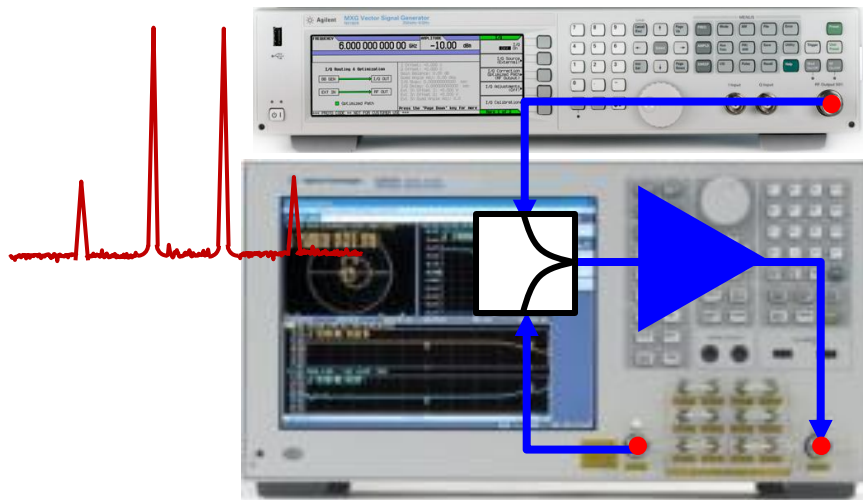


# IMD Measurement with E5072A ENA Series Network Analyzer



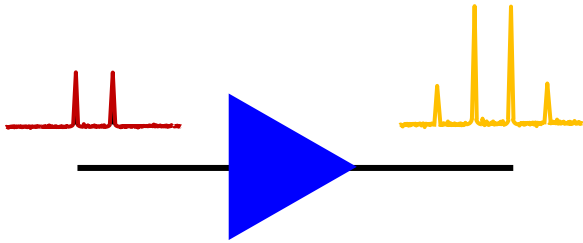
Agilent Technologies  
June 2012

# Contents

- What is intermodulation distortion (IMD)?
- IMD Measurement Wizard for E5072A
- Measurement Results
- Summary

# What is intermodulation distortion (IMD)?

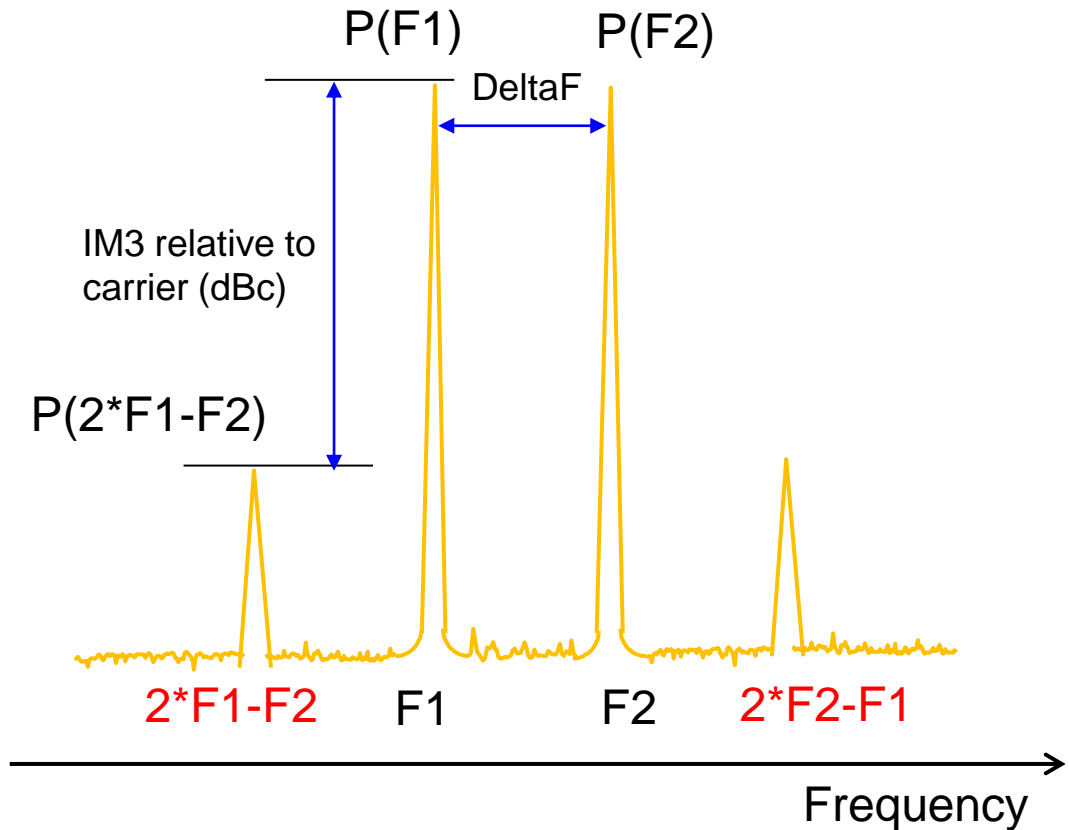
- A measure of nonlinearity of amplifiers.
- Two or more tones applied to an amplifier and produce additional intermodulation products.
- The DUT's output will contain signals at the frequencies:  $n \cdot F1 + m \cdot F2$ .



$$F_{\text{IMD}} = n \cdot F1 + m \cdot F2$$

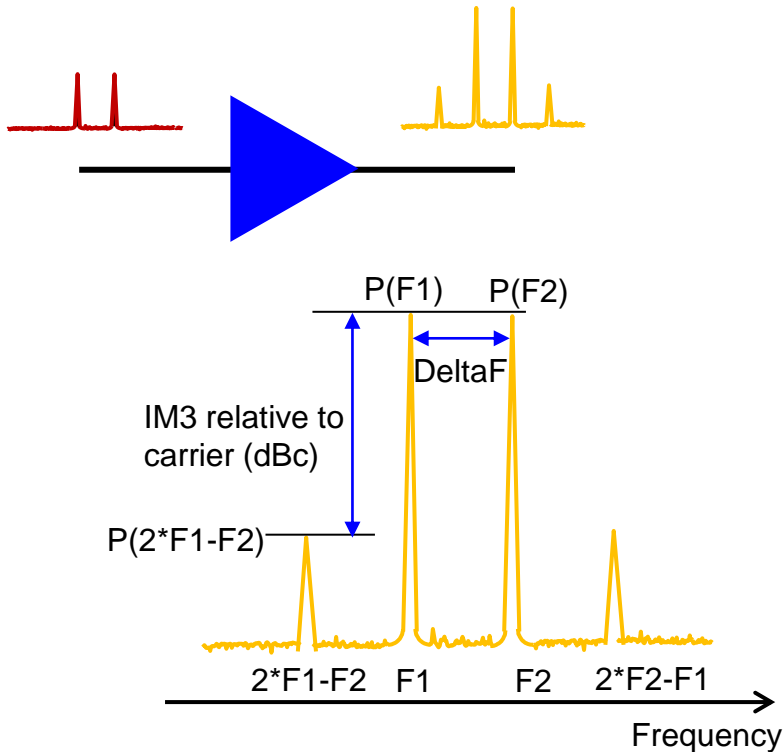
ex.)

