# Keysight Technologies
# Innovative Passive Intermodulation (PIM) and S-parameter Measurement Solution with the ENA

Application Note

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# Introduction

Passive intermodulation (PIM) is a form of intermodulation distortion that occurs in passive components such as antennas, cables, connectors, or duplexers with two or more high-power input signals. PIM becomes a big issue for modern communication industry. PIM from these passive components in the transmitter path falls in to the receiver path; thus the unwanted signals can increase the noise level of the receiver path that degrades quality of the wireless communication system. In order to comply with the regulations, PIM of passive components test becomes more important nowadays.

This application note introduces the test system that combines PIM and S-parameter measurements of passive components by using the vector network analyzer (VNA). The innovative solution with Keysight E5072A ENA Series Network Analyzer[1] is introduced in the document that provides Fast, Flexible and Accurate measurement capabilities. It is a higher-performance and cost-effective solution that can replace the conventional PIM test solutions.

[1] See the E5072A technical overview, product number 5990-8004EN for more detail about the E5072A.

# Passive Intermodulation (PIM)

PIM is an unwanted signal created by the mixing of two or more RF signals, caused by nonlinearity of the passive components in the RF path such as antennas, cables or connectors. PIM product is the result of high power tones mixing induced by ferromagnetic materials, junctions of dissimilar metals, metal-oxide junctions, contaminated junctions and loose RF connectors.

If the fundamental frequencies are $f_1$ and $f_2$, the frequency of PIM products (F_PIM) can be described by the equation:

$$F\_PIM = m * f_1 \pm n * f_2$$

Where m and n are positive integers and the sum of m and n is the product order. Typically 3rd order PIM products such as $2f_2 - f_1$ or $2f_1 - f_2$ have the highest power level, therefore they are a major concern and usually PIM test is performed for 3rd order products of devices under test (DUTs). 5th or 7th order PIM products are also tested, since these odd-order PIM products are typically close to fundamental frequencies and may interfere in the adjacent channels for communication (Figure 1).
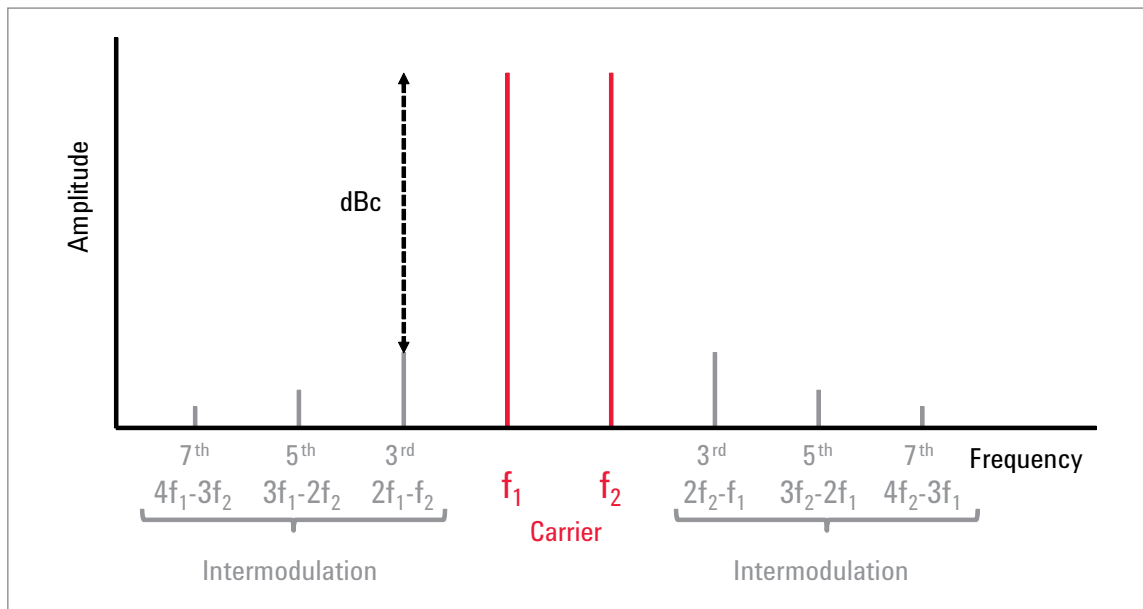
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*Figure 1. Intermodulation signals*

PIM is normally specified in terms of dBm and dBc, where dBm is a measure of the absolute value of PIM products and dBc is a measure of dB relative to a specified fundamental power level. For example, typical 20 watts or +43 dBm is input power level of two main signals and the PIM product created in DUT is -110 dBm, the PIM product is –153 dBc. Acceptable levels of PIM products are extremely low, in the range of –100 to –120 dBm with two fundamental tones at +43 dBm.

Figure 2 shows a typical block diagram of the front-end of wireless communication systems. Although filtering can reduce unwanted signals generated by power amplifiers in the trans-mitter path, PIM products from passive components such as antennas, cables or connectors in the RF signal path can not be filtered. The unwanted PIM products in the transmitter (Tx) path falls into the receiver (Rx) path, increases the noise level and degrades the quality of wireless communication. It is important to design and install low PIM passive components to guarantee the requirements or specifications of the systems.
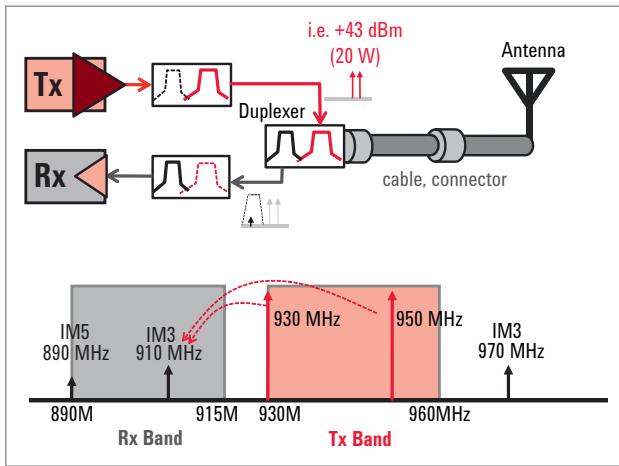


Figure 2. Typical block diagram and frequency band for communication systems

## Measuring PIM

A typical test configuration of two-tone reflected PIM test solution for 900 MHz band is shown in Figure 3. RF signals at fundamental frequency from signal generators (SG) are driven by power amplifiers. The two high-power tones (i.e. +43 dBm) in transmitter band are combined with a combiner or hybrid coupler and applied to the DUT through a duplexer. The PIM products generated by the DUT are reflected, and the systems receiver measures the 3rd, 5th, or 7th order IM products in the receiver band. For reflected PIM measurements of 2-port DUT with this configuration, a low PIM load is connected to the other end of the DUT to absorb high-power signals.

A key component used in the test system is a high-rejection duplexer. It filters intermodulation (IM) products or harmonics generated by power amplifiers in the transmitter path and reduces reflected high-power fundamental signals in the receiver path. For most analyzers, it is essential to suppress high power levels of main tones to measure very low levels of PIM products by the receivers. The duplexer's PIM performance needs to be lower than the DUT's . Since this narrowband component is installed in the system, the solution should be dedicated to a specific frequency band of interest. If you need to test PIM performance of the DUT in a broad frequency band, multiple sets of test systems are necessary for full device characterization.

The receiver must detect extremely low power level of PIM products such as down to -120 dBm or below. It is required to use narrow bandwidth for measurements, thus measurement time of PIM test is typically longer than other parameters such as S-parameters.

