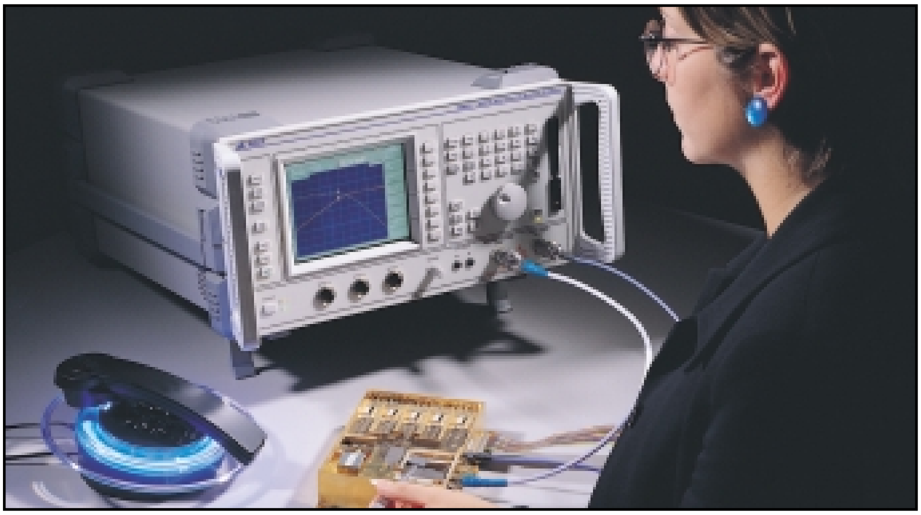
Application
Note

# Amplifier Characterization using the 6800 series Microwave Analyzers

By J McManus, Microwave Components Group



Measurement of amplifier characteristics including frequency response, spectral purity, gain compression and intermodulation distortion using the 6840 series Microwave System Analyzer.

Measurement of amplifier characteristics including frequency response and gain compression using the 6820 Microwave Scalar Analyzer.

## INTRODUCTION

This application note describes how to configure the 6800 series Microwave Analyzers (MSA) to characterize the key parameters of an amplifier.

When defining an amplifier it is usual to specify the following criteria.

1. The small signal frequency response.
2. The spectral purity; harmonic content and spurious signals.
3. The 1 dB compression point; the output power at which the gain of the amplifier drops to 1 dB below the small signal value.
4. Intermodulation distortion.

Traditionally these tests are carried out using a combination of a scalar analyzer, spectrum analyzer and a signal source.

The 6840 series Microwave System Analyzer will measure all these parameters.

The 6820 series Microwave Scalar Analyzer will measure frequency response and gain compression.

### Conventions

The following conventions are used to indicate keypresses on the MSA:

[**BOLD**]- Hardkey press, i.e. a dedicated front panel function key
[normal] - data entry via numeric keypad
[*Italic*]- Softkey press i.e. software menu key
[●] - toggle function enabled
[○] - toggle function disabled

## 1. FREQUENCY RESPONSE MEASUREMENTS (6820, 6840)

For this test the amplifier must be operated at a power level well below the 1 dB compression point. In the setup of Figure 1 a splitter and two detectors are used in what is known as the ratio method. The advantage this arrangement has over the single detector method is significantly improved source match, therefore mismatch uncertainty is reduced. The input power to the amplifier will be approximately 6 dB less than set on the MSA because of the loss in the splitter.

For this example we will arrange for -15 dBm at the input to the amplifier.

Assume the frequency range of the amplifier to be 1 to 14 GHz.

### 1.1 Test System Setup

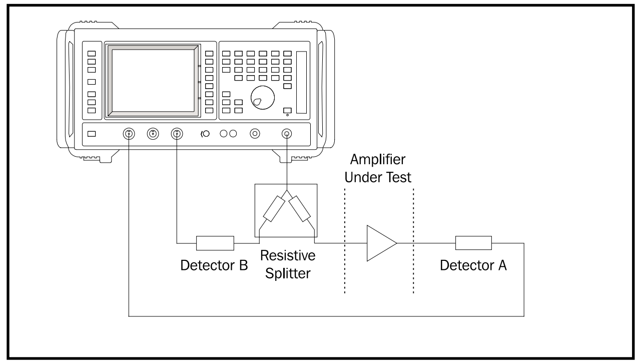



*Figure 1 - Frequency response test system*

The keypresses to set up the MSA are as follows.

