Agilent PNA and PNA-L Network Analyzers
Mixer Compression Magnitude and Phase (AM-PM) Measurements

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The step-by-step procedures in this document were written for PNAs and PNA-Ls with firmware revision A.06.03.05. If your network analyzer has a different firmware revision, the step-by-step procedures or screenshots may vary. The concepts and general guidelines still apply.

1. Mixer Test Options on PNAs and PNA-Ls

<table>
<thead>
<tr>
<th>Description</th>
<th>Option</th>
<th>PNA-L</th>
<th>PNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency-Offset Mode (FOM)</td>
<td>080</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Scalar Mixer Calibration (SMC)</td>
<td>082</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Reference Receiver Switch</td>
<td>081</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Vector Mixer Cal (VMC)</td>
<td>Part of 083</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Frequency Converter Application (FCA)</td>
<td>083</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

To test the compression and AM-PM of a mixer, the easiest solution is to use the Vector Mixer Cal, which would provide both the magnitude and phase information, easily and accurately. If you have a PNA-L (and thus only have SMC, not VMC), then you can use the SMC portion to measure the compression magnitude. You will need to use FOM to measure the AM-PM. You can also use FOM to measure the compression magnitude, as described in the next section, but the setup is more cumbersome.
2. **Measuring mixer compression magnitude using FOM (Option 080)**

Procedure to test compression magnitude of a mixer using Frequency-Offset mode (Option 080) on a 2-port PNA or PNA-L network analyzer with a single source.

Connect Mixer as shown.

Setting for our test mixer:
- Input or RF frequency: 2.6 or 2.62 GHz
- LO frequency: 2.2 GHz
- Output or IF frequency: 400 MHz

Since we are measuring compression over power, we set up a power sweep.

Power Sweep Settings:
Note: If your mixer is integrated with an amplifier and there is gain in the system, consider using the B receiver attenuators (the 35 dB step attenuators) to keep the mixers (B receiver) out of compression.

Set the # points and IFBW. Set up a R1 and B receiver measurement. The R1 receiver measures the incident power (or RF Power). The B receiver measures output power (or IF power). The ratio of B/R1 is conversion loss. S21 is also a ratio of output power to input power, but we cannot use S21, because we are testing a mixer. S21 is a ratio of the output power to the input power at the same frequency. Since our input and output signals are at different frequencies, we need two different channels for the two different receivers. When Frequency Offset is enabled, all receivers on the channel tune to the offset frequency, including the reference receiver. Therefore S21 (conversion loss) measurements will not display the response frequency relative to the input frequency.

Turn on the frequency-offset mode, though no actual offset setting is needed. Because we are measuring R1, which is at the input frequency.

Next copy channel 1 to channel 2, to set up the B measurement, for the IF or output frequency.

Change the measurement to B, and set the appropriate offset for the B receiver (measuring the output or IF of the mixer). The offset is -2.2 GHz in our example (our LO setting).
Trace > Measure > B
Have your LO connected and set to the right power level. Make sure the internal reference switch is set to the “internal” position. (Option 081, reference switch, available only on PNAs)

Put marker on both traces, and use coupled markers.

We’ll calculate the conversion loss on a third trace, using the equation editor. On channel 2, set up a new trace (not a new channel).

It’s okay if it’s S11, as the trace is only used as a place-holder for the equation editor. Go into the equation editor menu, and set it to measure Trace 2/ Trace 1. (Trace 1 being the straight line).

Place a marker on the equation editor trace. This equation trace is now the conversion loss of the mixer, and it should show the compression at the higher power levels.

Find the 1 dB Compression point using reference/delta marker on the equation editor trace.
In this example, the 1 dB compression for this mixer occurs at about -0.68 dBm of input power, with -6.7 dB of conversion loss.

Note: If you notice a roll-off or drop off at the first point, try changing the frequency or widening the IFBW to see if it resolves the issue.