To characterize reflected PIM performance of electrically long devices, one of the two main tones is swept while the other is fixed at the certain frequency. For example, a fixed frequency or continuous wave (CW) tone is placed at the low end of the transmitter band and the second tone is swept. Then a fixed tone is placed at the high end of the band and the second tone is swept.
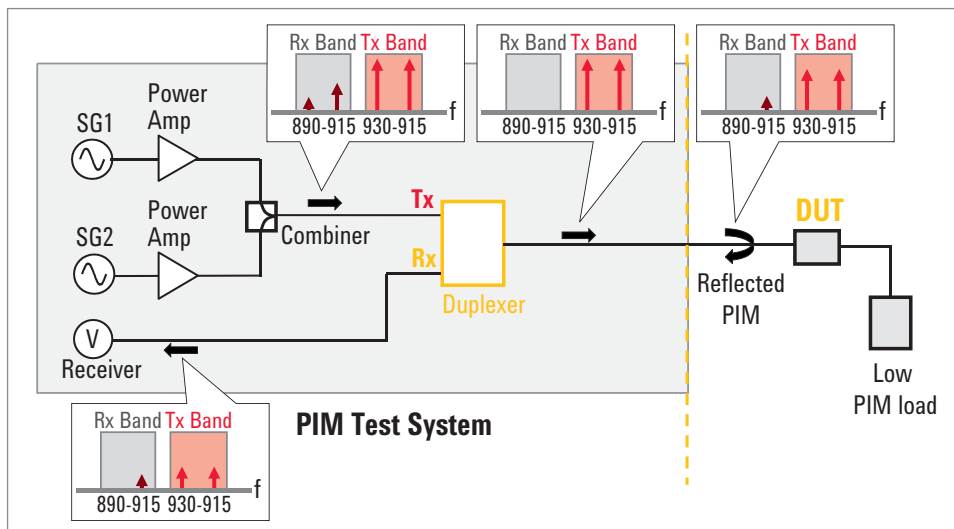


Figure 3. Typical configuration of reflected PIM test system for 900 MHz band

# Challenges with current solutions

Today PIM testing is performed with either dedicated standalone PIM analyzers or rack and stack system solutions with the combination of generators, receivers and additional components. There are measurement challenges with current PIM test solutions to improve productivity of PIM measurements.

## 1.  Total throughput

With the growing demand of the PIM testing, it is always required to reduce measurement time. However, when using multiple instruments for PIM measurements, all the measurement instruments in the test system are controlled by a system controller and measurements have to be synchronized for each data point. Therefore total measurement process takes long time to complete especially for swept-frequency PIM measurements with a lot of data points.

S-parameters such as return loss or insertion loss are important parameters for passive components, and both PIM and S-parameters measurements need to be tested in the final stage of productions. Conventional test systems require the set of a VNA and several PIM measurement solutions dedicated for individual frequency bands. When different test stations are used for total device characterization, the time required to connect and disconnect the components can be greater than the actual testing time.

## 2.  Multiband test

Many of PIM analyzers are designed for a specific frequency band due to included narrowband components such as a duplexer. In order to test the DUT that supports multiband operation, it is necessary to purchase additional analyzers for other frequency bands of interest. Overall cost of test systems with multiple instruments becomes very expensive needed for maintenance, calibration and repair.

## 3.  Calibration of power levels

Power levels of PIM products are really sensitive to input power level of fundamental tones, therefore it is highly recommended to calibrate the power levels of main tones for accurate PIM measurements. However, most of PIM test analyzers available in the market do not offer any power calibration method that can be performed by operators, so you have to rely on the periodic calibration and performance verification provided by equipment vendors that are usually performed once a year. Users need extra margin/guard band on their measurement limits of DUTs when considering measurement errors in the analyzers such as temperature drift which power amplifiers. User calibration methods must be offered for designers and manufacturers who want to have a good production yield of their components.

## Solution with the VNA

An alternative solution is proposed by Keysight Technologies, Inc. that includes the VNA in the test system. It can combine both the PIM and S-parameter measurements to verify the overall performance and quality of your passive components. The simple test configuration for 1-port DUT is presented in Figure 4.

Keysight E5072A ENA series network analyzer with configurable test set is used in the test system, because absolute measurements of PIM products with very low signal levels are possible by directly accessing the internal receivers such as receiver B. The E5072A has frequency-offset mode option (E5072A option 008) that enables the source and receiver to sweep at different frequencies [1]. The signal from the E5072A's source is used for one of the fundamental tones, and the power levels of PIM products from the DUT are monitored in the receivers. The signal from an external SG such as Keysight MXG is used for the other fundamental tone. The E5072A can be a system controller and directly operate the SG connected to the E5072A via USB/GPIB interface

(i.e. Keysight 82357B). By combining the frequency offset sweep with the E5072A and the SG, fast swept-frequency PIM measurements can be performed.

State-of-the-art features are offered with this VNA-based solution, so you can improve your productivity of PIM and S-parameter measurements that are not possible with conventional solutions available in the market.

## Benefits and key features

The innovative solution with the ENA series offers higher performance than conventional solutions with lower total investment for the PIM and S-parameter measurements. The solution has new key features of Flexible configurations, Fast measurement speed and Accurate measurements, which can replace the existing test systems for passive component tests. You can add the new capabilities on your current test system including the VNA with the minimum additional cost.
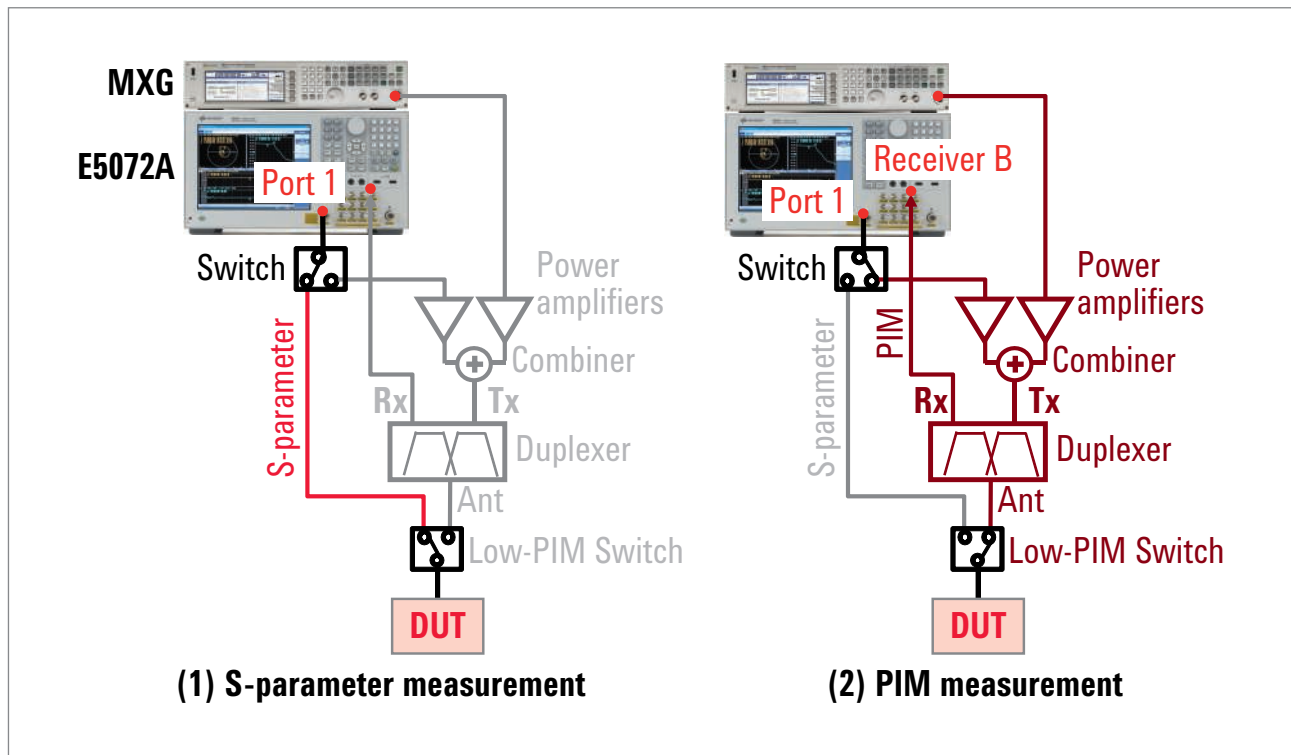


Figure 4. Configuration of the new test system for 1-port DUT

1.  See the E5072A configuration guide, part number 5990-8001EN (http://literature.cdn.keysight.com/litweb/pdf/5990-8001EN.pdf) for more detail.

## 1. Flexible configurations

Especially for PIM measurements of passive components, the time required to connect and disconnect the components can become greater. With the VNA-based solution, both PIM and S-parameter measurements can be performed without changing physical connections of the DUT (Figure 4). It reduces the time you spend in connecting and disconnecting a DUT and significantly improves your overall test throughput.

With the demanding needs of PIM measurements for wireless communication industries, every passive component in the RF signal path needs to be tested, which include 1-port antennas, 2-port cables and connectors, or 3-port duplexers. Some standalone PIM analyzers are specifically designed for reflected PIM measurements of 1-port DUT, therefore the analyzers with the internal duplexer are not best suited for PIM tests of 3-port duplexers.

