

IMD and RF Power Measurements with the Keysight PNA-X N5249A

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Introduction

The aim of this Technical Report is to explain how to manually configure and calibrate the Keysight N5249A 4 port PNA-X to make frequency sweep IP2, IP3, Gain and RF power sensing (with USB power sensor HP U2004A) measurements simultaneously, without using Keysight's upgrade options.

The PNA-X has been purchased in 2015 with only the Frequency Offset (Option 080), that means the ability to tune the receiver at frequencies other than those of the transmitter.

In 2016 has been upgraded with the Internal Combiner & Mechanical Switches (Option 423) that adds an internal mechanical combiner which combines RF signals from two sources internally, simplifying test set-ups for two-tone measurements.

Another Upgrade was made in 2016 with the Source-Corrected Noise Figure Measurements (Option 029) that adds the possibility to make Noise measurements with the cold source method using the PNA-X.

This technical report explains the procedure for calibration and measurement of non-linearity's RF devices with or without the upgrade of the Option 423.

1. Without Option

1.1. Source Power Calibration

Before calibrating is necessary to make a proper setup of the instrument:

- I. Stimulus → Frequency → Frequency offset...: set to **OFF**
- II. The channel that will be calibrated must contain all the frequencies for the measurements (i.e. frequency span must be greater than the frequencies that will be measured: from $[2f_{1min}-f_{2min}]$ to $[2f_{2max}-f_{1max}]$ for IMD3 and $[2f_1, f_1+f_2$ and $2f_2]$ for the IMD2)
- III. Set up Power&Attenuation, IFBW and number of points desired.

Set up the connection as in **Errore. L'origine riferimento non è stata trovata.**:

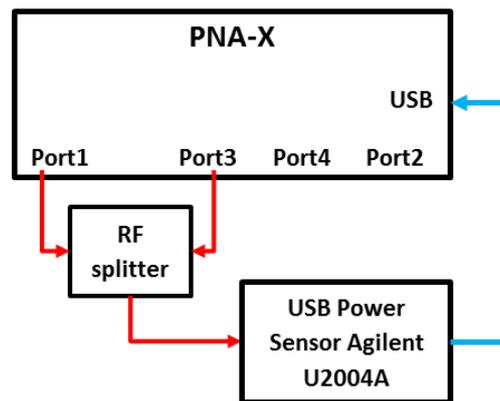


Figure 1 - Source Power Calibration without Option 423.

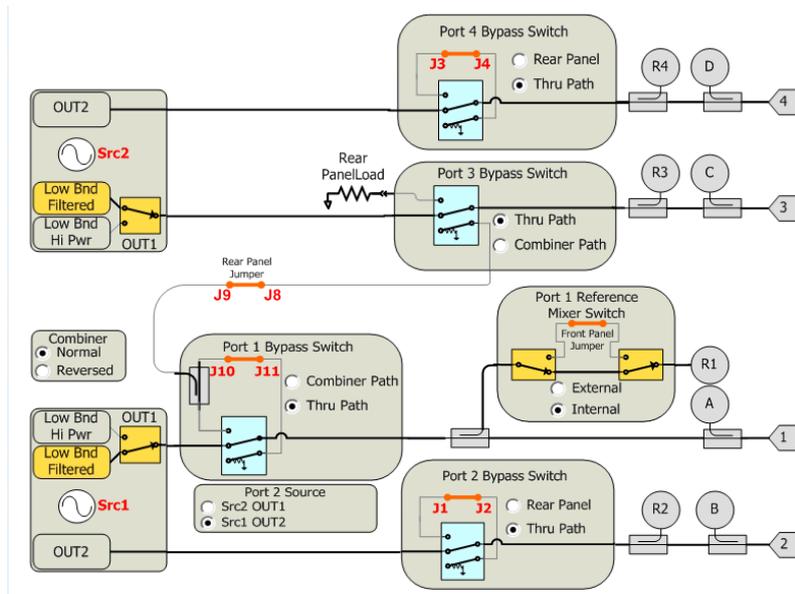


Figure 2 – PNA-X path configuration.

Response → Calibration → Power Calibration → Source Power Calibration (see Figure 3)

1. Stimulus → Power & Attenuation → Set Port1 ON and other ports OFF.

Set **Power Offset**=0dB in the display window (now has been calibrating source port 1)

Channel&Source Port selection: Ch.1 → Port 1

- i. Options → Use Power Meter (Select: Calib the PNA ref. receiver, see Figure 4) → OK
- ii. Power Meter Configuration → Select: USB
- iii. Sensor → Internal Zero → Zero → OK

Exit from *Sensor* and select (in *Power Meter Settings* window) Take Calibration Sweep.

