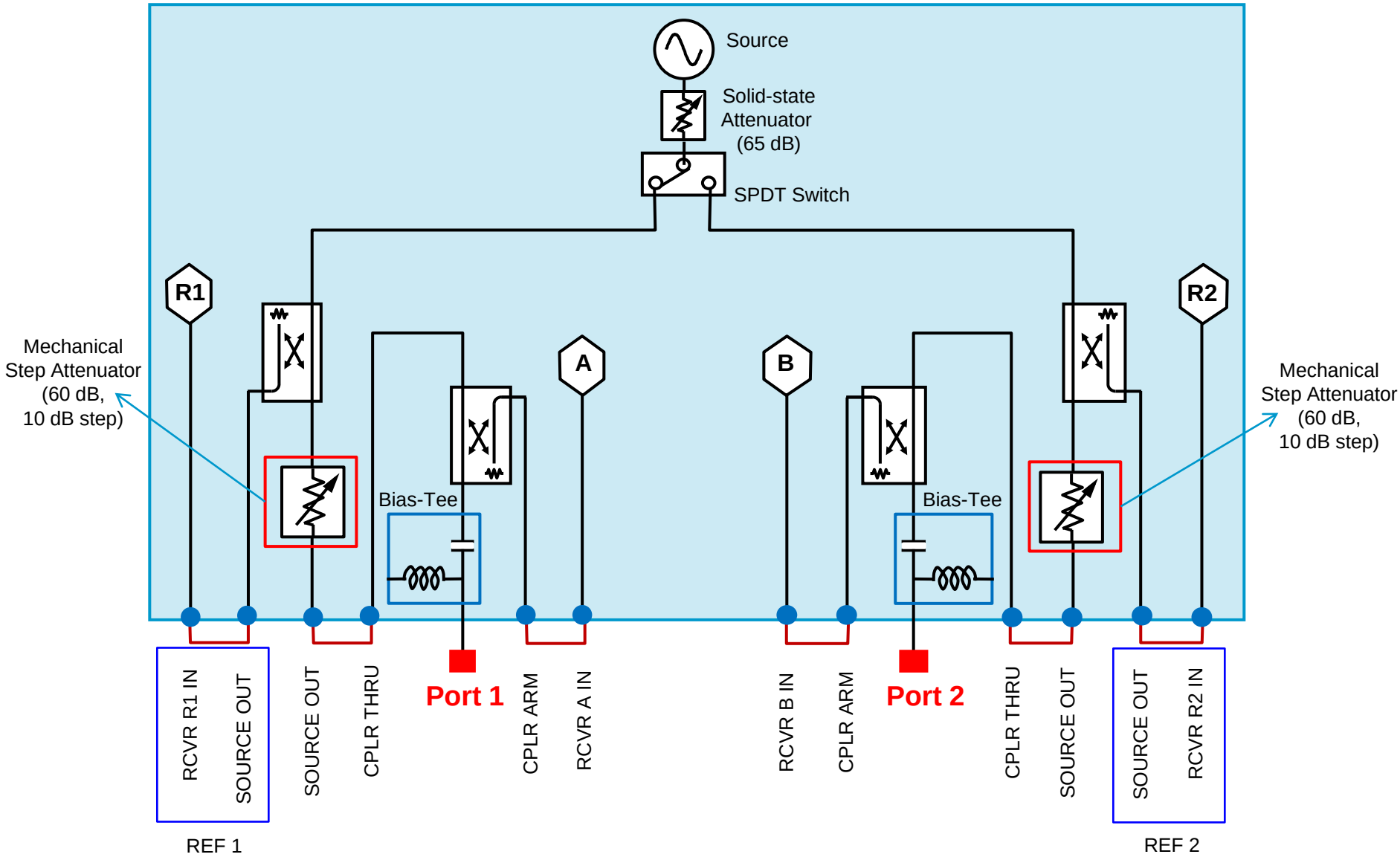


E5072A Block Diagram



- Input power at the port ("CPLR ARM") should be at least below +12 dBm as the damage level of the input is +15 dBm.
- Input power at the DUT is **below -14 dBm** for the main tone from the SG due to the coupling factor (i.e. 26 dB) of the E5072A's internal bridge.