Since the new solution consists of the analyzers and individual components, you can expand your test capabilities easily with alternative configurations for any types of components. You can measure 3-port DUT such as a duplexer with the minimum change in the test configuration (Figure 5).

Because of the narrowband duplexer included in the standalone PIM analyzers, PIM measurements of passive components with multiband operation such as BTS antennas can be headache for test engineers. Multiple analyzers and sequential measurements are required for total characterization of a single DUT.

Since the E5072A and SG operate in a broad frequency range depending on selected options, the broadband PIM test solutions can be configured by using the filter/duplexer module and switch matrix to select the frequency band. (Figure 6)

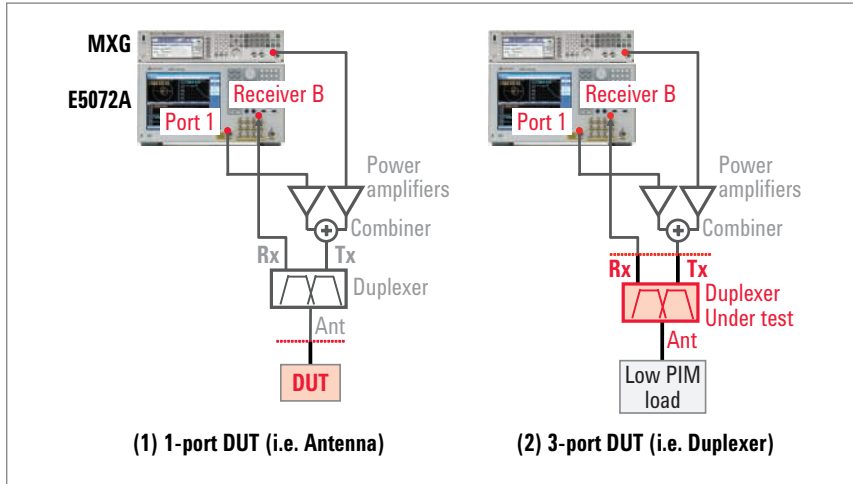The test configuration ca be optimized with flexible setup to meet your future demands of component tests.



**(1) 1-port DUT (i.e. Antenna)**     **(2) 3-port DUT (i.e. Duplexer)**

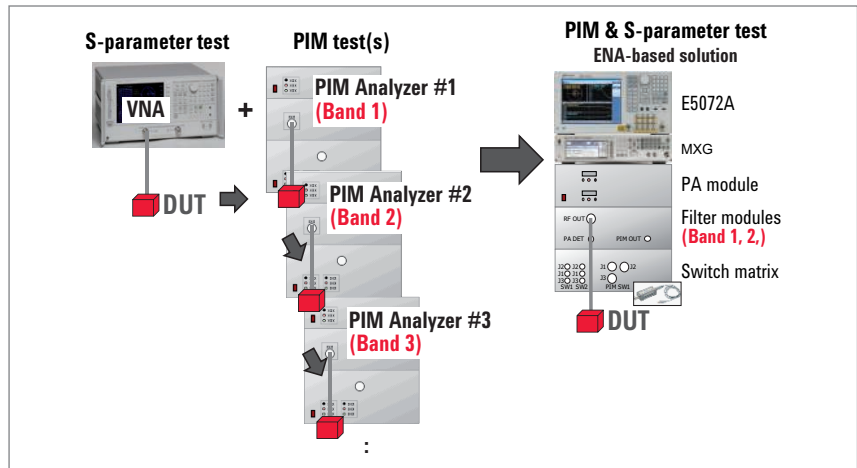*Figure 5. Flexible PIM test configurations for 1-port and 3-port DUT*



*Figure 6. Expansion of the test capabilities for multiband DUT*

## 2. Fast measurements

The E5072A has superior RF performance including measurement speed which is suited for high-volume manufacturers. Especially its frequency-offset sweep eliminates the need for additional time to control other instruments, so the total time of the measurement sequence is dramatically reduced for swept-frequency PIM measurements.

The E5072A's high receiver sensitivity enables you to select wider IF bandwidth (IFBW) for PIM measurements, which guarantees much faster measurements compared to current PIM analyzers. The comparison of measurement speed is shown in Figure 7. Swept-frequency PIM measurements are performed for the 3rd order PIM products of a device for GSM 850 MHz band. (Upward and downward sweeps in the transmitter band, total 72 points). The solution with the E5072A has a clear advantage in measurement speed over current PIM analyzers.

You can maximize the throughput of your measurements by optimizing stimulus parameters such as wider IFBW with the E5072A. The high test speeds benefit high-volume manufacturers and have a significant impact on the total cost of test per component.
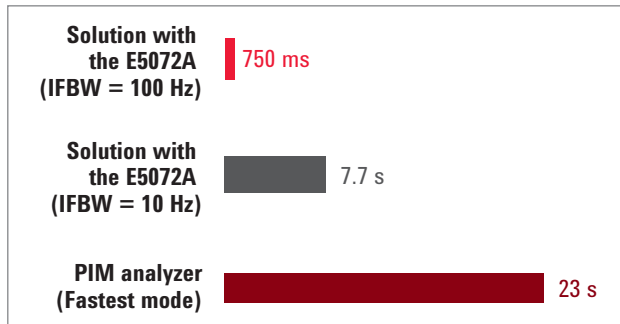
## 3. Accurate measurements

PIM is very sensitive to input power levels to the DUT. Theoretically PIM products will grow by 3 dB for 1 dB change in input power. The typical measured data of PIM amplitude over input power level is presented in Figure 8. From Figure 8, ± 1 dB variation in power level at the DUT is responsible for ± 2.8 dB of measurement variation in the 3rd order PIM, meaning that care must be taken in specifying the DUT's input power levels. It is essential to calibrate the power level of fundamental tones for accurate PIM measurements. However, current PIM test solutions do not provide power calibration for users, so the change in the test system such as temperature drift of power amplifiers can cause variation of the input power level to the DUT giving unexpected errors in measurement results. It is desirable to set power levels accurately if you want to characterize nonlinear PIM performance of the DUT.

The E5072A has capabilities of power calibration techniques which provide great power level accuracy for measurements. Especially its receiver leveling function enables you to compensate the variation of power amplifiers' output power and achieve the greater power accuracy at the DUT's input compared to conventional solutions. Accurate PIM measurements in your production environments will increase test efficiency and product yield.
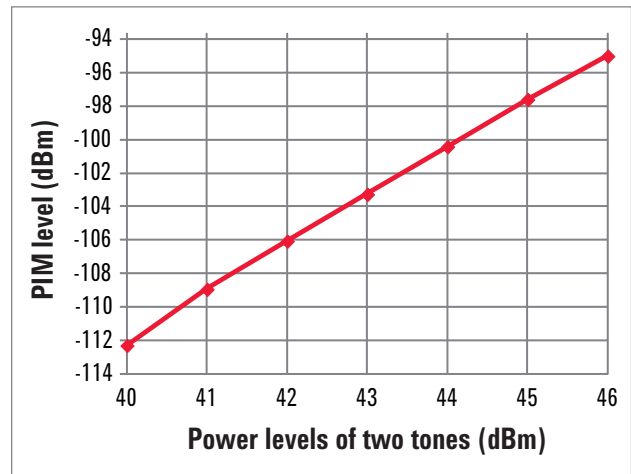
Figure 8. PIM level vs. Input power level

*Figure 7. Comparison of measurement speed in GSM 850 MHz band*

# Measurement Example

A measurement example with the ENA-based solution will be introduced for 1-port DUT that requires swept-frequency PIM measurement as well as S-parameter (i.e. return loss) measurements. The following instructions will focus on measurement setup of PIM measurements. For basic S-parameter measurements using the E5072A, details can be found in the E5072A help at:
**http://ena.tm.keysight.com/e5072a/manuals/webhelp/eng/**

# System configuration

The typical measurement configuration is shown in Figure 9. The E5072A is the center of the test system and control all connected peripherals such as MXG or power meter. The USB/GPIB interface (i.e. Keysight 82357B) is connected to the USB port of the E5072A and the GPIB port of the MXG. This interface is necessary to control the MXG from the E5072A. 10 MHz reference is connected between the two instruments. The power sensor is used for power level calibration with the E5072A. Both power meter/sensor over GPIB or USB are supported for the calibration procedure by the E5072A. The USB power sensor (i.e. Keysight U2000 series) can be connected directly to the E5072A USB port.