If everything goes well it will be displayed: "PASS".

- 2) Stimulus → Power & Attenuation → Set Port3 ON and other ports OFF.

Set **Power Offset**=0dB in the display window (now has been calibrating source port 3)

Channel&Source Port selection: Ch.1 → Port 3

- i. Options → Use Power Meter (Select: Calib the PNA ref. receiver) → OK
- ii. Power Meter Configuration → Select: USB
- iii. Sensor → Internal Zero → Zero → OK

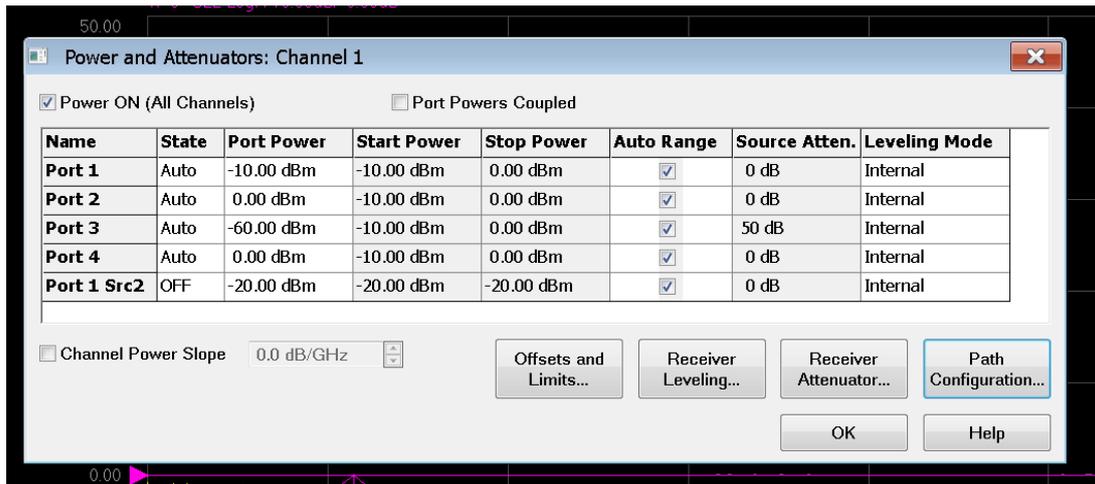


Figure 3 – PNA-X Power and Attenuators configuration menu.