E5072A Block Diagram

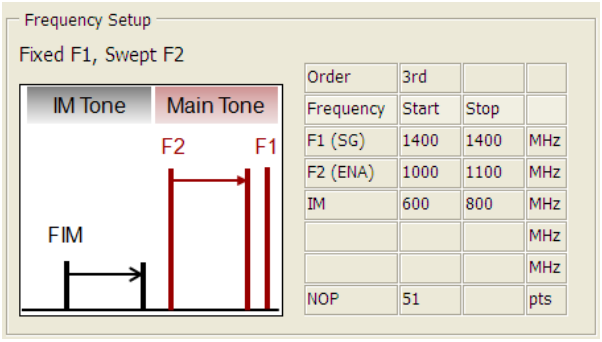


Measurement Example

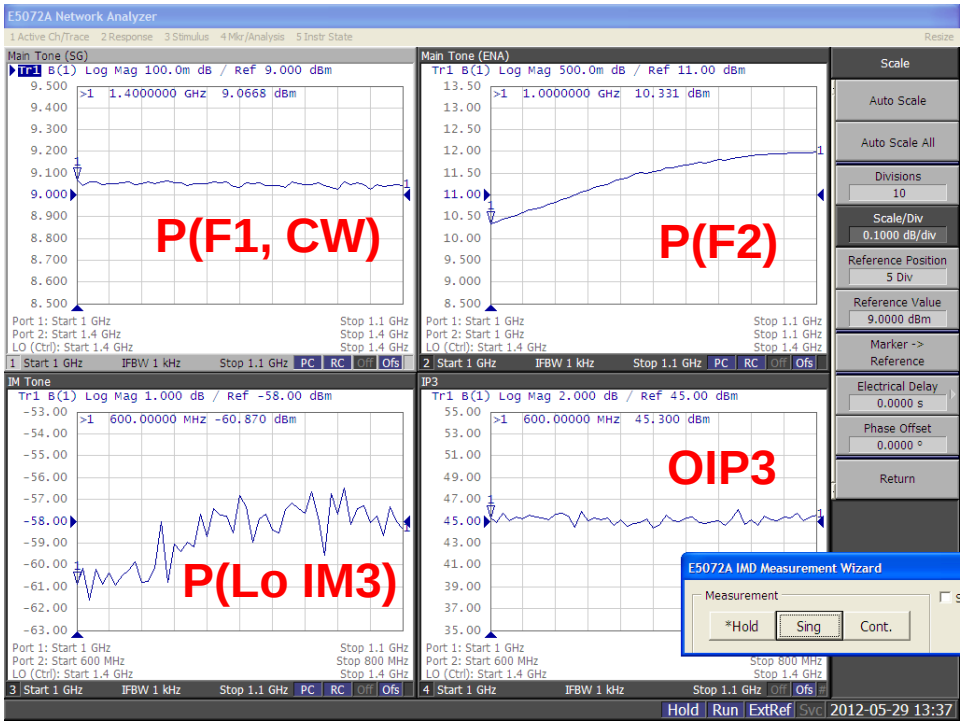
Using the internal bridge

Measurement result (fixed F1, swept F2)

DUT: RF amp. Pin (F1) = Pin (F2) = -20 dBm, IFBW = 1 kHz



Ch 1:
Pout (@ Main tone frequency from SG (CW), in dBm)



Ch 2:
Pout (@ Main tone frequency from ENA, in dBm)

Ch 3:
Power of IM product (@ Lo IM3, in dBm)

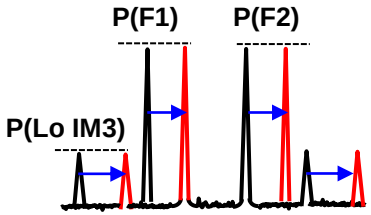
Ch 4:
Calculated OIP3 (in dBm)

IP3 (dBm) = P(F2) + (P(F1) - P(2*F2-F1)) / 2

• Output power of the main tones and IM power level is displayed to calculate output IP3 of the DUT.