The E5072A's source from port 1 is used for the one fundamental tone that can be either fixed or swept in measurement frequency, while the MXG is used for another fundamental tone that is fixed at a certain frequency. Two tones are combined by a hybrid coupler and unnecessary harmonics of main tones are filtered with the transmitter (Tx) filter and duplexer in the transmitter path.

PIM products are generated at the DUT by high-power two tones. Reflected PIM signals go through the receiver path of the duplexer and are measured by the E5072A's receiver B. Proper IFBW should be selected depending on the required receiver sensitivity for measurements. The minimum IFBW available with the E5072A is 10 Hz, and noise floor of the E5072A's receiver input is below −135 dBm with IFBW at 10 Hz [1].

The E5072A's receiver R1 monitors input power level to the DUT via high-power coupler in the transmitter path and the receiver leveling function using the receiver measurements of the E5072A is enabled to compensate the variation of output power levels of power amplifiers. It eliminates short-term temperature drift of the amplifiers and guarantees to achieve constant input power level to the DUT within the required tolerance of measurements. Optional attenuators are inserted before the receiver to avoid compression or damage by high-power input [2]. Refer to Appendix A, for the block diagram of the E5072A.

RF switches (indicated as "SW1", "SW2" or "SW3" in Figure 9) are installed in the system that select the signal paths between PIM and S-parameter measurements. The switch before the DUT ("SW3") should have good PIM performance lower than the measured DUT.
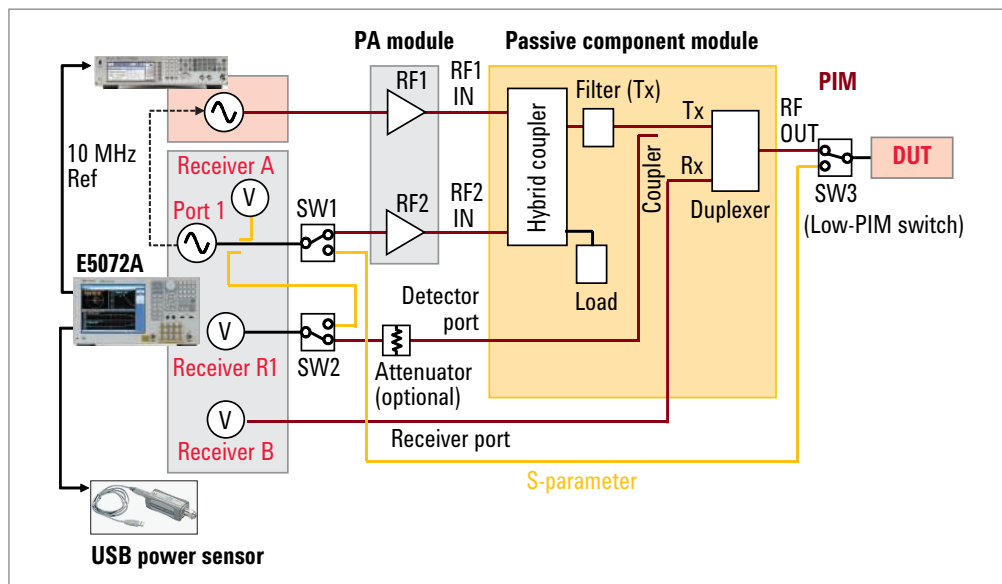


Figure 9. System block diagram of PIM and S-parameter measurements of 1-port DUT

1. This value is supplemental performance data that is most likely to occur. It is not guaranteed by the product warranty.

2. The damage level and compression levels of the receiver inputs are listed in the E5072A data sheet at:
http://literature.cdn.keysight.com/litweb/pdf/5990-8002EN.pdf

# PIM measurement software

In most cases, measurement speed is not the only factor in increasing throughput in testing. The time spent connecting the devices to measurement instruments, calibrating the instrument and setting up of the measurement parameters is much longer than actual measurement time. To accelerate time-to-market, you need easy-to-use measurement software that guides you through measurement procedures to minimize the setup time.

A sample program of PIM measurement software for the E5072A is available on Keysight website (www.keysight.com/find/pim). The utility software sets up necessary parameters on the E5072A. It also features a calibration wizard that provides step-by-step instructions of power calibration procedures for PIM measurements. The PIM measurement software for the E5072A saves you a lot of setup and calibration time and eliminates many of the operator errors in measurement procedures.

The software runs in the E5072A's Microsoft VBA Macro Programming capability, and it controls all peripherals connected to the E5072A without the use of additional system software running on an external PC. As the source code of this software is not password protected, you can customize the software easily for your own PIM measurements.

For more detail about the operation of the PIM measurement software, refer to the operation guide available at the website above.

The PIM measurement software for the E5072A provides three PIM measurement modes including 1) PIM with fixed frequency tones, 2) swept-frequency PIM measurements, and 3) PIM spectrum measurements (Figure 10). PIM with fixed frequency tones reveal the intermittent problem with testing of PIM products over time for dynamic testing requirements. Swept-frequency PIM measurements enable you to sweep both upward and downward frequencies in the transmitter band for the most comprehensive PIM test. With PIM spectrum measurements, you can verify the quality of PIM products in real time.

You will be able to test either low-side or high-side, multiple PIM products (3rd, 5th, and 7th) in the receiver path with two tone frequencies in the transmitter path. The measurement software gives you easy access to change measurement parameters such as the receiver's IFBW or desired power levels of two tones. You can optimize your test setup and perform efficient and accurate PIM measurements.
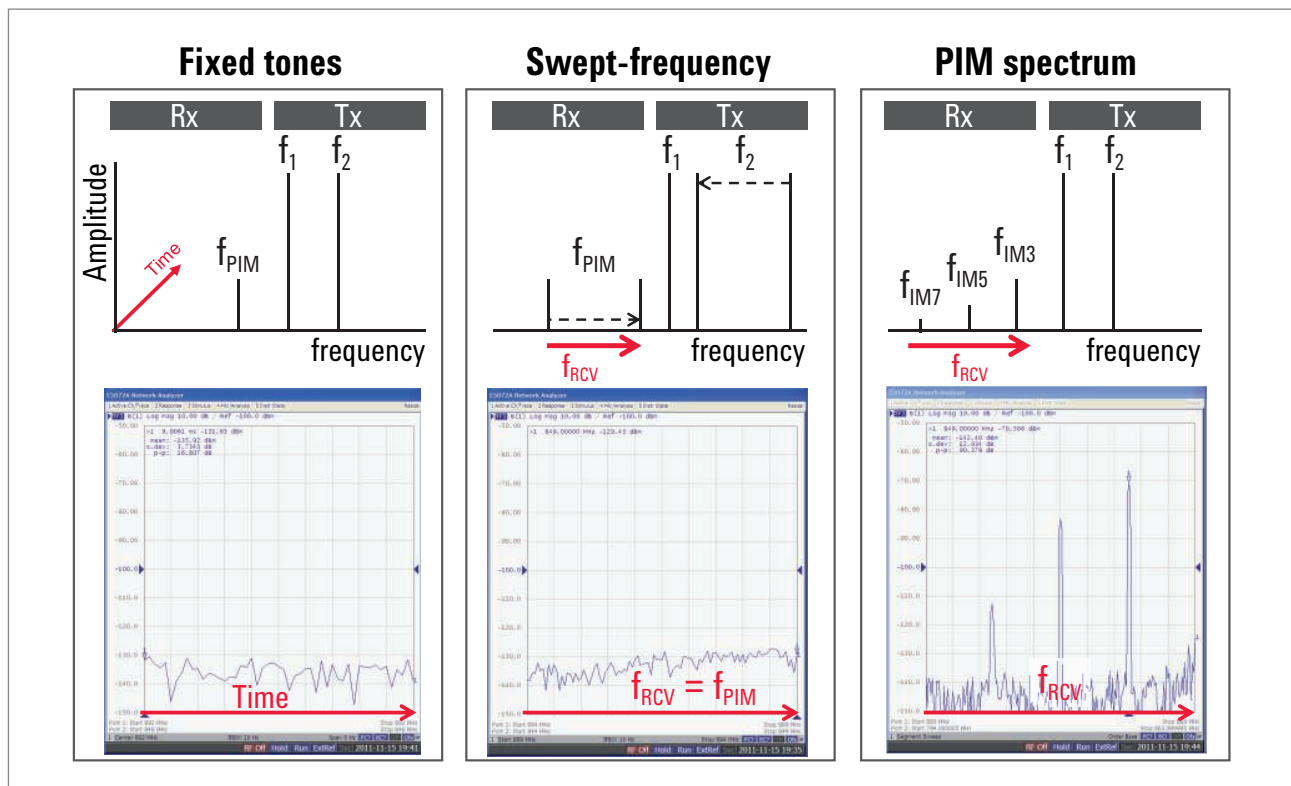