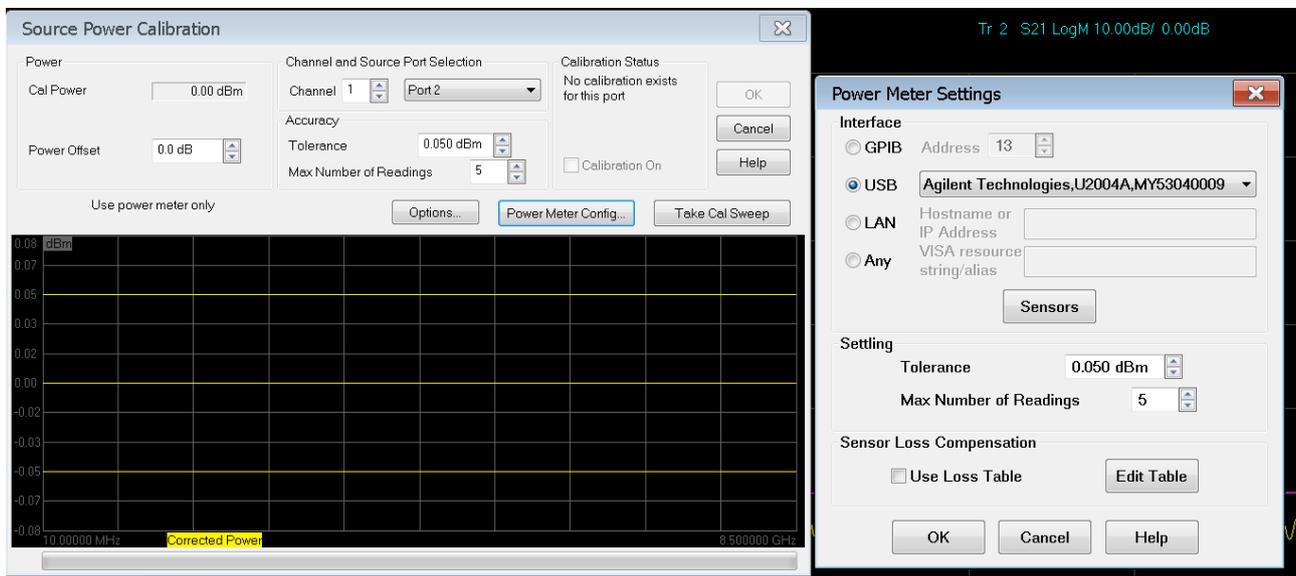


Figure 4 – PNA-X Source Power Calibration and Power Meter Settings menu.

Exit from *Sensor* and select (in *Power Meter Settings* window) Take Calibration Sweep.

If everything goes well it will be displayed: “PASS”.

In the bottom bar will be displayed “SrcPwrCal” (see Figure 5).



Figure 5 – PNA-X message after Source Power Calibration.

1.2.Receiver Power Calibration

Set up the connection as in Figure 6 to make the Receiver Power Calibration.

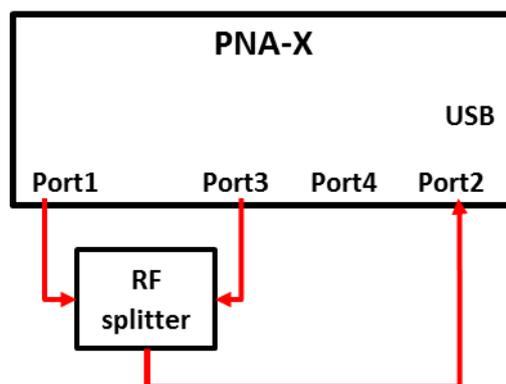


Figure 6 - Receiver Power Calibration bench setup without Option 423.

Stimulus → Power & Attenuation → Set Port1 ON and other ports OFF.

1. Right click in the trace → Measure → *Receiver* section → Activate B → Source Port1
2. Response → Receiver Power → Next → Take Receiver Cal Sweep → Next → Finish

In the bottom bar will be displayed “**C:Response**” (as in Figure 7).

It is recommended to save the instrument state:



Figure 7 - PNA-X message after Receiver Power Calibration.

File → Save As.. → Save as Type “State and Cal Set Data (*.csa)”.

2. With Option 423

2.1. Source Power Calibration

Before calibrating is necessary to make a good setup of the instrument:

- I. Frequency offset: **OFF**
- II. The channel that will be calibrated must contain all the frequencies for the measurements (i.e. frequency span must be greater than the frequencies that will be measured: from $[2f_{1min}-f_{2min}]$ to $[2f_{2max}-f_{1max}]$) for IMD3 and $[2f_1, f_1+f_2$ and $2f_2]$ for the IMD2)
- III. Set up IFBW and number of points desired.
- IV. In **Stimulus** → **Power** → **Path Configuration...** → **Configuration** (window menu) → select Port 1 2-Tone.

Set up the connection as in Figure 8:

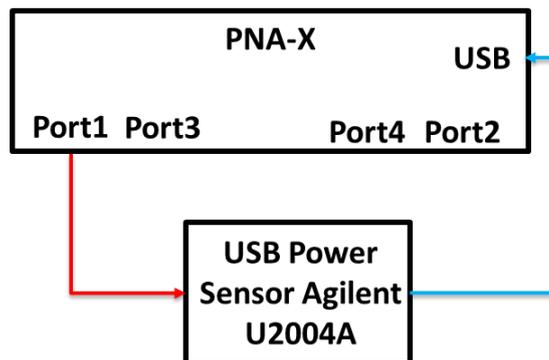


Figure 8 - Source Power Calibration bench setup with Option 423.