The above measurement is uncalibrated. Generally it is a good idea to set up a measurement without a calibration to make sure it works, and that the numbers are roughly correct. The exception to this process is the Vector Mixer Calibration (VMC) application, where uncalibrated VC21 measurements have no value. Also, if you have any receiver attenuator settings or have external attenuation, the uncalibrated values could be x dB off, with x equal to the amount of attenuation.

The level of calibration for a compression measurement is dependent on the measurement needs for accuracy. If you are going to go through a Cal procedure, the assumption is that you want accuracy. And the easiest way to get the most accurate magnitude conversion loss compression measurement is to use the Scalar Mixer Calibration application. SMC corrects for both power level adjustments and mismatch errors. The following section describes the calibration procedure using FOM, but better accuracy is achieved with an SMC Calibration.

### 3. Calibrating mixer compression magnitude using FOM (Option 080)

The procedure in this section describes how to get an accurate conversion loss value at the same time as find the 1 dB compression point.

There are multiple steps involved in this process. However, the concept is quite simple. To make absolute power measurements on a network analyzer (an R1 or B receiver measurement), you need a Receiver Power Cal. A Receiver Power Cal calibrates the receiver for absolute power measurements. Note that traditional network analysis focuses on relative measurements (S-parameters), and the well-known 2-port Calibration removes systematic errors such as directivity and load match. While a 2-port Cal can just be started on its own using a
Cal kit, a receiver cal first requires an accurate source power cal, a parent cal. A Receiver Cal is a simple normalization, similar to a Response Cal, though slightly different (no phase information in a Receiver Cal).

A Source Power Cal calibrates the source using a Power Meter. Once the source is calibrated (a known quantity, a known unit), then the receiver can be Calibrated based on that source.

We need to perform a Receiver Cal on the B measurement, if we want accurate output power. So we’ll have to start with a Source Power Cal. We need to pay attention to the frequencies though, since we are testing a mixer.

1. **Channel 2:** Calibrate Port 1 Source for IF frequency using a Power Meter Cal
2. **Leave Power Sensor connected to port 1. Click on Channel 1 Trace (R1). Perform a Source Power Cal at the RF frequency (Step 2).** Step 2 does not follow the logic of the source Cal/receiver Cal for the B receiver. However, to minimize the number of connections and disconnections, we perform the step here. It’s a calibration of the source at the RF frequency. **Channel 1: Calibrate Port 1 Source for RF frequency using a Power Meter Cal**
4. **Switch to Channel 2: Make through Connection between port 1 and port 2. Channel 2: Perform Receiver Cal at IF frequency**
5. **Channel 2: Change Port 1 to input frequency & set FOM offset to get desired IF**

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**Step 1**

![Image of Frequency Offset Settings](image1)

This is the IF Frequency. CW setting in power sweep mode.

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![Image of CW Frequency](image2)

This is the IF Frequency.

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Source Power Cal at IF Frequency on Channel 2 (B Trace).
**Step 2**  
Source Power Cal at RF Frequency on Channel 1 (R1 Trace).

**Step 3**  
Disconnect power sensor.

**Step 4** Switch back to Channel 2/Trace B. Receiver Cal at IF Frequency.

**Step 5**  
Change FOM setting back. So source is at RF frequency. Offset set such that receiver is at IF frequency.

You can also obtain a Receiver Cal on the R1 measurement. Simply select the R1 trace and go through the Receiver Cal procedure.

The Scalar Mixer Calibration would greatly simplify this whole process AND increase accuracy by adding mismatch correction to the conversion loss measurements, for a measly $5,000.

Note: If you’re using a PNA or PNA-L, and your analyzer is not equipped with Option 082 or 083 (which supply SMC), I highly recommend you try and purchase it. It’s a firmware option, can be purchased and upgraded quickly and easily (no need to even move the PNA), and it’s truly worth the money.
Now you have a Calibrated compression measurement, as shown in the image below.

An alternative to this method is to perform a wide frequency span source power calibration on channel 1, and then copy it to channel 2. On Channel 1, you can either set up a wide frequency sweep covering both input and output frequencies, or set up a segment covering the input/output frequencies. Then you perform one source power cal and can copy it to channel 2.