*Figure 10. Three measurement modes with PIM measurement software*

# Step-by-step guide for measuring PIM

This section describes necessary steps to measure PIM performance of a passive component. Typical reflection PIM measurement is needed for 1-port DUT of GSM band (900 MHz) under a condition of two fundamental tones at +43 dBm. The PIM measurement software running on the E5072A is used for easy and fast setup and measurements. This measurement process is described in the following steps:

| | |
|---|---|
| Step 1 | Setup of test configuration |
| Step 2 | Setup of measurement parameters |
| Step 3 | User calibration |
| Step 4 | Measurement |

## Step 1 Setup of test configuration

The test configuration used for the measurement is the same as presented in Figure 9. RF signals from the E5072A and MXG are driven by the power amplifiers and then applied to the passive component module. The combined two tones are applied to the DUT through a duplexer, and reflected PIM signals from the DUT are measured at the E5072A's receiver B.

To confirm the connections of the SG and power sensor with the E5072A, you can initiate the Keysight Connection Expert on the E5072A with the softkey under [System] > Misc Setup > GPIB Setup > System Controller Configuration.. Verify the E5072A can successfully recognize the connected peripherals. (Figure 11)
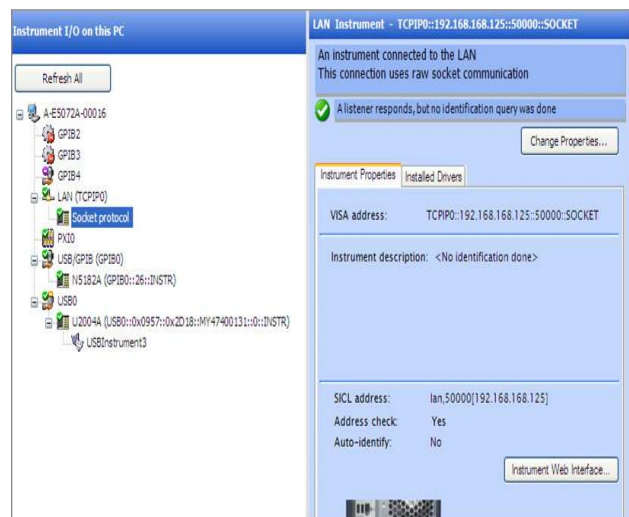


*Figure 11. Verification of connection using Keysight Connection Expert on the E5072A*

## Step 2 Setup of measurement parameters

Load the PIM measurement software on the E5072A and launch the VBA program by the E5072A firmware, **[Macro Setup]** > **Load project..** > Select the latest version of the measurement software (*.vba) and **[Macro Run]**
The main window appears on the right of the E5072A's display (Figure 12). The window gives you easy access to softkeys for measurement setup, user calibration and performing PIM measurements.

PIM measurement software has a function of importing setup files (*.ini) that include stimulus parameters such as measurement frequency range, target power levels of two tones or number of points (NOP), and other necessary parameters for user calibration. These parameters are then automatically set up by the E5072A.
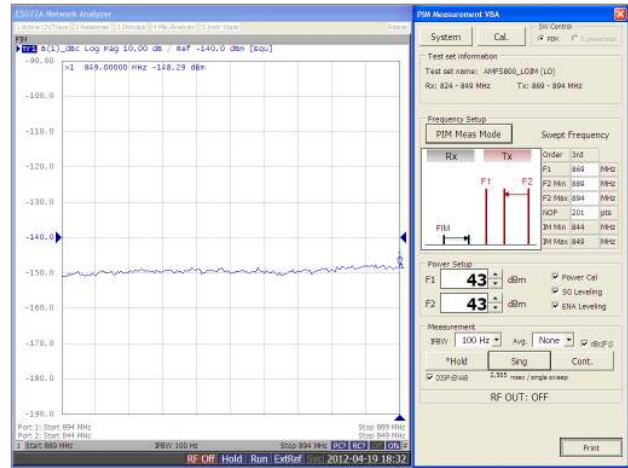


*Figure 12. Main window of PIM measurement software for the E5072A*

## Step 3 User calibration

The calibration procedure is the important part of measurements with the VNA and it is necessary to perform power level calibrations before PIM measurements. If the calibration is inaccurate, you will not measure the true PIM performance of your DUT. The E5072A offers various power calibration techniques for users to achieve more accurate results. Unlike conventional solutions, you can perform power level calibrations by the E5072A anytime you want, when test environments such as system configurations are changed.

### Power calibration
Power calibration using a power meter / sensor connected to the E5072A adjusts the E5072A's output power to achieve the desired power level at the calibration plane. Power calibration transfers the accuracy of the power sensor used and sets the power level at the calibration plane within a specified tolerance.

### Receiver calibration
Receiver calibration is necessary for absolute measurements in dBm using the E5072A's receivers. The calibration mathematically removes frequency response in the receiver path and adjusts the E5072A's readings to the same as the targeted power level calibrated by power calibration. With the receiver calibration, it is possible to achieve accurate absolute power measurements (in dBm) with the E5072A.

### Receiver leveling
The E5072A has receiver leveling function that uses the receiver measurements to adjust the source power level across a frequency band. Before each measurement sweep, a variable number of background sweeps are performed to repeatedly measure power at the receiver. Those power measurements are then used to adjust the E5072A's source power level for providing targeted leveled power at the DUT's interface. The receiver leveling function compensates temperature drift of power amplifiers in real time, providing accurately leveled power at the DUT during PIM measurements.

## 3-1. Receiver calibration for measuring PIM

Receiver calibration is necessary to measure power levels of incoming PIM products. The calibration is conducted in the frequency range of PIM products that are measured at the E5072A's receiver B. It is recommended to perform power calibration before receiver calibration in order to transfer the power accuracy of the connected power sensor into the receivers. The configuration of receiver calibration is shown in Figure 13 and Figure 14. The power sensor is connected to the port 1 to calibrate the power level at the calibration plane (Figure 13), and then the calibrated source power is connected to the receiver path to perform receiver calibration of the receiver B (Figure 14). Absolute measurements of PIM products are possible using the receiver B after the calibration procedure. Note that target power level of power calibration should be specified correctly to avoid the receiver compression during the receiver calibration.
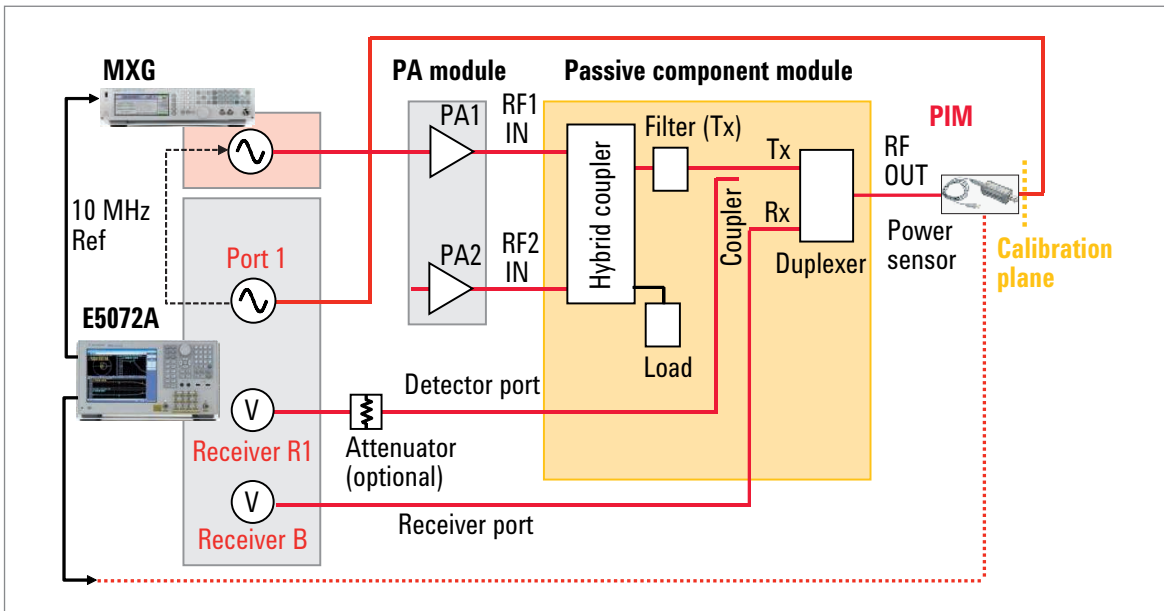