- Lo  $F_{\text{IM3}} = 2 \cdot F1 - F2$
- Hi  $F_{\text{IM3}} = 2 \cdot F2 - F1$
- Lo  $F_{\text{IM5}} = 3 \cdot F1 - 2 \cdot F2$
- Hi  $F_{\text{IM5}} = 3 \cdot F2 - 2 \cdot F1$
- Lo  $F_{\text{IM7}} = 4 \cdot F1 - 3 \cdot F2$
- Hi  $F_{\text{IM7}} = 4 \cdot F2 - 3 \cdot F1$

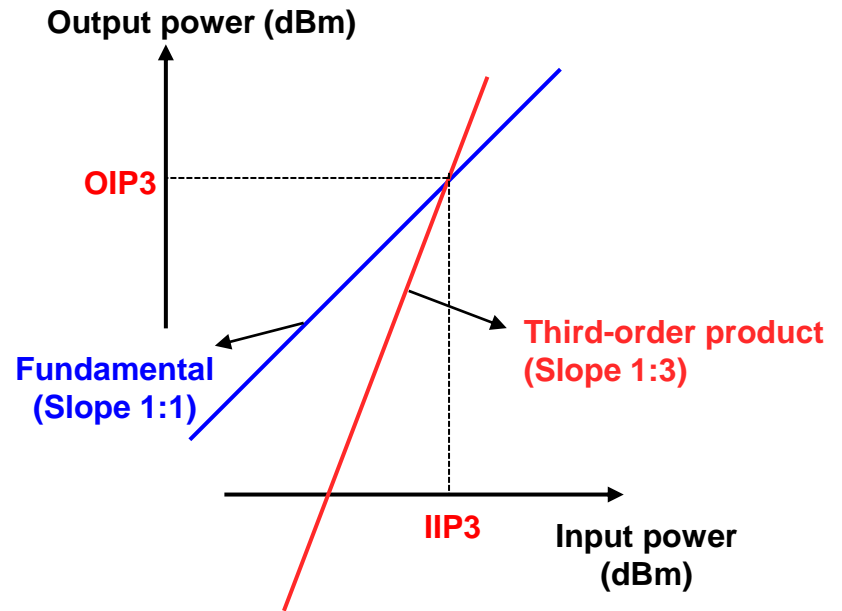


# Third-order Intercept Point (IP3)

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



$P(F_1)$ : Power level of low tone  
 $P(F_2)$ : Power level of high tone  
 $P(2F_1 - F_2)$ : Power level of low-side IM3 signal  
 $P(2F_2 - F_1)$ : Power level of high-side IM3 signal



IP3 can be calculated by the equation using low-side IM3:

$$\text{IP3 (dBm)} = P(F_1) + (P(F_2) - P(2F_1 - F_2)) / 2$$

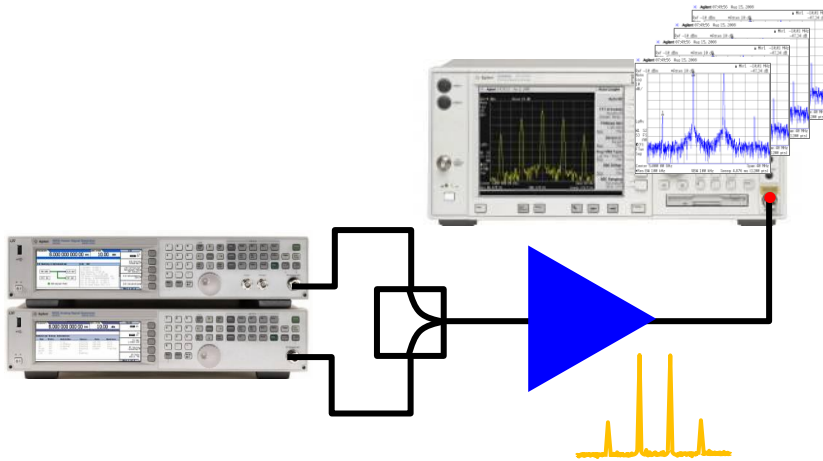
When high-side IM3 is used, the equation is:

$$\text{IP3 (dBm)} = P(F_2) + (P(F_1) - P(2F_2 - F_1)) / 2$$

# Intermodulation Distortion

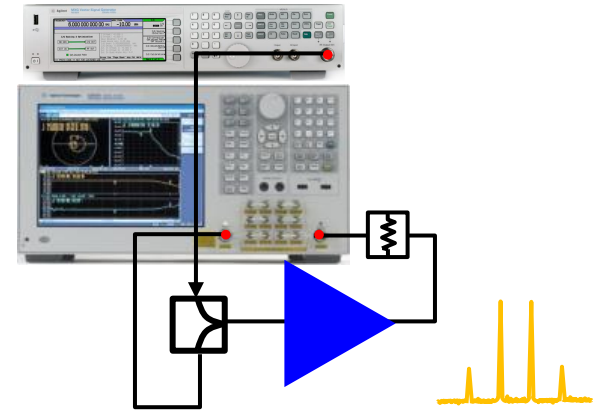
## Solution with ENA

### 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



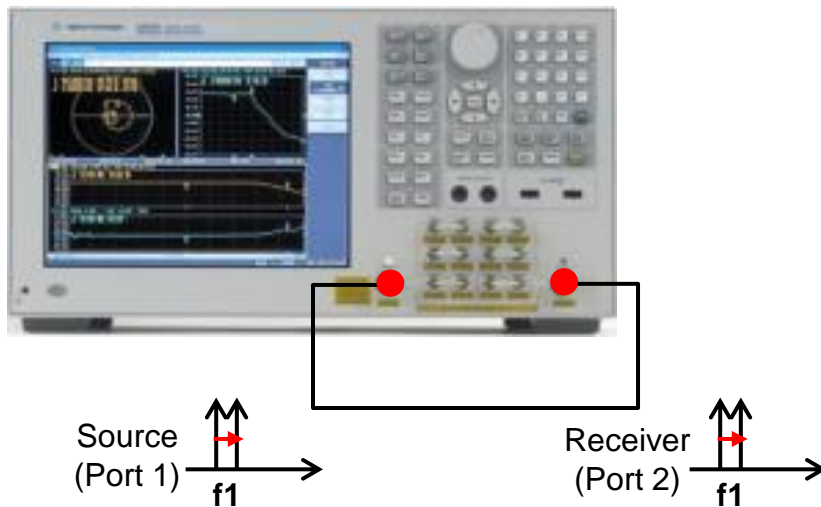
- ENA with **frequency-offset mode (FOM) option** can set different frequencies at the source and receiver.
- **Real-time** swept frequency IMD measurements can be performed.
- Source power calibration and receiver calibration is available with VNA for accurate absolute power measurements.