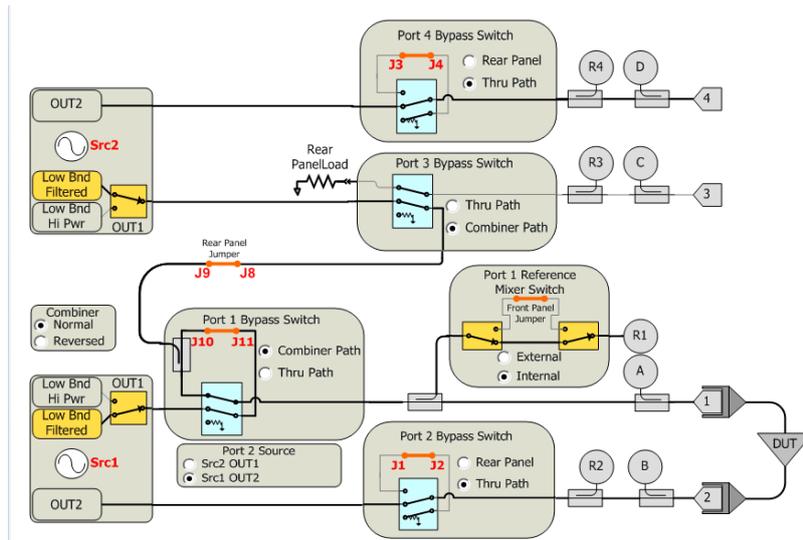


Figure 9 – PNA-X path configuration.

Response → Calibration → Power Calibration → Source Power Calibration

2. Stimulus → Power & Attenuation → Set Port1 ON and other ports to OFF.

Set **Power Offset**=0dB in the display window (now has been calibrating source port 1)

Channel&Source Port selection: Ch.1 → Port 1

- i. Options → Use Power Meter (Select: Calib the PNA ref. receiver) → OK
- ii. Power Meter Configuration → Select: USB
- iii. Sensor → Internal Zero → Zero → OK

Exit from *Sensor* and select (in *Power Meter Settings* window) Take Calibration Sweep.

If everything goes well it will be displayed: “PASS”.

3) Stimulus → Power & Attenuation → Set Port1 Src2 ON and other ports OFF.

Set **Power Offset**=0dB in the display window (now has been calibrating source physical port 1 named Port1 Src2)

Channel&Source Port selection: Ch.1 → Port 1 Src 2

- i. Options → Use Power Meter (Select: Calib the PNA ref. receiver) → OK
- ii. Power Meter Configuration → Select: USB
- iii. Sensor → Internal Zero → Zero → OK

Exit from *Sensor* and select (in *Power Meter Settings* window) Take Calibration Sweep.

If everything goes well it will be displayed: "PASS".

In the bottom bar will be displayed "**SrcPwrCal**" (see Figure 5).

2.2.Receiver Power Calibration

Set up the connection as in Figure 10 to make the Receiver Power Calibration.

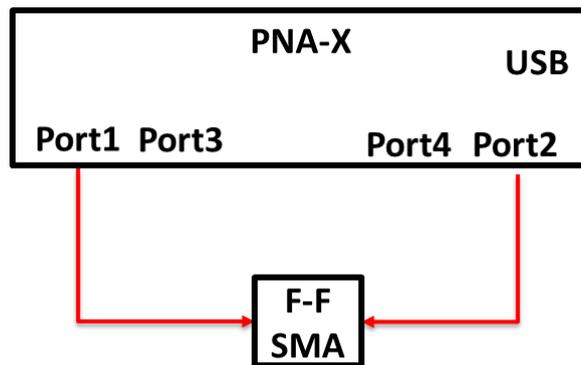


Figure 10 - Receiver Power Calibration bench setup with Option 423.

Stimulus → Power & Attenuation → Set Port1 ON and other ports to OFF.

3. Right click in the trace → Measure → *Receiver* section → Activate B → Source Port1
4. Response → Receiver Power → Next → Take Receiver Cal Sweep → Next → Finish

In the bottom bar will be displayed "**C:Response**" (see Figure 7).

It is recommended to save the instrument state and calibration
File → Save As.. → Save as Type "State and Cal Set Data (*.csa)".

3. Instrument set up to acquire IP2, IP3

Recall of Source&Receiver Power Calibration (File → Recall..)

Now is necessary to set the instrument to acquire an IMD measurement, with a variable central frequency and fixed tone spacing of 1MHz, varying RF power. First of all the PNA-X must be set up in **Frequency Offset mode**.

To add IP3 measurement, must be followed the points below:

- 1) Set up PNA-X to display tone1 (f1) in channel1:
Stimulus → Frequency Offset:
 - a) select **Primary** setting the range test frequencies; *
 - b) set up **Frequency Sweep**;
 - c) **Source 1** is fc-f1: -500kHz, multiplier=1;
 - d) **Source 2** is fc-f2: +500kHz, multiplier=1;
 - e) **Receiver** is the frequency at which we want the receiver will be tuned (-500kHz, tone1).
- 2) **Measure → Receiver** select **Activate B** (RX port2) from the second drop-down menù, “ / 1.0 ” and **Port 1** than **Apply**.
- 3) **Stimulus → Power & Attenuation** → Enable (ON) port1 and 3, while disable porte2 and 4.