If you save & recall the instrument state AND have an equation editor trace setup, the equation editor trace may not update after a recall. Go into the equation editor menu, click and unclick the equation, and it will come back and start sweeping.
4. Measuring mixer compression phase (AM-PM) using FOM (Option 080)

AM-PM Conversion of mixers using the frequency-offset mode is done using a reference mixer. Connect the mixers as shown in the diagram below.

AM-PM is the change in phase when a device is in compression. Often it is defined as the 1 dB phase change, at the 1 dB compression point.

AM-PM is measured by comparing the output of the DUT to the output of the reference mixer (B/R1 measurement). The reference mixer is kept out of compression by the addition of an attenuator in the RF path. The reference mixer can be identical to the mixer under test.

Configure the PNA for a power sweep and frequency-offset settings. Also, set the reference switch (available with Option 081) to external mode. If your PNA does not have a reference switch or you have a PNA-L, the measurement path is automatically set to the external path. In such a scenario, if you get a phase-lock lost error message, turn frequency-offset mode On to eliminate that error.

Power Sweep Menu
Frequency Offset Menu – Both B & R1 receivers will measure the IF frequency. So set the FOM menu for the appropriate offset.

Reference Switch Menu

Configure the PNA to measure B/R1. In this case, both B and R1 are at the IF or output frequency, with the same LO, so you can have a valid phase comparison of B/R1. Set up two B/R1 traces. One in log mag format, one in phase, as shown below.

On the magnitude trace, you can find the 1 dB compression. Then on the phase trace, measure the AM-PM Conversion.

A few notes:
- Use Coupled Markers (coupling between traces) for easier measurements.
- No calibration is necessary in the AM-PM measurement, as it is all relative.
- If you need to trouble-shoot, you can individually measure B and R1.
- If the mixers are the same type of mixer, in the linear range, the difference between B & R1 should be the loss of the attenuator.
5. Measuring mixer compression magnitude using SMC (Option 082)

Setup an SMC measurement. See the PNA Help System for detailed information on SMC.
http://na.tm.agilent.com/pna/help/PNAWebHelp/FreqOffset/FCA_cals.htm#SMC

For the input (in yellow), select the Start/Stop mode, but Set the start and stop frequency to the same value.

Switch to Power Sweep. Note: You can’t use the front panel hardkeys. You need to use the drop down menu.

Set the points & IFBW. Now you have an uncalibrated SMC measurement.

6. Calibrating mixer compression magnitude using SMC (Option 082)

Perform an SMC Calibration. Use the Cal Wizard. Guidance provided in the PNA Help System.
http://na.tm.agilent.com/pna/help/PNAWebHelp/FreqOffset/FCA_cals.htm#SMC

Once the Cal is performed, you can find the 1 dB compression point using the markers.

7. Measuring mixer compression phase (AM-PM) using SMC (Option 082)

This measurement is not feasible, since SMC is only for scalar measurements and does not include phase information. For AM-PM measurements of mixers, use the basic frequency offset mode (080) or the Vector Mixer Calibration, VMC.
8. Measuring mixer compression magnitude & phase (AM-PM) using VMC (Option 083)

Set up a VC21 trace for both magnitude & phase. See the PNA help system for a detailed VMC Guide.
http://na.tm.agilent.com/pna/help/PNAWebHelp/FreqOffset/How_to_make_a_VMC_Fixed_Out_measurement.htm
http://na.tm.agilent.com/pna/help/PNAWebHelp/FreqOffset/ConfigureMixer.htm#PowerSweep

Change to Power Sweep using drop down menu. Hardkeys don’t function as expected. The uncalibrated VC21 values don’t have absolute meaning, as they are relative measurements, relative to the reference mixer.

9. Calibrating mixer compression magnitude & phase (AM-PM) using VMC (Option 083)

Calibrate the VMC trace using the guided calibration. See the PNA Help System for more information.
http://na.tm.agilent.com/pna/help/PNAWebHelp/FreqOffset/FCA_Cals.htm#VMCSetup

The VC21 magnitude and VC21 phase values provide the 1 dB compression point for both magnitude and phase.