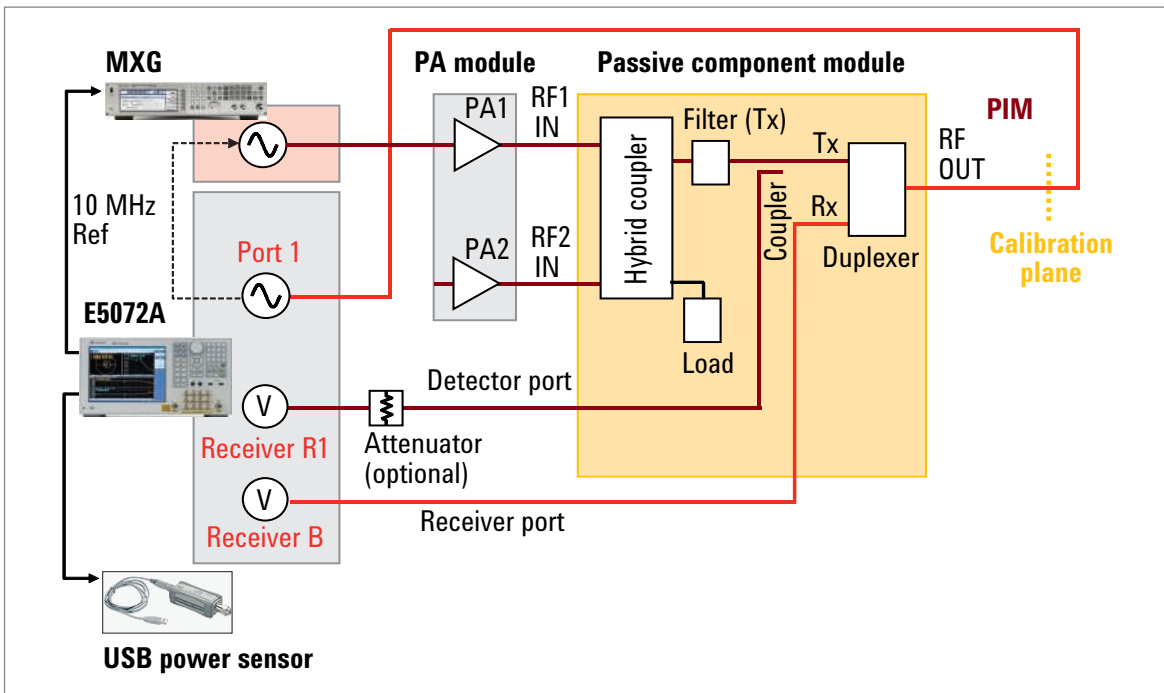Figure 13. Power calibration for receiver calibration of the receiver B



Figure 14. Receiver calibration of the receiver B

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## 3-2. Power calibration of two fundamental tones

With power calibration, the source power levels of the MXG and E5072A are adjusted automatically to achieve the desired high-power levels of two fundamental tones at the calibration plane (DUT's input). Power calibration transfers the accuracy of the power sensor connected, and sets the power level at the DUT's input within a specified tolerance.

Since the power amplifiers in the test system are turned on during the power calibration, the high-power load should be connected before calibration to absorb high-power signals from the power amplifiers. The configuration of power calibration for the MXG is illustrated in Figure 15.

The power sensor is connected to the detector port, and the DUT's input power is adjusted at the desired power level by power calibration. The difference in loss between the transmitter path (RF1 & RF 2 IN to RF OUT) and the detector path (RF1 & RF2 IN to Detector Port) is used as a power offset for calibration of power levels of two fundamental tones at the DUT in this procedure. Power calibration is performed for the MXG and E5072A respectively, and you can get great power accuracy for two fundamental tones in each frequency sweep range. Note that the E5072A's source should be turned off during power calibration of the MXG, and the MXG's source should be turned off during power calibration of the E5072A. Power leveling of the E5072A is performed by the receiver leveling function of the E5072A's firmware, while leveling of the MXG is done by the measurement sequence implemented in the PIM measurement software.
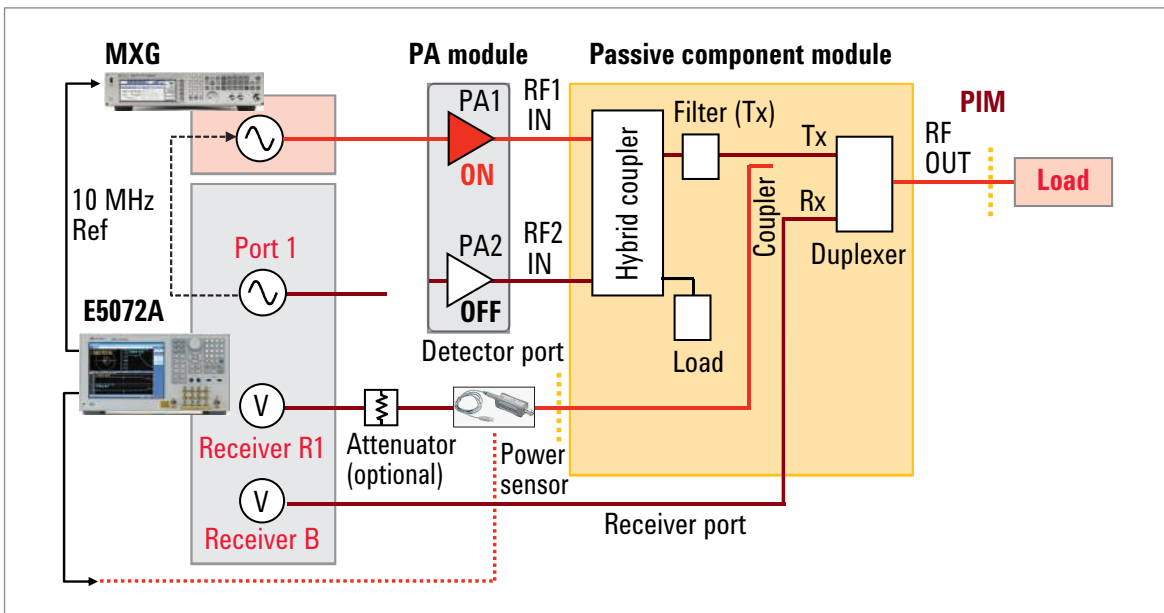


Figure 15. Power calibration of the fundamental tone from the MXG

## 3-3. Leveling of two fundamental tones

The E5072A's receiver leveling function is enabled to achieve accurate power levels of two tones to the DUT's input. Background receiver measurements using the receiver R1 are performed before each PIM measurement, and the source power levels of the E5072A and MXG is adjusted automatically. You can eliminate temperature drift and gain variation of the power amplifiers. Also power linearity of high-power tones can be improved by great receiver linearity provided by the E5072A. Unexpected measurement errors of PIM results can be avoided with the leveling feature.

Since the level accuracy of the receiver leveling depends on the receiver's absolute power measurement accuracy, power calibration and receiver calibration for the receiver R1 should be performed before enabling receiver leveling. These calibrations

are necessary for each frequency range of two fundamental tones from the MXG and the E5072A. Power calibration and receiver calibration require the E5072A's source and receiver, so the E5072A's source from port 1 is connected to the power amplifier (PA1) for the frequency range of the MXG during the calibration procedure (Figure 16 & 17). And then the E5072A's source is connected to the power amplifier (PA2) for the frequency range of the E5072A (Figure 18 & 19).