[**PRESET**] [*Full*]
[**SCALAR**] [*Yes*] [*Input Selection*] [*A/C*]
[**SOURCE**] [*Set Start Frequency*] [1] [**G n**] [*Set Stop Frequency*] [14] [**G n**]
[*Set Output Power*] [-9] [**ENTER**]
[**SOURCE ON/OFF ●**]

### 1.2 Test System Calibration

To calibrate the system connect detector A to the output of the splitter. Press

[**CAL**] [*Zero Detectors*] [*Through Cal*] [*Continue*]

### 1.3 Example Measurement

Insert the amplifier as shown in Figure 1. Turn on the amplifier. The frequency response can now be observed. The markers are used to find the small signal gain and the 3 dB bandwidth.

[**SCALE/FORMAT**] [*Autoscaling*] [*Autoscale*]
[**MARKER**] [*Active Mkr to Maximum*] [*Marker Functions*] [*Bandwidth*] [*Set n dB*] [-3] [**ENTER**]
[*Bandwidth Search*]

The unit now displays the 3 dB bandwidth and centre frequency. To display the actual frequencies of the 3 dB points;

[**MARKER**] [*More*] [*Mkr Table* ●]

The display now looks like Figure 2

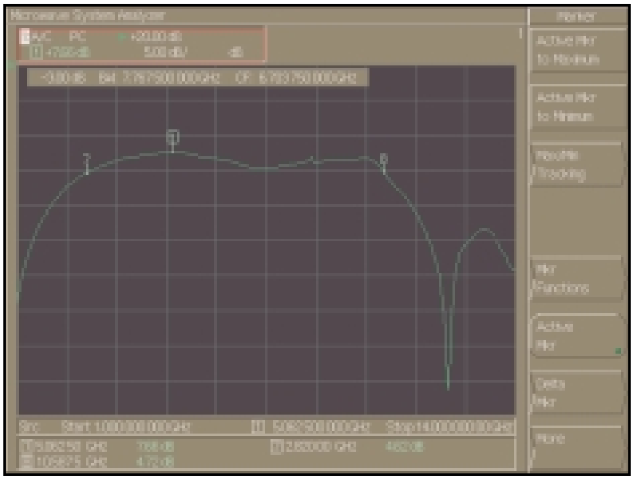


Figure 2 - Small Signal Frequency Response

## 2. HARMONIC DISTORTION MEASUREMENTS (6840)

In this test the internal source and spectrum analyzer are used together to measure harmonic distortion. The MSA source has very low harmonics (<-55 dBc) therefore the uncertainty associated with the measurement of the amplifier harmonic distortion is reduced without the need to introduce low pass filters on the source output.

When measuring harmonic distortion ensure that the reference level is set higher than the largest signal present and also that there is sufficient input attenuation, otherwise distortion products may be generated by the measuring system.

For this example we will arrange for the input to the amplifier to be 2 GHz and 10 dBm.

### 2.1 Test System Setup

To measure the harmonic distortion of an amplifier the system setup is shown in Figure 3.

