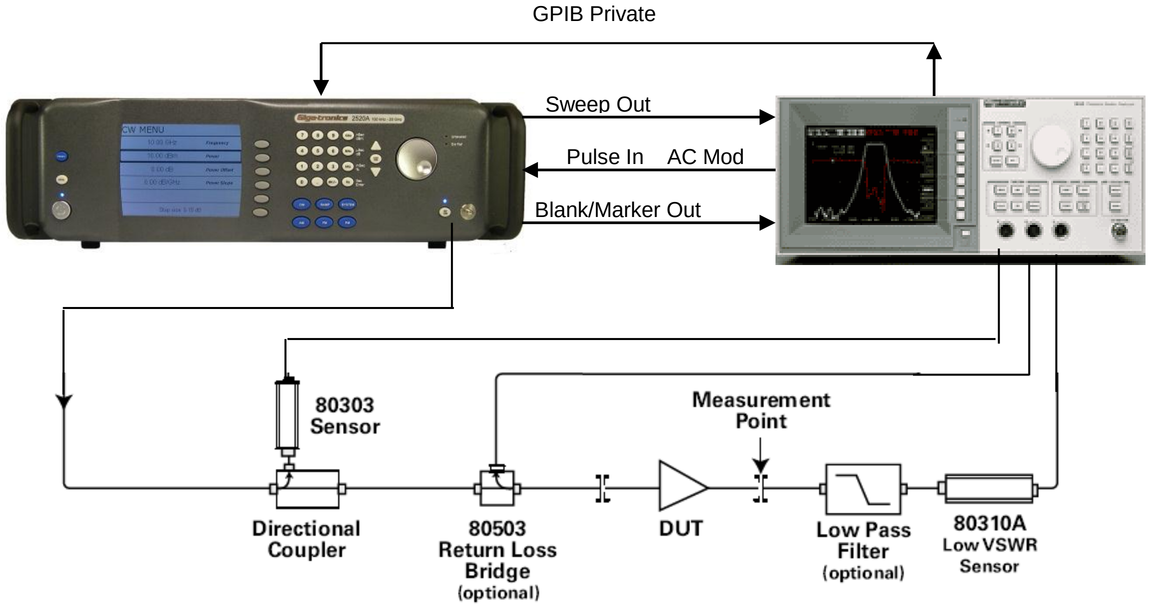
Technical Brief

Power Amplifier Gain Compression Measurements



Overview

The 1 dB gain compression of an amplifier describes the region where the gain drops off 1 dB compared to the small signal linear region. The industry standard for specifying the gain and output power of an amplifier is the 1 dB gain compression point (P1dB). By improving the accuracy of the 1 dB compression point measurement, manufacturers can provide more competitive products that are not specified in an overly conservative way.

This application note describes how the fast and accurate frequency sweep of the Giga-tronics 2500B Microwave Signal Generator, combined with the power meter accuracy of the Giga-tronics Model 8003 Scalar Network Analyzer, can be used to tune amplifiers for optimum performance whilst reducing test times.

Scalar Network Analyzer versus Power Meter

The traditional approach to measuring gain compression is to use a power meter. A difficulty in obtaining accurate data of gain compression is the fact that amplifiers are at their 1 dB gain compression point only at particular frequencies. In order to verify the worst case 1 dB compression point when using a power meter, many repetitions might be necessary at different frequencies. This approach is time consuming and expensive.

Power measurement at the 1 dB compression point using the swept frequency method offers improved convenience over single frequency methods. Unlike single frequency methods, all portions of the band of operation can be viewed simultaneously, averting the problem of the operator overlooking potential “holes” that might exist in the amplifier’s response. It is also possible with this method to simultaneously use the scalar network analyzer to tune gain and return loss “interactively” while making the measurement to obtain the best possible overall performance.

Scalar network analyzers are the instruments of choice for production testing and tuning of microwave amplifiers. Scalar network analyzers allow fast, swept frequency measurement of amplifier gain, return loss (VSWR) and power output. The problem was that, historically, power measurements using scalar network analyzers were just an approximation. This was due to their inherent lack of power measurement accuracy and NIST traceable standard within the instrument. Typical power measurement accuracy for earlier scalar analyzers might range from ±0.5 dB to greater than ±2.0 dB. This would depend on a number of factors, such as the scalar analyzer used, sensor type, frequency range, and the power level to be measured. The Giga-tronics 8003 Scalar Network Analyzer incorporates a built-in power meter and diode sensor for performing fast, accurate power measurements. It can be viewed as a swept power meter with scalar analyzer speed, processing power and convenience.