# VNA features

## Frequency Offset Mode (E5072A Option 008)

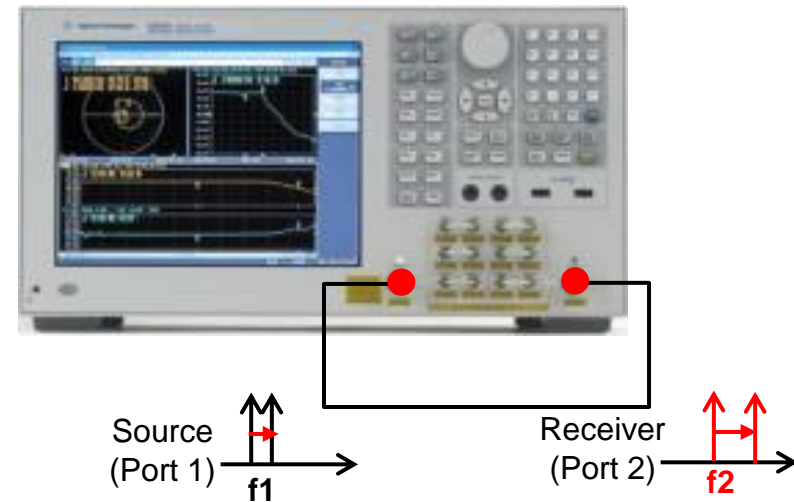
- Sets different frequency range for the source and receivers.
- Can be used for harmonics or intermodulation distortion (IMD) measurements with the VNA.

### Normal Sweep



Source and receiver are tuned at **the same** frequency range. (i.e. S-parameter).

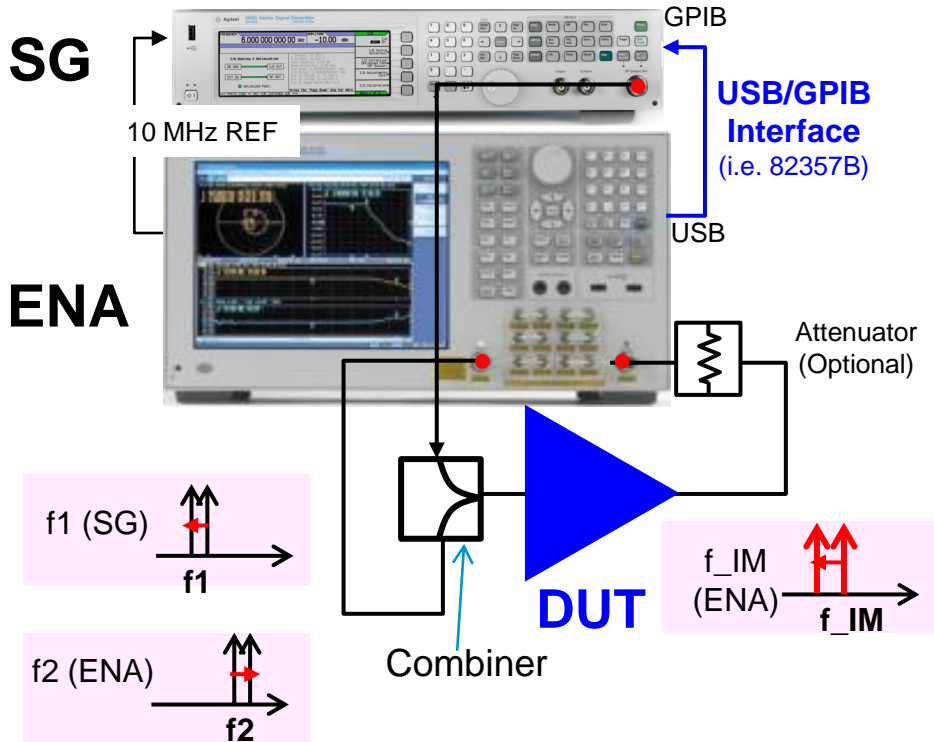
### Frequency-offset Sweep



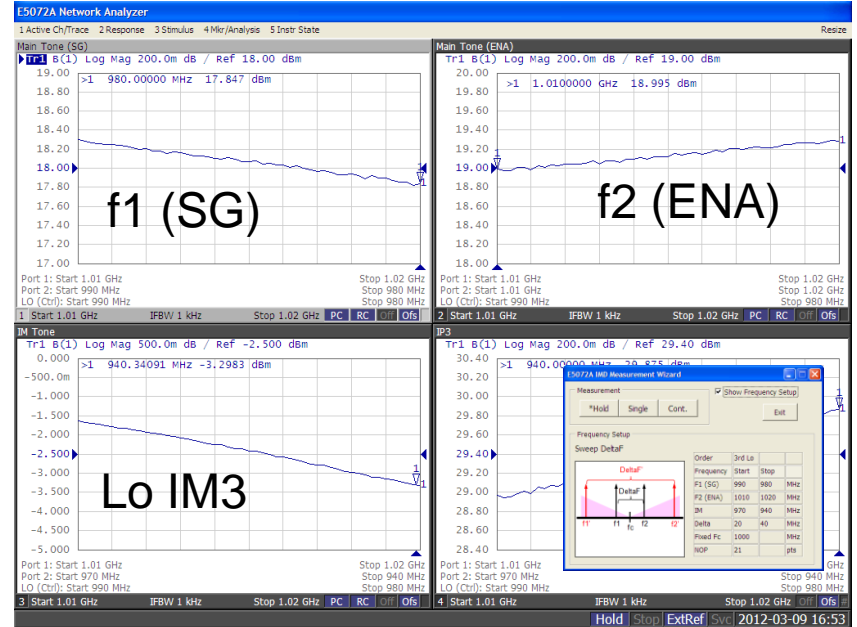
Source and receiver are tuned at the **different** frequency range (for harmonics, IMD test etc.)