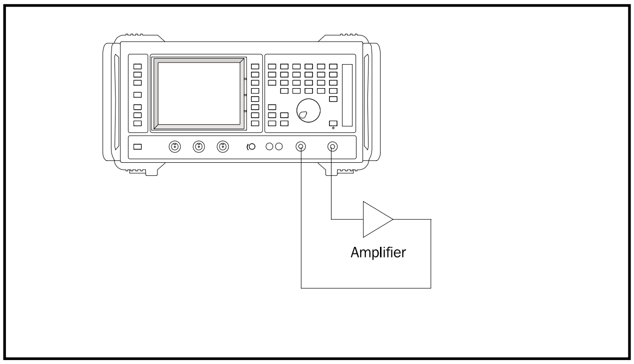



Figure 3: Harmonic Distortion Test System

The keypresses are as follows:

[**PRESET**] [*Full*]
[*Cntr/Span* ○] [*Set Start Frequency*] [1] [**G n**] [*Set Stop Frequency*] [10] [**G n**] [*Set Ref Level*] [15]
[**ENTER**] [**SOURCE**] [*Set Frequency*] [2] [**G n**]
[*Set Output Power*] [10] [**ENTER**]
[**SOURCE ON/OFF ●**]

### 2.2 Example Measurement

Turn on the amplifier. The output spectrum is now displayed. To display the harmonic levels relative to that of the carrier;

[**MARKER**] [*Peak Search Functions*] [*Identify Peaks*]
[*Return to Marker*] [*Mkr Functions*]
[*Measure Rel to Carrier* ●]

The display now shows 8 markers in the order of the relative amplitude to the carrier. As this function always displays 8 markers some of these markers may be displaying the peaks of the noise floor. To turn off these markers

[**MARKER**] [*More*] [*Set-up Mkrs*]

Now use the arrow softkeys in conjunction with the [Marker On ○] to turn off any unwanted markers.
[*Return to Marker*] to remove the table.

The display now looks like Figure 4.

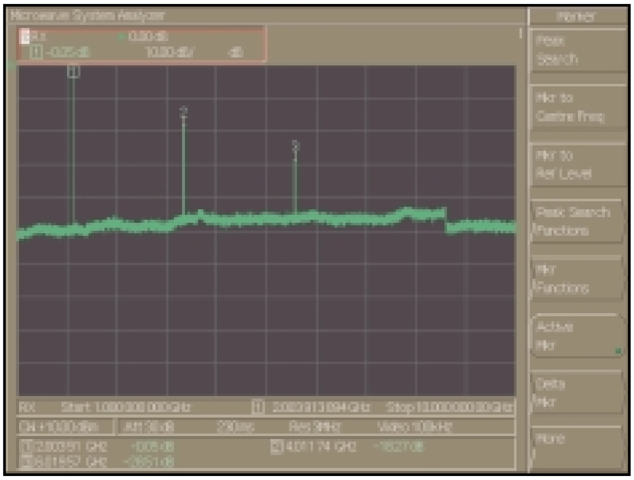


Figure 4 : Measured Harmonic Response

## 3. SWEPT HARMONIC MEASUREMENTS (6840)

The full harmonic response of an amplifier can be determined quickly by using the scalar source and the tuned input.

In this test setup, the source sweeps between two frequencies. The frequency gain response is taken over the fundamental frequency range and normalized to give a 0 dB value.

The measurement of harmonics takes place by sweeping the tuned input at the harmonic frequency while sweeping the source at the fundamental.

In this example we will measure the second harmonic for a 2 - 4 GHz fundamental, at 10 dBm input.

### 3.1 Test System Setup

To measure the harmonics, connect the system as shown in Figure 3.

The keypresses to set up the MSA are as follows;

[**PRESET**] [*Full*]
[**SCALAR**] [*Yes*] [*Input Selection*] [*Tuned Input*] [*Tuned Input*]
[*Set Res B/W*] Use [⇩] to set bandwidth to 10 kHz.
[*Set Operating Level*] [20] [**ENTER**]

This should be set to a value above the highest fundamental output power, to avoid overloading the spectrum analyzer input.

[**SOURCE**] [*Set Start Frequency*] [2] [**G n**] [*Set Stop Frequency*] [4] [**G n**]
[*Set Output Power*] [10] [**ENTER**]
[**SOURCE ON/OFF ●**]

### 3.2 Test System Calibration

The next step is to normalize the gain response. This ensures that all measured harmonic powers are displayed in dB relative to the carrier. If the absolute power is required, then this step should be omitted.