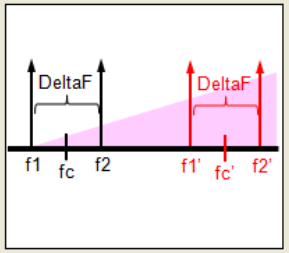
Measurement Example

Using the internal bridge



Frequency Setup

Sweep fc

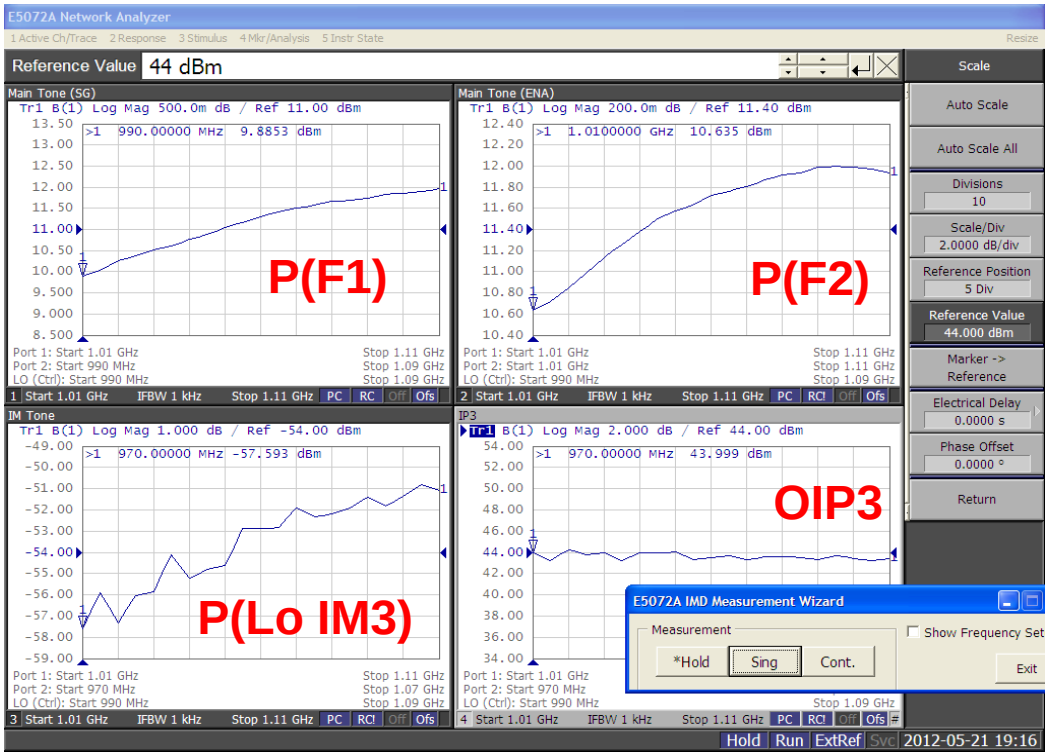


Order	3rd Lo		
Frequency	Start	Stop	
F1 (SG)	990	1090	MHz
F2 (ENA)	1010	1110	MHz
IM	970	1070	MHz
Fc	1000	1100	MHz
Fixed Delta	20		MHz
NOP	21		pts

Measurement result (Sweep fc)

DUT: RF amp. Pin (F1) = Pin (F2) = -20 dBm, IFBW = 1 kHz

Ch 1:
Pout (@ Main tone frequency from SG, in dBm)



Ch 2:
Pout (@ Main tone frequency from ENA, in dBm)

Ch 3:
Power of IM product (@ Lo IM3, in dBm)

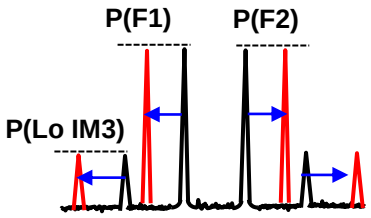
Ch 4:
Calculated OIP3 (in dBm)

IP3 (dBm) = P(F1) + (P(F2) - P(2*F1-F2)) / 2

• Output power of the main tones and IM power level is displayed to calculate output IP3 of the DUT.