# IMD Measurement

## Configuration of IMD measurement with VNA



## Measurement example (sweep delta)

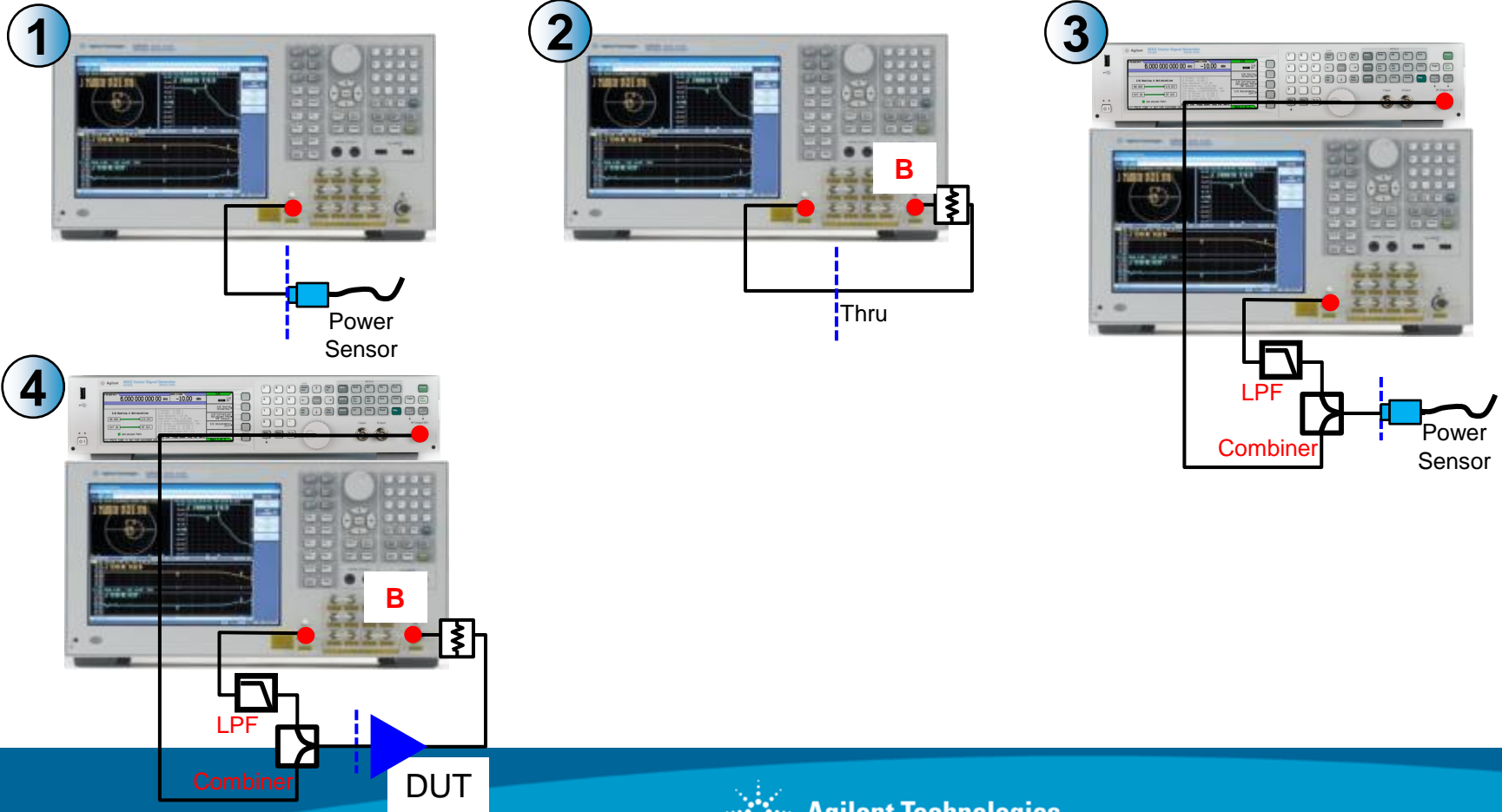


Power levels of main tones and IM products in swept frequencies can be monitored with the VNA's absolute measurements.

# Measurement Procedure

## Power calibrations for IMD measurements

1. Perform source power cal with a connected power sensor. (power cal for receiver cal)
2. Perform receiver cal for the receiver B by connecting thru between port 1 and port 2.
3. Connect external components including a combiner. Perform source power cal for E5072A and SG at the calibration reference (DUT's input).
4. Connect DUT and perform measurements.

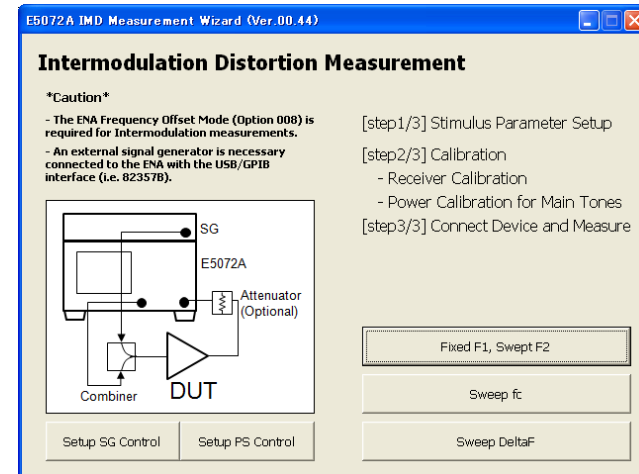




# IMD Measurement Wizard for the E5072A

## 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**
  - **Sweep DeltaF**
- 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)

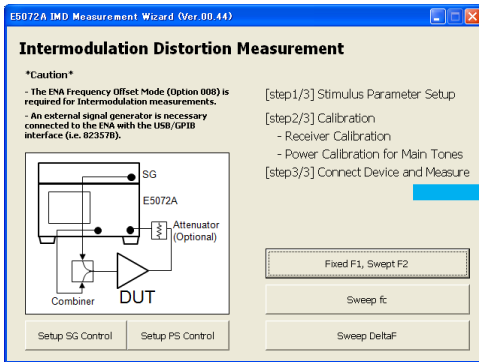


Available at: [www.agilent.com/find/enavba](http://www.agilent.com/find/enavba)

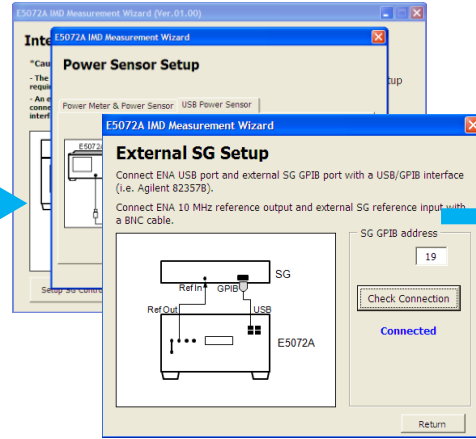
# IMD Measurement Wizard

## Overview

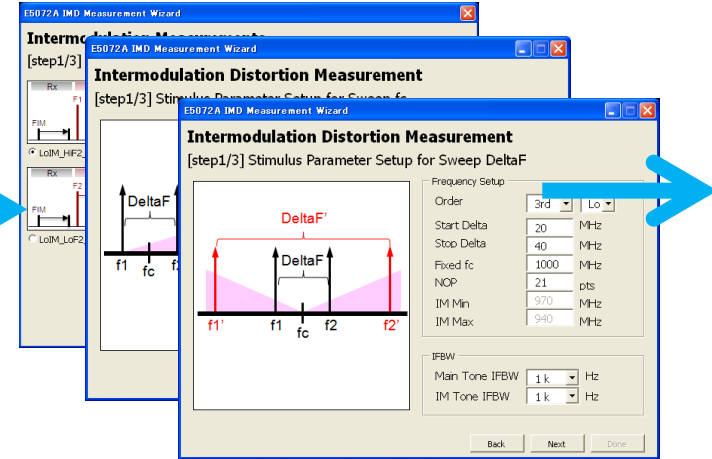
### Introduction



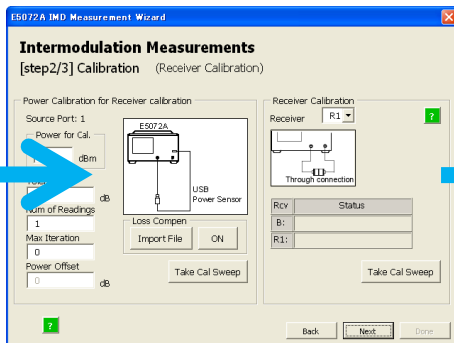
### Peripherals Setup (SG, Power sensor)