The sweep speed of the scalar network analyzer is influenced by the frequency switching speed of the signal source. For optimum frequency accuracy, the signal source needs to be a synthesized signal generator set for digital step sweep. Switching times for a typical synthesized signal generator are in the 5 to 10 ms range that can result in a sweep too slow for optimum tuning. For example, an amplifier that operates in X-band may need to be characterized from 8 to 12 GHz at 10 MHz steps. For a source stepping at 10 ms per step, the result is a sweep 4 seconds long — too slow for “real-time” tuning. For a more optimal tuning rate of 200 ms, the step size using this source will have to be 500 MHz wide — too wide to catch glitches or find the true compression point. What is needed is an accurate, fast switching signal source. The Giga-tronics 2500B series Microwave Signal Generators provide frequency switching speeds of under 500 µs per step (as fast as 200 µs per step for 10 MHz steps) for optimum speed and measurement accuracy. With the fast frequency speed of the 2500B series Microwave Signal Generators and the power meter accuracy of the 8003 scalar network analyzer, gain compression measurements can now be made with very fine frequency resolution without sacrificing overall measurement speed or accuracy. Using this system for the example given above, the Giga-tronics 8003 Scalar Network Analyzer will measure the X-band amplifier from 8 to 12 GHz in 10 MHz steps easily in the desired 200 ms or less time frame.

Description of Operation

The following method allows the scalar network analyzer to be set to simultaneously display the gain and output power of the amplifier under test. The input power to the amplifier under test is gradually increased until it is determined that, at some point in the band, the amplifier's gain has decreased by 1 dB. This is the first frequency and the lowest input power level at which the amplifier under test is at the 1 dB compression point. The "Search" feature of the 8003 can be used if desired to automatically position the cursor at the -1 dB point with respect to the 0 dB reference. Simultaneously, the channel connected to the amplifier's output displays the power output. The cursor then provides the frequency where the 1 dB compression point first occurs as well as the output power of the device.

Selecting between AC and DC Detection

The 8003 scalar network analyzer is able to use the AC or DC detection mode. In the AC detection mode, each point on the sweep is measured twice, once with the signal source power on and then with the signal source power off. Consequently, this method provides zeroing for each point measured. The AC detection method offers a maximum dynamic range of 90 dB without the need to re-zero the sensors. It should be noted that AC detection might induce problems with amplifiers, especially those with Automatic Level Control (ALC). For such devices, switch the analyzer to the DC detection mode for best results.

Configuring the 8003 SNA and 2500B Microwave Signal Generator for Gain Compression Measurements

Figure 1 below, describes how to set up the 8003 scalar analyzer and 2500B microwave signal generator to perform a low power (< 20 dBm) 1 dB gain compression measurement. For high power measurements, the return loss bridge is replaced with a high power coupler. Also, in order to measure the high output of the DUT, the sensor is connected to the coupled port of a high power coupler, which is terminated by a high power load.