[**CAL**] [*Through Cal*] [*Continue*]

### 3.3 Example Measurement

To measure the second harmonic response press,
[**SCALAR**] [*Conversion Measurement*] [*Advanced Setup*] [*Set Frequency scaling*] Enter the harmonic number of interest (in this example 2).
[2] [**ENTER**] [*Apply Scale Offset ●*]

The frequency axis changes to indicate the measured frequency, the source is however still sweeping at the fundamental. The display looks like Figure 5.

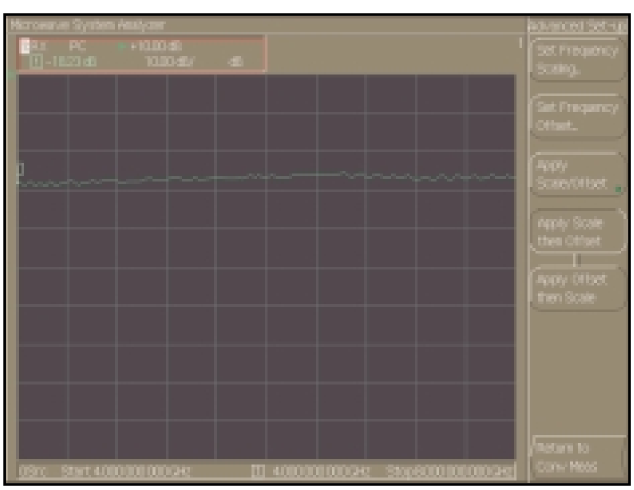


*Figure 5 : Second Harmonic Response*

To change the screen to display the third harmonic, press [3] [**ENTER**] (this assumes that the frequency scaling window is still active.)

The markers can now be used to display the harmonic power in dBc.

## 4. MEASURING GAIN COMPRESSION (6820, 6840)

### 4.1 Test System Setup

The test system set up is shown in Figure 6.

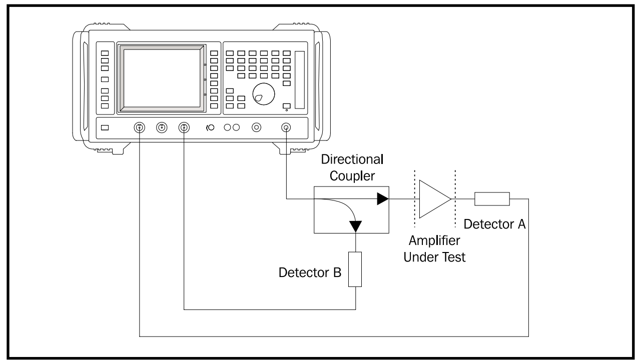



*Figure 6: Gain compression Test System*

One detector is configured to monitor the input power (input C). The other is used to measure the output power. A low loss coupler is shown but a resistive splitter could equally be used if the 6 dB loss can be tolerated.

In this test the amplifier will be driven at a constant frequency and the power ramped between two levels. The lower level should be low enough to measure the small signal gain. The upper level should be large enough to cause compression.

Care must be taken not to exceed the amplifier input damage level. For amplifier output powers exceeding 20 dBm, an attenuator should be fitted to detector A.

If the power rating of the amplifier is such that the MSA cannot drive the amplifier into compression then a second amplifier should be inserted between the MSA and the coupler.

To ensure measurement accuracy it should be noted that, at the 1 dB compression point, the output harmonic levels can typically be -20 dBc. When measured with a broadband detector, these signals contribute to measurement errors (see Appendix; Reducing Harmonic Errors in Amplifier Measurements Using Scalar Analyzers). Therefore, it is good practice to insert a low pass filter between the amplifier under test and the detector A.

The keypresses for setting up the MSA are as follows.

This assumes an input frequency of 4 GHz, a start power of -15 dBm and a stop power of 10 dBm.