Power leveling of the two tones at the DUT's input is achieved by enabling receiver leveling with the E5072A. Power level dependency of PIM products can be monitored, if you change the input power level. Note that the fundamental power levels are instantly adjusted by receiver leveling during measurements.
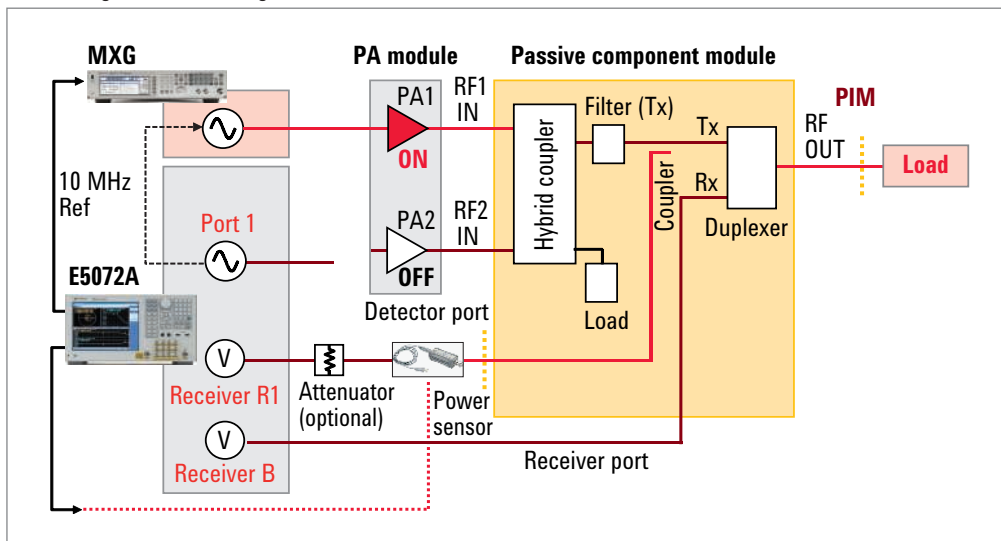


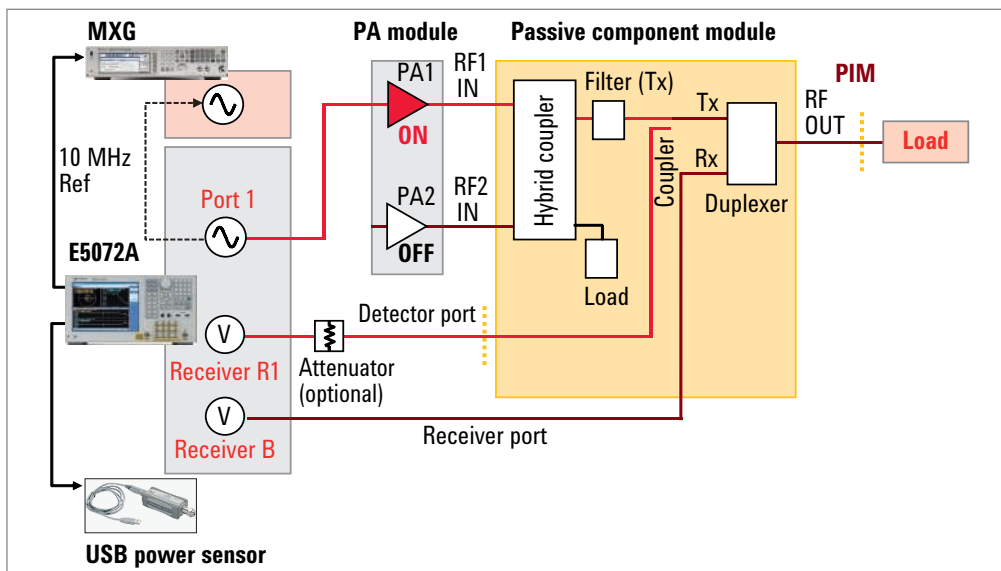*Figure 16. Receiver leveling - Power calibration in frequency range of MXG (RF1)*



*Figure 17. Receiver leveling - Receiver calibration in frequency range of MXG (RF1)*
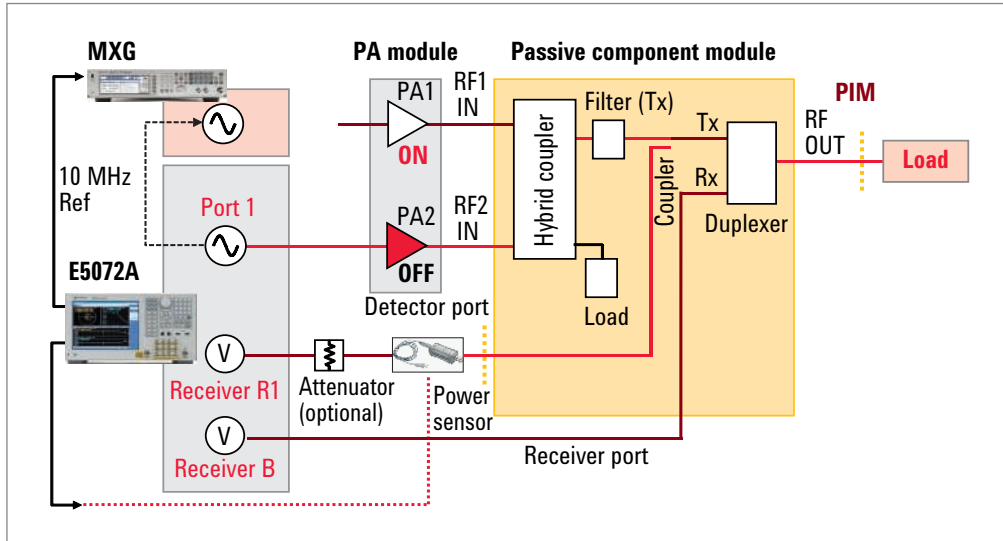
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*Figure 18. Receiver leveling - Power calibration for frequency range of E5072A (RF2)*
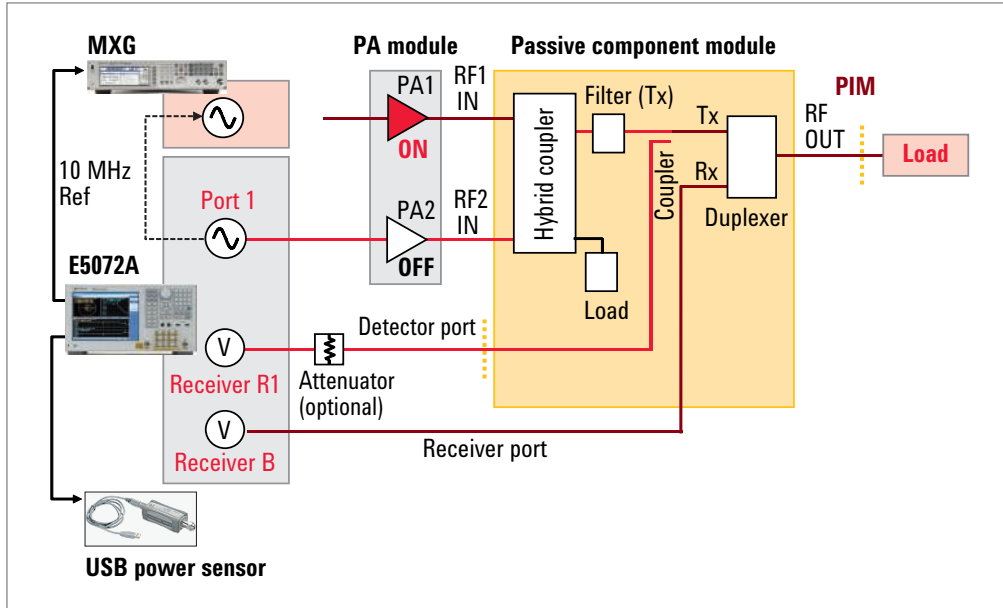


*Figure 19. Receiver leveling - Receiver calibration for frequency range of E5072A (RF2)*