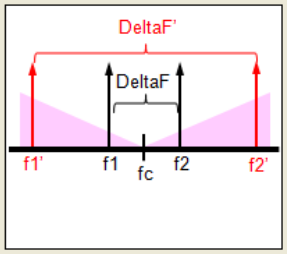
Measurement Example

Using the internal bridge



Frequency Setup

Sweep DeltaF

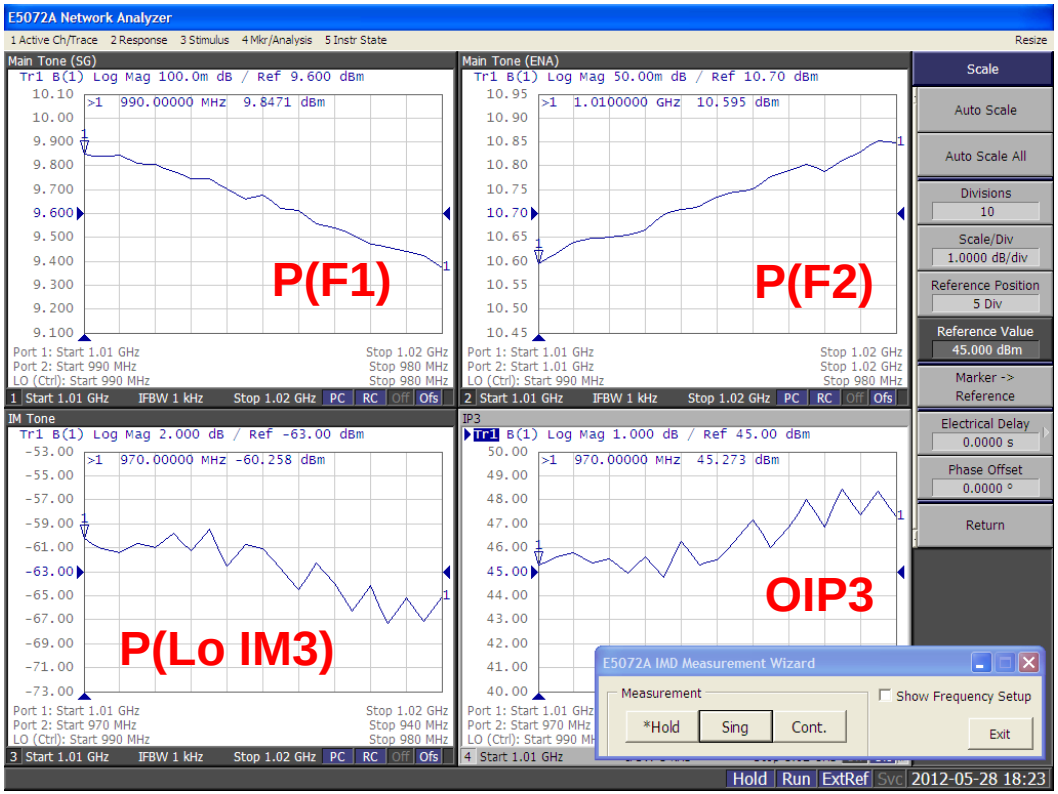


Order	3rd Lo		
Frequency	Start	Stop	
F1 (SG)	990	980	MHz
F2 (ENA)	1010	1020	MHz
IM	970	940	MHz
Delta	20	40	MHz
Fixed Fc	1000		MHz
NOP	21		pts

Measurement result (Sweep DeltaF)

DUT: RF amp. Pin (F1) = Pin (F2) = -20 dBm, IFBW = 1 kHz

Ch 1:
Pout (@ Main tone frequency from SG, in dBm)



Ch 2:
Pout (@ Main tone frequency from ENA, in dBm)

Ch 3:
Power of IM product (@ Lo IM3, in dBm)

Ch 4:
Calculated OIP3 (in dBm)

IP3 (dBm) = P(F1) + (P(F2) - P(2*F1-F2)) / 2

- Output power of the main tones and IM power level is displayed to calculate output IP3 of the DUT.

Resources

- Configuration Guide (5990-8001EN)
- Data Sheet (5990-8002EN)
- Quick Fact Sheet (5990-8003EN)
- Technical Overview (5990-8004EN)
- Application Note
  - High-power measurement using the E5072A (5990-8005EN)
  - Basics of RF amplifier measurements with the E5072A (5990-9974EN)

- ENA Series: www.agilent.com/find/ena
- E5072A Product page: www.agilent.com/find/e5072a