[**PRESET**] [*Full*] [**SCALAR**] [*Yes*]
[**SOURCE**] [*Select Source Mode*] [*Power Sweep*]
[*Return to Source*][*Set Start Power*] [-15] [**ENTER**]
[*Set Stop Power*] [10] [**ENTER**]
[*Set Frequency*] [4] [**G n**] [**SOURCE ON OFF ●**]
[**SCALAR**] [*Input Selection*] [*A/C*]

### 4.2 Test System Calibration

The next step is to normalize the response at the coupler output port by connecting detector A directly to this port.

The keypresses for calibration are;

[**CAL**] [*Zero Detectors*] [*Through Cal*] [*Continue*]

### 4.3 Example Measurements

Connect the amplifier to the output of the coupler and detector A to the output of the amplifier. Turn on the amplifier. The gain is calculated in the instrument by ratioing the measurement with the normalization readings. The output power measurement at the point where the gain drops by 1 dB gives the 1 dB compression point value. Use the marker functions to read the 1 dB compression point.

[**SCALE/FORMAT**] [*Autoscaling*] [*Autoscale*]
[**MARKER**] [*Active Mkr to Maximum*] [*More*]
[*Place Mkr at Active*] [2] [**ENTER**] [*Mkr table* ●]
[*Return to prior menu*] [*Delta Mkr*]
[*Delta Mkr* ●][*Return to Marker*] [*Mkr functions*]
[*Search*]
[*Set Search Value*] [-1] [**ENTER**] [*Search Right*]
[**MARKER**] [*Delta Mkr*] [*Delta Mkr* ○]

Marker 1 value is the 1 dB compressed gain and is positioned at the relevant source input power.

Marker 2 value is the small signal gain measurement. To find the corresponding output power;

[**DISPLAY**] [*Channel 1 Meas 2* ●]
[**SCALAR**] [*Input Selection*] [*A*]
[**SCALE/FORMAT**] [*Autoscaling*] [*Autoscale*]

Marker 1 on channel 2 now shows the output power at the 1 dB compression point. The display now looks like Figure 8.

## 5. MEASURING GAIN COMPRESSION USING THE TUNED INPUT (6840)

Compression measurements can also be made using the spectrum analyzer as a tuned input. By measuring the compression in this way ratioed measurements can be carried out with only one detector; additionally there is no need for the low pass filtering because the power is measured at the fundamental only. Another advantage of using the spectrum analyzer in this way is that the output spectrum and compression characteristics can be viewed simultaneously.

### 5.1 Test System Setup

To measure compression using the tuned input the setup shown in Figure 7 should be used.

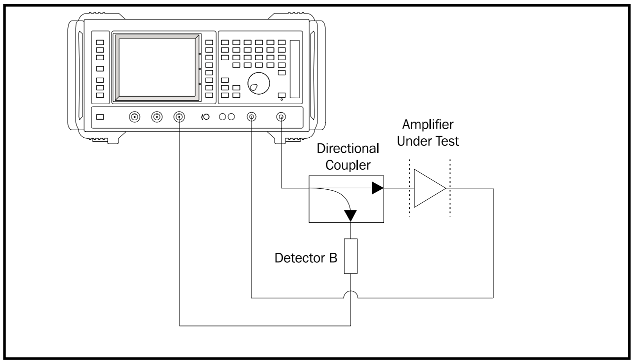



*Figure 7 Gain Compression using the Tuned Input*

This example uses the same powers and frequencies as before. The keypresses to set up the MSA are as follows;

[**PRESET**] [*Full*]
[**SCALAR**] [*Yes*] [*Input Selection*] [*Tuned Input*] [*Tuned Input/C*]
[**SOURCE**] [*Select Source Mode*] [*Power Sweep*]
[**SOURCE**] [*Set Start Power*] [-15] [**ENTER**] [*Set Stop Power*] [10] [**ENTER**] [*Set Frequency*] [4] [**G n**]
[**SOURCE ON/OFF** ●]

### 5.2 Test System Calibration

The keypresses for calibration are;

[**CAL**] [*Zero Detectors*] [*Through Cal*] [*Continue*]

### 5.3 Example Measurements

Insert the amplifier between the coupler output and the spectrum analyzer input. Turn on the amplifier.