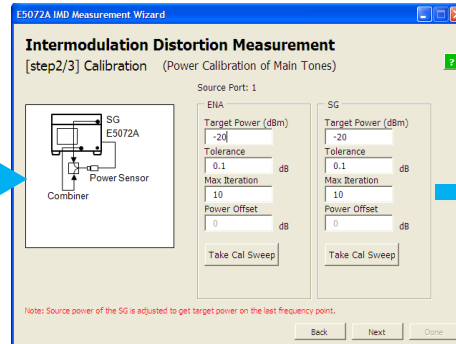
### Stimulus Parameter Setup (IM order, frequency, NOP, IFBW etc.)



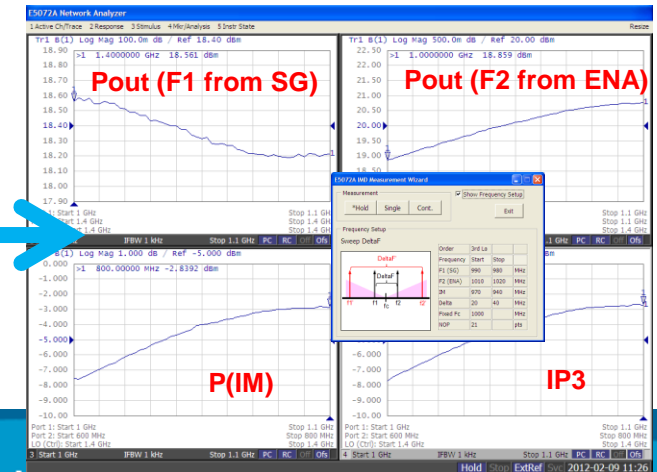
### Calibration (Receiver cal)



### Calibration (Power Cal)



### Measurement Result



# IMD Measurement Type

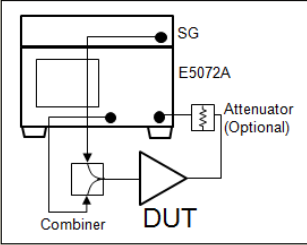
## Introduction

**E5072A IMD Measurement Wizard (Ver.00.44)**

### Intermodulation Distortion Measurement

**\*Caution\***

- The ENA Frequency Offset Mode (Option 008) is required for Intermodulation measurements.
- An external signal generator is necessary connected to the ENA with the USB/GPIB interface (i.e. 82357B).



[step1/3] Stimulus Parameter Setup

[step2/3] Calibration

- Receiver Calibration
- Power Calibration for Main Tones

[step3/3] Connect Device and Measure

Fixed F1, Swept F2

Sweep fc

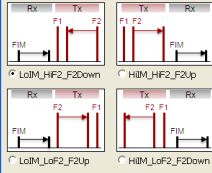
Sweep DeltaF

Setup SG Control   Setup PS Control

**E5072A IMD Measurement Wizard**

### Intermodulation Measurements

[step1/3] Stimulus Parameter Setup for Swept Frequency



Frequency Setup

Order: 3rd

F1 (SG): \_\_\_\_\_ MHz

F2 (ENA) Min: \_\_\_\_\_ MHz

F2 (ENA) Max: \_\_\_\_\_ MHz

NOP: \_\_\_\_\_ pts

IM Min: \_\_\_\_\_ MHz

IM Max: \_\_\_\_\_ MHz

IFBW: Main Tone IFBW \_\_\_\_\_ Hz, IM Tone IFBW \_\_\_\_\_ Hz

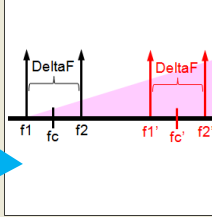
Back Next Done

1. Fixed F1, Swept F2

**E5072A IMD Measurement Wizard**

### Intermodulation Distortion Measurement

[step1/3] Stimulus Parameter Setup for Sweep fc



Frequency Setup

Order: 3rd, Lo

Start fc: 1000 MHz

Stop fc: 1100 MHz

Center fc: 1050 MHz

Span fc: 100 MHz

Fixed DeltaF: 20 MHz

NOP: 21 pts

IM Min: 970 MHz

IM Max: 1070 MHz

IFBW: Main Tone IFBW 1k Hz, IM Tone IFBW 1k Hz

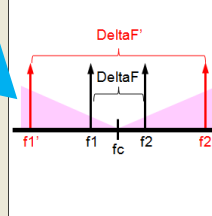
Back Next Done

2. Sweep fc

**E5072A IMD Measurement Wizard**

### Intermodulation Distortion Measurement

[step1/3] Stimulus Parameter Setup for Sweep DeltaF



Frequency Setup

Order: 3rd, Lo

Start Delta: 20 MHz

Stop Delta: 40 MHz

Fixed fc: 1000 MHz

NOP: 21 pts

IM Min: 970 MHz

IM Max: 940 MHz

IFBW: Main Tone IFBW 1k Hz, IM Tone IFBW 1k Hz

Back Next Done

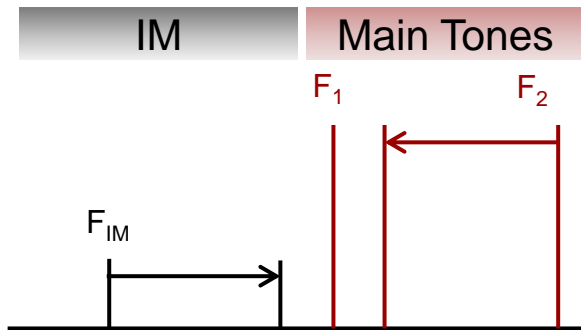
3. Sweep DeltaF

# IMD Measurement Type

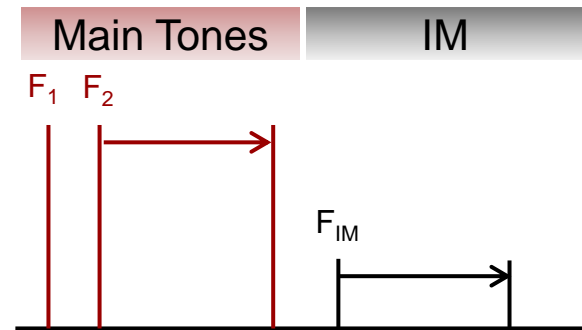
## 1. Fixed F1, Swept F2

- One of the main tones from the SG is fixed at a certain frequency ( $F_1$ ), while the other  $F_2$  from the ENA's source is swept.