Repeat 3 times point 1) (copying Channel 1) changing with: tone2 (f2), IMD3L (2f1-f2) and IMD3H (2f1-f2) changing only point **1.e)** with the correspondent **Receiver** frequency (+500kHz,-1500kHz e +1500kHz).

Moreover should be set up correctly section **2)** for every channel.

For a better trace reading, name's trace can be edited. From the previous 4 traces already done could be created **IP3** traces.

In section Marker Analysis → Analysis → Equation Editor → typing the IP3 calculus equation:

$$\text{Trace2} \times \text{sqrt} (\text{Trace2}/\text{Trace4}) \quad [\text{in dB: } \frac{1}{2}*(3f1-\text{IMD3})]$$

It is possible to create a worst case formula taking into account the worst case:

$$\text{min}(\text{Tone1}, \text{Tone2}) \times \text{sqrt} (\text{min}(\text{Tone1}, \text{Tone2})/\text{max}(\text{IMD3L}, \text{IMD3H}))$$

* Frequency range must be chosen taking into account the frequencies which will be measured with the receivers (2f1-f2 for the lowest and 2f2-f1 for the highest), not to exit the frequency range of the desired measuring points.

4) To add an **IP2 measurement**, points 1 to 3 must be repeated with the following changes:

- Trace Tone IP2:

Stimulous → **Frequency Offset**:

- **Primary**: $[f_{start}:f_{stop}/2]$;

- **Source 1**: -500kHz, multiplier=1;

- **Source 2**: +500kHz, multiplier=1;

- **Receiver**: one of the 2 fundamental tones for example tone1, -500kHz).

- Trace HD2:

In **Stimulous** → **Frequency Offset**:

- **Primary**: $[f_{start}:f_{stop}/2]$;

- **Source 1**: -500kHz, multiplier=1;

- **Source 2**: +500kHz, multiplier=1;

- **Receiver**: correspond to $2f_c$ so Receiver should be 0Hz, **Multiplier = 2**.

- Trace OIP2:

Using the equation editor and typing the following formula:

$$\text{Tone IP2} \times (\text{Tone IP2} / \text{HD2})$$

$$[\text{in dB: } 2f_1 - \text{HD2}]$$

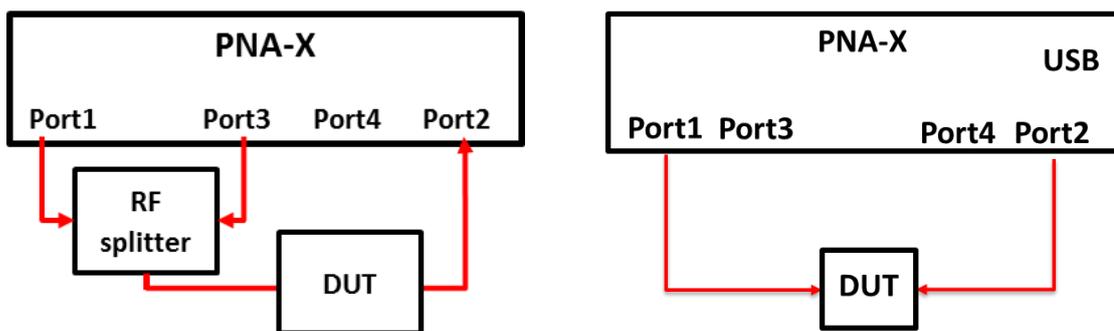


Figure 11 – Measurement setup (left: without Option 423, right: with Option 423).

4. Instrument set up to measure the Gain

To create a **Gain** trace: Trace → Measure → Receiver → **Activate B / R1** and **Source Port 1**.

Is recommended to **save the instrument state**.

5. RF power measurement with USB power sensor

1. *Frequency Offset* must be set to OFF and *Sweep Type* to Frequency Sweep;
2. Add the USB Power Sensor in the PNA-X:
Utility → **Configure** → **External Device Configuration** → Set USB interface and, clicking **Refresh**, select the Power Sensor correspondent address adding to the external device's list (can be useful give it a name as *Power Meter* to recognize it);
3. Create a trace to measure the RF power vs frequency: **Measure** → **Receivers** → enable **A** → select the *Power Meter* instrument in the window drop down menu **Numerator** than press **OK**.

Credentials for the remote control:

User: PNA-Admin

Password: pna