[**SCALE/FORMAT**] [*Autoscaling*] [*Autoscale*]
[**MARKER**] [*Active Marker to Maximum*] [*More*]
[*Place Mkr at Active*] [2] [**ENTER**] [*Mkr Table* ●]
[*Return to Prior Menu*] [*Delta Mkr*]
[*Delta Mkr* ●] [*Return to Marker*][*Mkr Functions*]
[*Search*]
[*Set Search Value*] [-1] [**ENTER**] [*Search Right*]
[**MARKER**]
[*Delta Mkr*][*Delta Mkr* ○]

As before Marker 1 shows the value of the compressed gain and is positioned at the relevant input power. Marker 2 shows the small signal gain value.

To find the corresponding output power;
[**DISPLAY**] [*Channel 1 Meas 2* ●]
[**SCALAR**] [*Input Selection*] [*Tuned Input*] [*Tuned Input*]
[**SCALE/FORMAT**] [*Autoscaling*] [*Autoscale*]
The display is as shown in Figure 9.

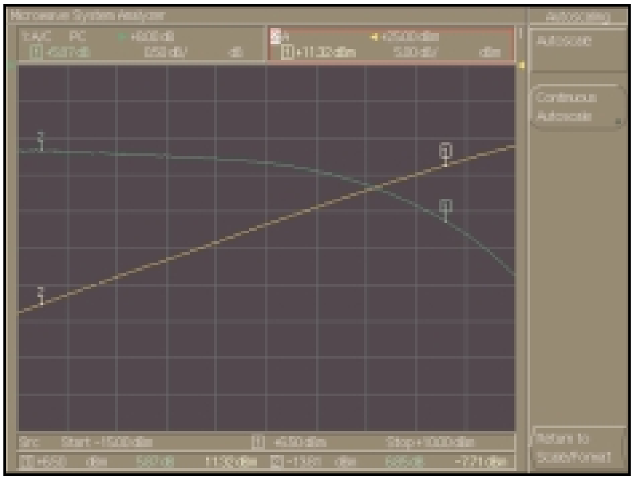


Figure 8 : Gain Compression Measured Using Setup in Figure 6

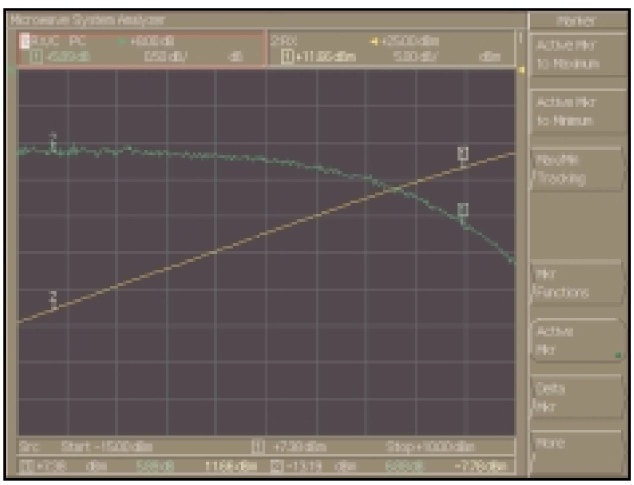


Figure 9 : Gain Compression Measured using Tuned Input

To display the harmonic level at the 1 dB compression point, note the input power level at which the 1 dB compression occurs from the marker 1 information. In this instance 7.38 dBm.

[**DISPLAY**] [*Dual Channel Display* ●] [**SWITCH CHANNELS**]
[**SPECTRUM**] [*Yes*] [*Cntr/ Span* ○] [*Start Frequency*] [3] [**G n**]
[*Set Stop Frequency*] [13] [**G n**] [*Set Ref Level*] [10] [**ENTER**]
[**SOURCE**] [*Set Frequency*] [4] [**G n**] [*Set output Level*] [7.38] [**ENTER**]

To display the harmonic level relative to the fundamental.