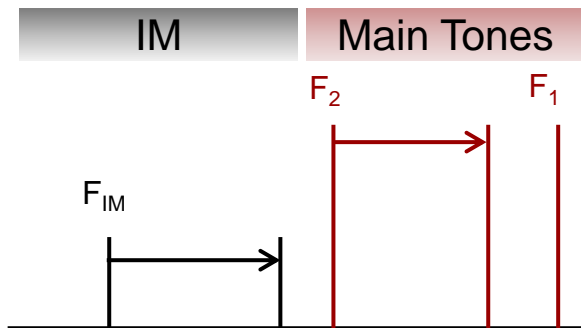
(1-1) Lo IM (Fixed  $F_1$ , downward-swept  $F_2$ )



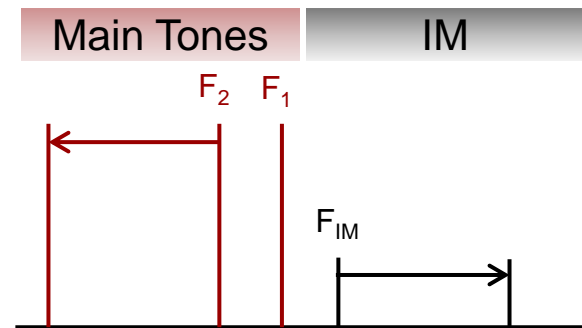
(1-3) Hi IM (Fixed  $F_1$ , upward-swept  $F_2$ )



(1-2) Lo IM (Fixed  $F_1$ , upward-swept  $F_2$ )



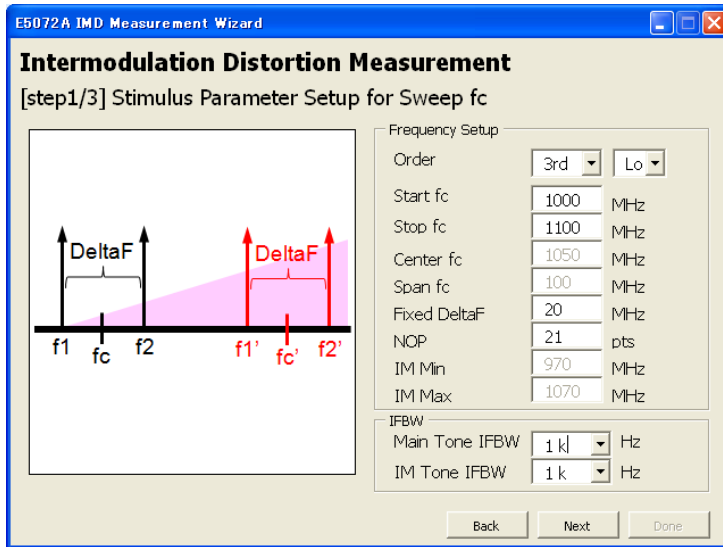
(1-4) Hi IM (Fixed  $F_1$ , downward-swept  $F_2$ )



# IMD Measurement Type

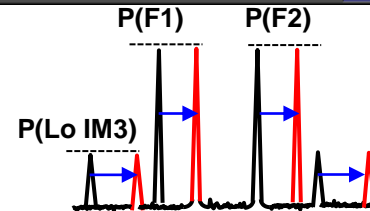
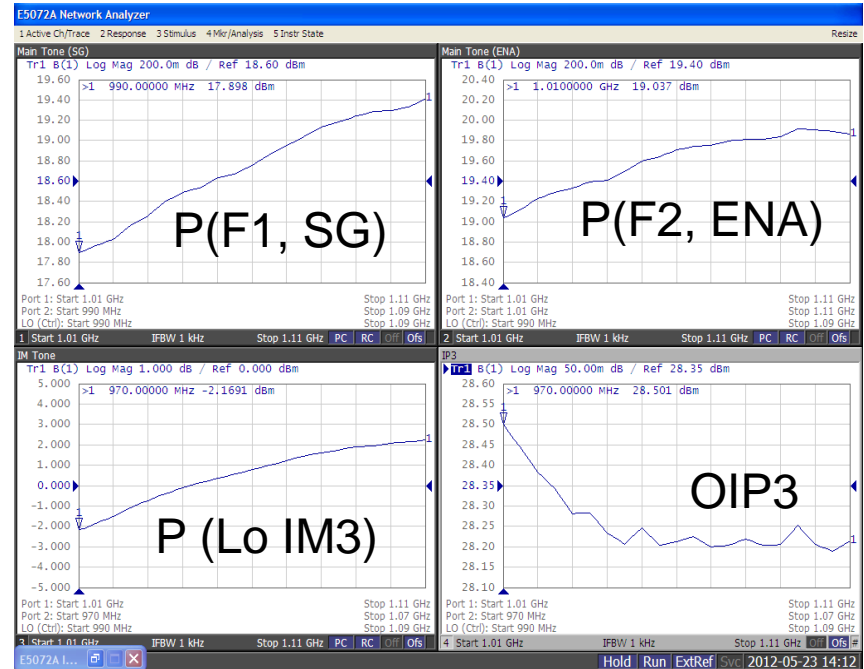
## 2. Sweep fc

### 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

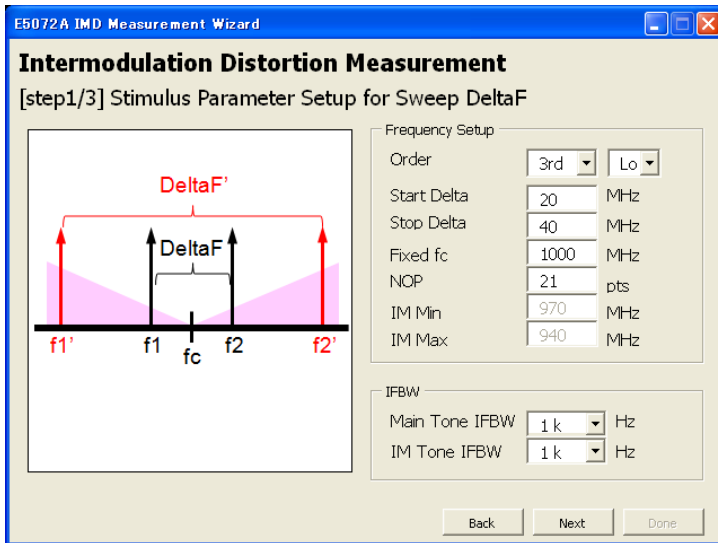


- Output power of the main tones and IM power level is displayed to calculate output IP3 of the DUT.