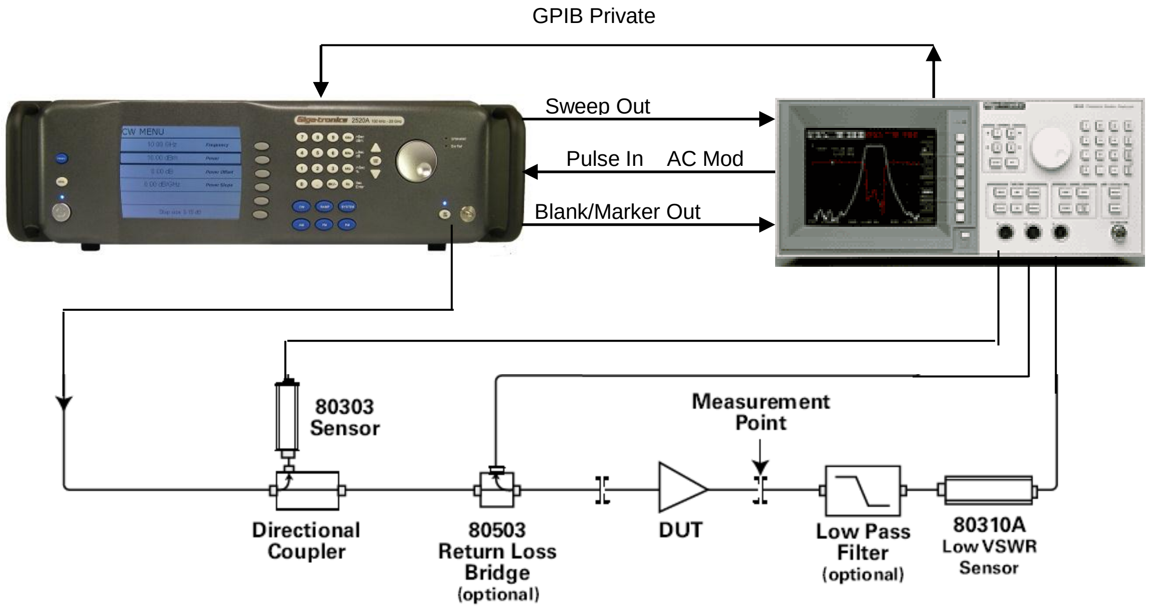


Fig 1 Connections Diagram

Calibration Procedure

The following procedure is used to calibrate out the couplers, bridges, and filter used in the low power measurement setup. The benefit of this approach is that the user can then effectively measure absolute power at the input and output of the DUT while the sensors are connected to couplers, etc. The low pass filter is used to minimize the effect of harmonics when measuring amplifiers at the 1 dB gain compression point.

Connect the equipment as shown in Figure 1 above. Include the DUT, which has been turned off.

Set Signal Generator Sweep Resolution

On the 2500B Select **[Ramp]** hardkey
Select **[Resolution]** softkey and use the **[Step Size]** increment key to set the resolution to 1601 points.

Set Signal Generator GPIB Address

Select **[System] [Menu 2][GPIB Address][Step Size Increment/Decrement**] and set address to 4.

Preset the 8003

Select [PRESET] [CONFIRM PRESET]

Turn ON the 8003 private bus connection to the signal generator

[CONFIG] [GPIB DEVICES] [PVT BUS ON/OFF]

Set Device Under Test (DUT) measurement parameters

Set the Start Frequency
[Start] Enter DUT start parameter **[GHz]**
Set the Stop Frequency
[Stop] Enter DUT stop parameter**[GHz]**
Set the Power Level
[Power] Enter DUT input Power Level
[Power On/Off] ON
Set the Sweep Speed
[Sweep Time] Enter sweep time

Turn OFF 8003 channels 3 and 4

[CH 3] [OFF] [CH 4] [OFF]

Define Channel 1 to display sensor C. Define Channel 2 to display the ratio of C/A:

[CH 1] [DEFINE] [SINGLE SENSOR] [C]
[CH 2] [DEFINE] [RATIO] [C/] [C/A]

Set Amplifier DUT Signal Input Level

Set the input power to the small signal region of the amplifier by observing that the power at the "Measurement" port is at least 10 dB below the anticipated value of P1dB:

Select **[POWER]** and adjust for small signal region.

Normalize the gain measurement using Path Calibration and set the scale factor to 0.5 dB:

[CAL] [THRU] [STORE THRU A] [STORE THRU C] [SCALE] [AUTOSCALE] [0.5] [GHz/dB]

Increase the input power until the trace displaying gain on channel 2 is -1 dB:

[POWER] Adjust for displayed gain of -1 dB.

Turn off path calibration for channel 1, autoscale, and read the output power:

[CH 1] [MEAS] [ABS PWR/PATH CAL] [SCALE] [AUTOSCALE]

Cursor Measurement of Compression Point

Turn on the cursor and set it to the maximum output power of channel 1. This is the maximum output power of the amplifier when the 1 dB gain compression point is reached:

[CH 1] [CURSOR] [SEARCH] [MAX] [CURSOR] Read Pc1dB

Simultaneous Return Loss Measurement

Note that Channel 3 may be configured for a simultaneous return loss measurement using **Input B**. Press the [**Channel 3] key [DEFINE]** key [**SINGLE SENSOR] key**

Calibrate for return loss by pressing the [**CAL]** front panel key and the [**SHORT/OPEN]** softkey and store the short and open measurements. Channel 3 is now configured for a return loss measurement. For improved accuracy, the frequency response of the bridge should be removed by storing the characteristics in memory and using the [**MEAS-TRACE N]** feature of the 8003.

Read the output power and return loss of the amplifier at the frequency where the 1 dB compression point is reached. This method emphasizes the importance of using a swept frequency test for verifying the precise frequency where the amplifier first reaches gain compression.