[**MARKER**] [*Peak Search*] [*Marker Function*]
[*Measure Rel to Carrier* ●]
[*Return to Marker*] [*Peak Search Function*] [*Next Peak*]

The display now looks like Figure 10.

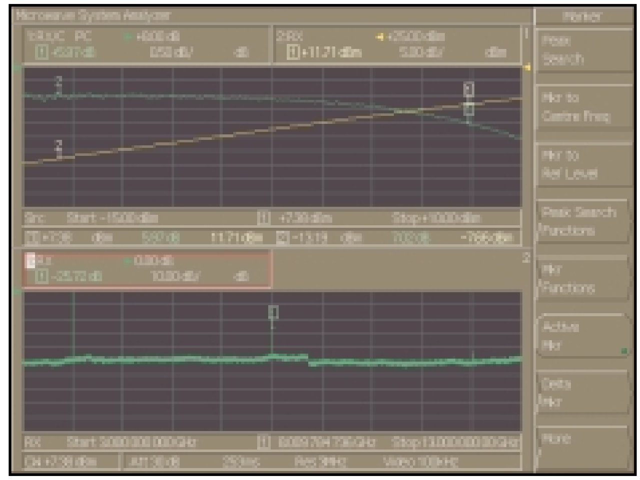


Figure 10 : Tuned Input Gain Compression with Output Spectrum at Compression

## 6. MEASURING GAIN COMPRESSION WITH SWEPT FREQUENCY (6820, 6840)

The compression measurements described above are all made at a constant frequency. It is possible to make swept frequency compression measurements, although the 1 dB compression point will generally only occur at a single frequency. To obtain the 1 dB compression point at any other frequency it is necessary simply to adjust the input power.

### 6.1 Test System Setup

Connect the instrument as shown in Figure 1. For amplifier output powers exceeding 20 dBm, an attenuator should be fitted to detector A.

The keypresses to set up the MSA are as follows:

[**PRESET**] [*Full*]
[**SWITCH CHANNEL**] Sets the instrument into Scalar Network Analyzer Mode
[**DISPLAY**] [*Channel 2 Meas 2* ●] Switch on second measurement on channel 2.

[**SELECT MEAS**] Activate measurement 1.
[**SCALAR**] [*Input Selection*] [*A / C*]
[**SELECT MEAS**] Activate measurement 2.
[*C*] [**SELECT MEAS**] Reactivate measurement 1.

### 6.2 Example Measurement

Define the source conditions:

[**SOURCE**] [*Set Start Frequency*] [1] [**G n**] [*Set Stop Frequency*] [14] [**G n**]

The source output power must be low enough to ensure that the amplifier small signal gain is measured and is operated well away from compression.

[*Set Output Power*] [-15] [**ENTER**]

[*Sweep Time*] [*User Set Sweep Time*] Sets the default of 1 second sweep time to reduce peak to peak noise.

Normalize the Display:

[**CAL**] [*Zero Detectors*]

[**SOURCE ON/OFF**] The source RF output is switched on to perform the normalization.

[**SAVE/RECALL**] [*Save Trace*] [*New Store Name*] Type in Store Name e.g. GC1 [*Done*] [*Save*]

[*Apply Trace Memory*] [*Relative to Memory*] [*Select*] Select Store e.g. GC1

Measurement 1 now shows normalized gain at a 0 dB reference level, with measurement 2 showing the input power level to the amplifier. This makes the assumption that the splitter has identical loss in both arms.

Select appropriate scaling and format on each measurement e.g. 1 dB/Div

[**SCALE/FORMAT**] [*Set Scale...*] [1] [**ENTER**]

Use the marker to set the test frequency.

Set the marker to the test frequency at which to measure the 1 dB compression point. This frequency can be changed, and the new 1 dB compression point measured as below if the amplifier response is not flat across the frequency band.