# IMD Measurement Type

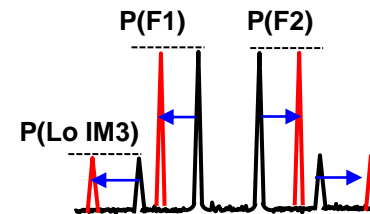
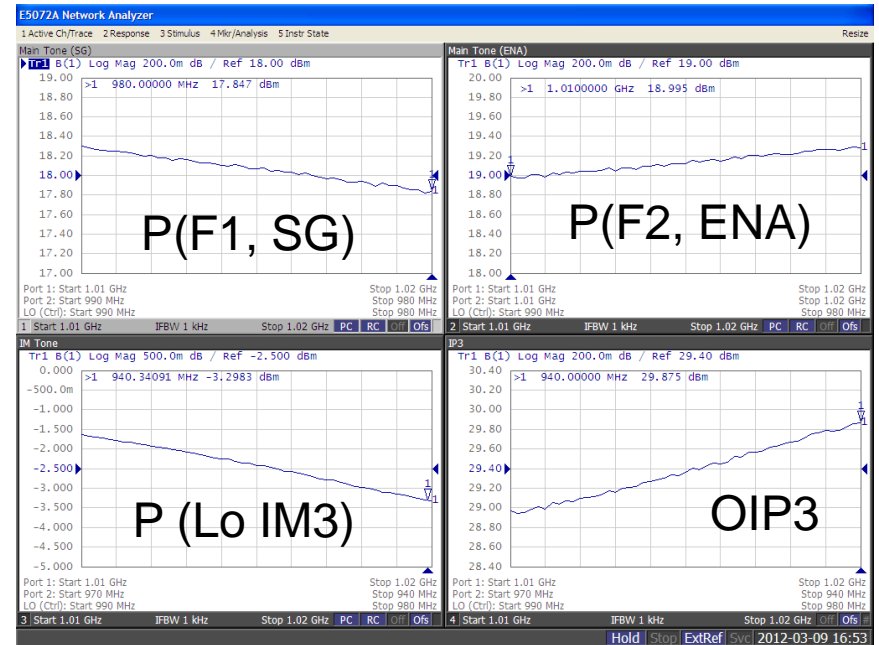
## 3. Sweep DeltaF

### 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.

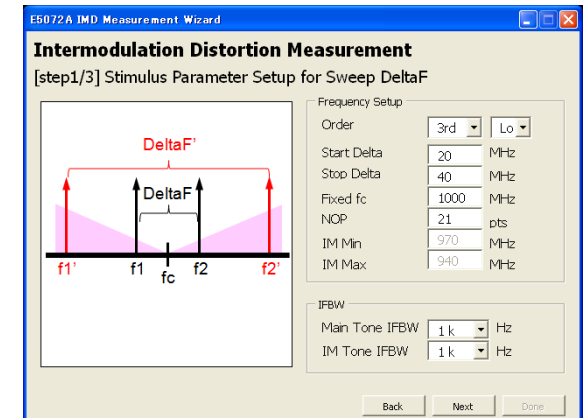
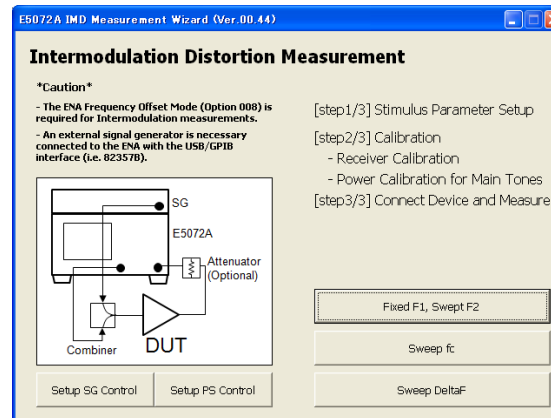
### Measurement Result



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

# Summary

- IMD measurements can be performed with the combination of the ENA (E5072A with option 008) and connected SG.
- Test time can be reduced when swept-frequency IMD tests are necessary.
- IMD measurement wizard is offered for the ENA that provides:
  - Various sweep types to fully characterize the DUT
  - Quick and easy measurements with intuitive GUI
  - Step-by-step power calibrations



# Resources

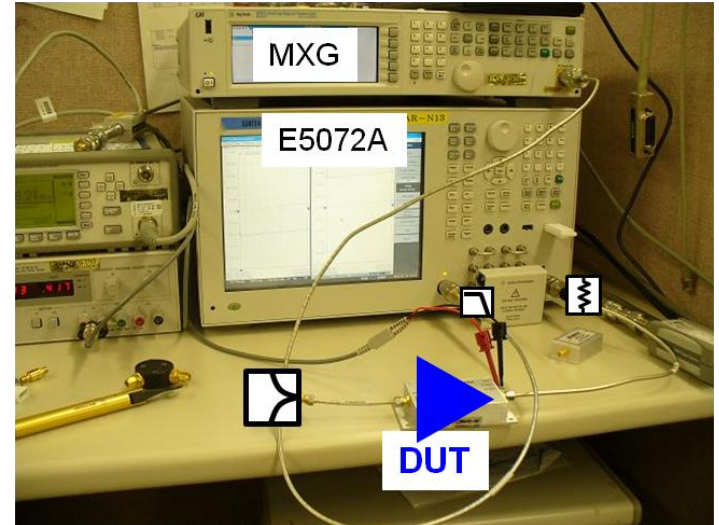
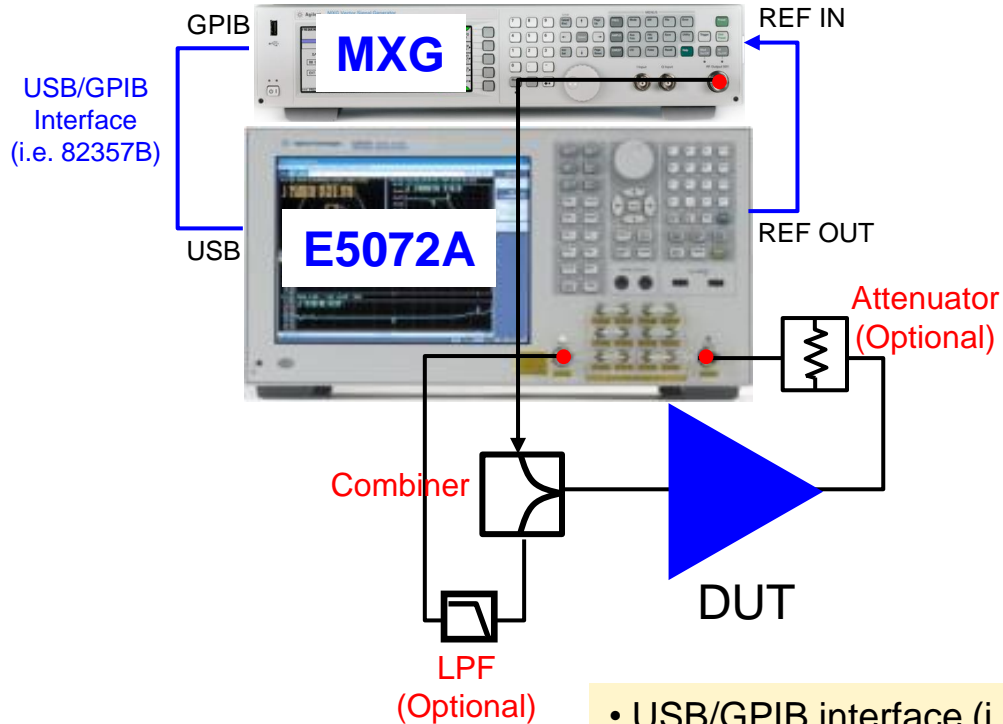
- Application Notes
  - Amplifier and CW Swept Intermodulation-Distortion Measurements ([1408-9](#))
  - Making Accurate Intermodulation Distortion Measurements with the PNA-X ([1408-17](#))
  - Basics of RF amplifier measurements with the E5072A ([5990-9974EN](#))
- E5072A Literatures
  - Configuration Guide ([5990-8001EN](#))
  - Data Sheet ([5990-8002EN](#))
  - Quick Fact Sheet ([5990-8003EN](#))
  - Technical Overview ([5990-8004EN](#))
- Web Page:
  - ENA Series: [www.agilent.com/find/ena](http://www.agilent.com/find/ena)
  - E5072A Product page: [www.agilent.com/find/e5072a](http://www.agilent.com/find/e5072a)
  - Passive intermodulation (PIM) solution page: [www.agilent.com/find/pim](http://www.agilent.com/find/pim)