## Step 4 Measurement

After the necessary calibration procedure, the DUT is connected and PIM measurements are performed (Figure 20). Make sure the DUT is connected properly before turning on power amplifiers.
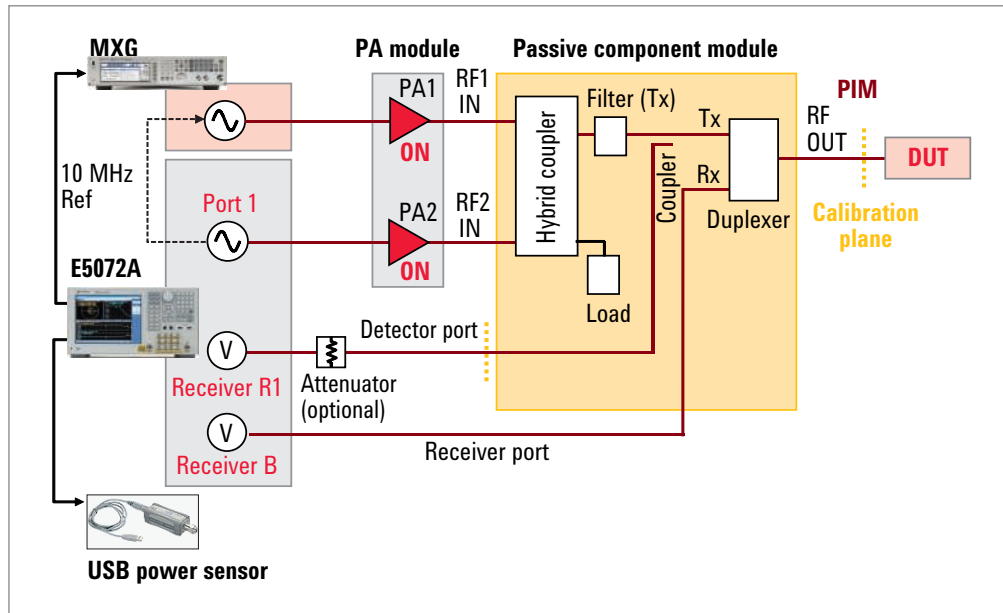


*Figure 20. Connecting DUT for PIM measurements*

# Measurement results

Quick test can be performed to verify that test system is calibrated properly. Connect the low PIM load to the RF OUT of the test system and perform a PIM measurement. Figure 21 shows measured 3rd-order PIM product of a low PIM load in dBc relative to fundamental tones of +43 dBm. The system's residual PIM performance can be around −170 dBc (or −127 dBm) with the E5072A's IFBW of 10 Hz. It is recommended that the measured PIM value of the DUT should be higher enough (at least 10 dB above) than the residual PIM level of the system.

Figure 22 shows a typical result of swept-frequency PIM measurement with +43 dBm two-tone signals for the 850 MHz band DUT. Low-side, 3rd-order PIM products are measured from 844 to 849 MHz by holding the main tone at 869 MHz and sweeping the other tone from 894 to 889 MHz. You can minimize the trace noise with the E5072A's minimum IFBW of 10 Hz. Also you can improve the throughput by selecting the appropriate IFBW of the E5072A receivers, depending on the required measurement accuracy.

# Summary

The innovative solution with the E5072A provides cost efficiency for testing PIM and S-parameter in production, QA and R&D. With the key features of Flexible configurations, Fast measurements and Accurate measurements, you can replace the existing test systems of passive components and maximize your test productivity.
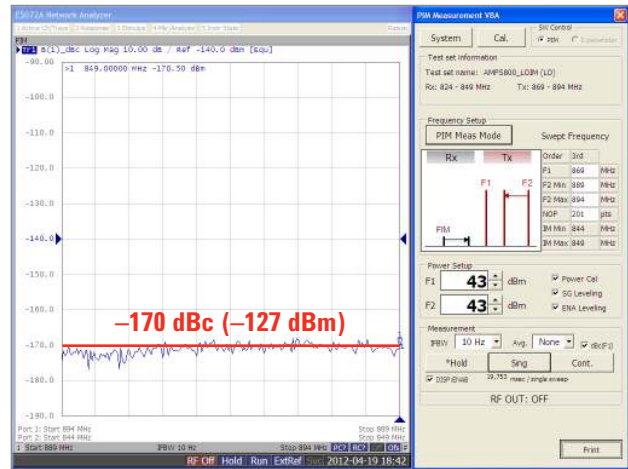


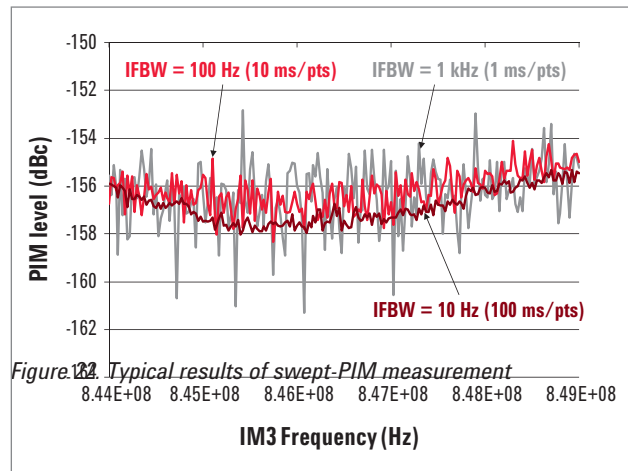Figure 21. System residual PIM performance with a low PIM load



Figure 22. Typical results of swept-PIM measurement

# Appendix A. Block diagram of the E5072A

The E5072A with a configurable test set provides access to the signal paths between the internal source, receivers, bridges, and the analyzer's test ports. The block diagram of the E5072A is shown in Figure 23. Each test port (port 1 and port 2) of the E5072A is associated with six SMA connectors for direct receiver access on the front panel (Figure 24).
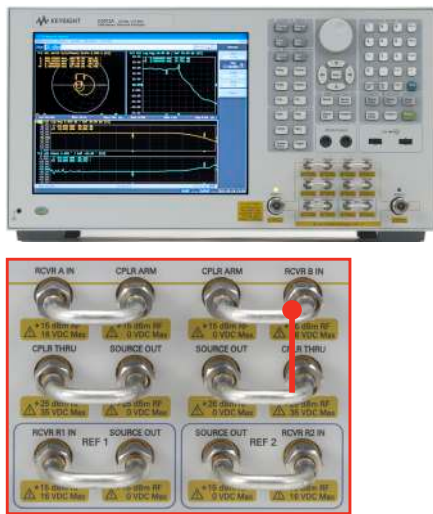




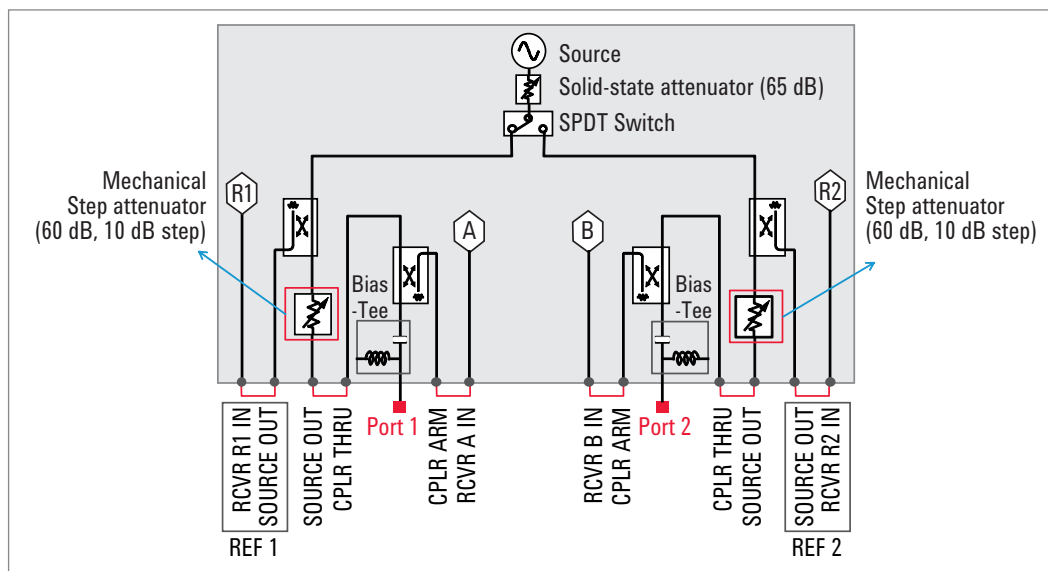*Figure 24. Test port jumpers on front panel*

# References

PIM measurement web page:
http://www.keysight.com/find/pim

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http://literature.cdn.keysight.com/litweb/pdf/5990-8001EN.pdf

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ENA series web page: http://www.keysight.com/find/ena

E5072A web page: http://www.keysight.com/find/e5072a

*Figure 23. Block diagram of the E5072A*

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