# Appendix

# Test Configuration

## Using the external combiner



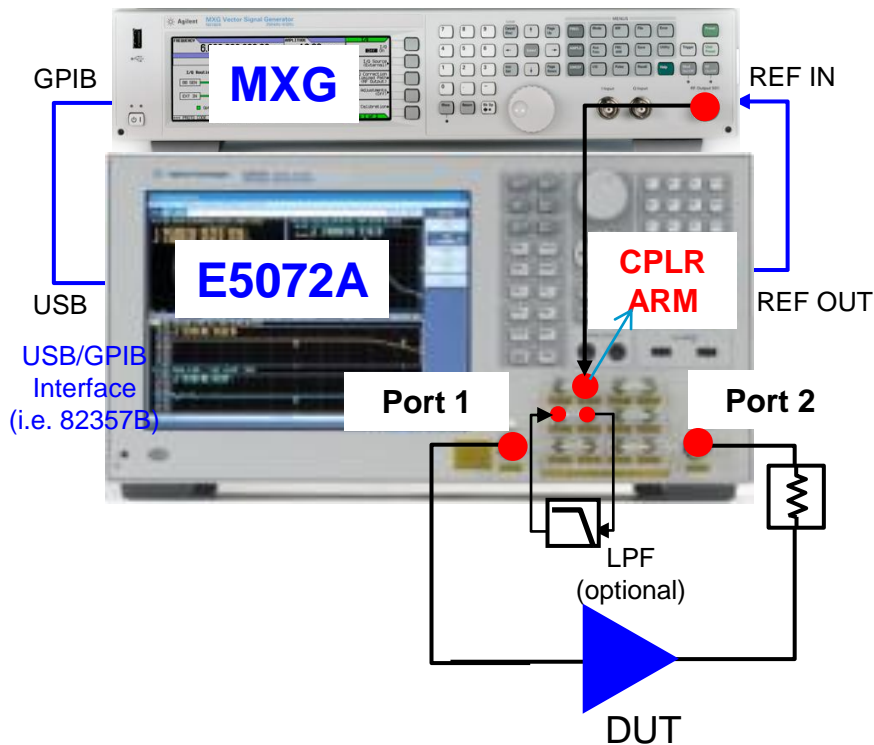
- USB/GPIB interface (i.e. Agilent 82357B) is necessary to control the SG from the ENA firmware.
- 10 MHz reference is connected between the instruments.
- A high-isolation combiner is recommended.
- An optional LPF is needed to eliminate source harmonics from the ENA.
- An optional attenuator is needed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

# Test Configuration 2

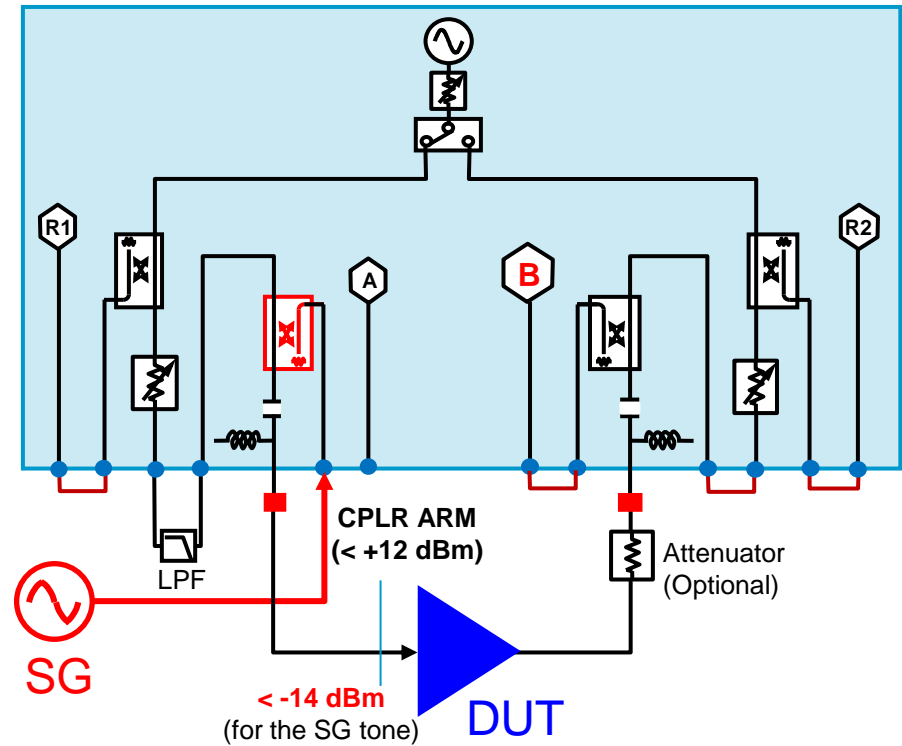
## Using the internal bridge as a combiner

- 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  $+12 \text{ dBm}$  as the damage level of the input is  $+15 \text{ dBm}$ .
- Input power at the DUT is **below  $-14 \text{ dBm}$**  for the main tone from the SG due to the coupling factor (i.e.  $26 \text{ dB}$ ) of the E5072A's internal bridge.