[**MARKER**] [*More*] [*Position Active Marker...*] [4] [**G n**]

Set the Input Power increment e.g. 0.1 dB

[**UTILITY**] [*Set Inc/Dec Steps*] [0.1] [**ENTER**]

[*Return to Utility*]

To make the measurement:

[**SOURCE**] [*Set Output Power*]

Increase the source power until the normalized gain shown by the marker in measurement 1 reads -1.00 dB. Adjust the output power using the up/down arrow keys for coarse adjustment and the rotary knob for fine adjustment.

The input power level (measured as channel C) at the -1.00 dB compression point will now be displayed by the marker in measurement 2 at the chosen test frequency.

To measure the 1 dB compression point at another frequency, reposition the active marker and adjust the source power as necessary.

To obtain the output power (measured as channel A) at the 1 dB compression point and this test frequency, change measurement 2 to read channel A directly. Remember to take account of the attenuator on detector A, if used.

[**SELECT MEAS**] [**SCALAR**] [*Input Selection*] [*A*]

## 7. MEASURING INTERMODULATION DISTORTION (6840)

Intermodulation occurs when multitone signals are incident on non-linear devices. The individual signals interact with each other via the amplifier's non-linearity to produce output components that appear at the frequencies $mf_1 \pm nf_2$

where m and n are any integer value and $f_1$ and $f_2$ are any input frequencies.

A common figure of merit for the intermodulation performance is the two tone third order intercept point (IP3). This is defined as the power level at which the extrapolated linear response of either of the two fundamentals $f_1$ and $f_2$ intersects the third order intermodulation product level (see Appendix). This definition assumes that the intermodulation products rise at a fixed rate. If they do not then the performance should be expressed as a dB difference for a given test input level.

To measure the IP3 two signal sources are required. The sources must have good harmonic performance or additional low pass filtering should be used. The two sources are set up such that the signals have a small frequency difference. These are passed through a combiner before being applied to the amplifier under test.

The amplifier will generate third order products, the frequencies of interest being $2f_1 - f_2$ and $2f_2 - f_1$.

### 7.1 Test System Setup

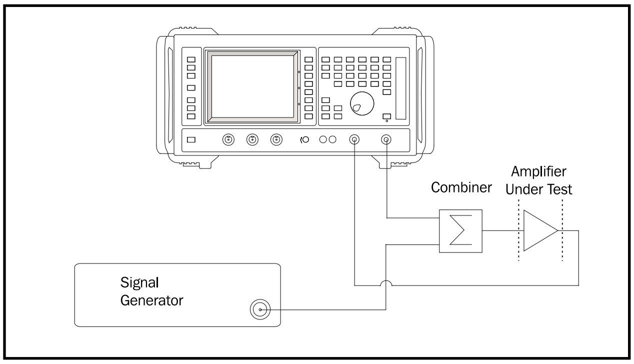



*Figure 11 : Basic Intermodulation test setup*

### 7.2 Test System Calibration

To ensure that the input to the amplifier has only the two wanted tones present, steps should be taken to isolate the signal sources from each other. This eliminates any measured third order products being attributable to the test system. Several schemes are shown in the Appendix.

In this example we will use a frequency difference of 2 MHz setting the sources up for 8.999 GHz and 9.001 GHz and using the setup of Figure 16 with isolators, initially without the amplifier under test. For the combiner we will use a resistive splitter.

To set up the MSA source and spectrum analyzer:

[**PRESET**] [*Full*]
[*Set Cntr Frequency*] [9] [**G n**] [*Set Span*] [10] [**M µ**]
[*Set Ref Level*] [0] [**ENTER**] [*More*] [*Set Res BW*] [⇩]
to display 30 kHz
[**SOURCE**] [*Set Frequency*] [8.999] [**G n**] [*Set Output Level*] [5] [**ENTER**] [**SOURCE ON/OFF ●**]

Now set the signal generator to a frequency of 9.001 GHz and an output level of 5 dBm.

Check that only the two tones are displayed, no intermodulation products should be seen above the noise floor. This is shown in Figure 12.

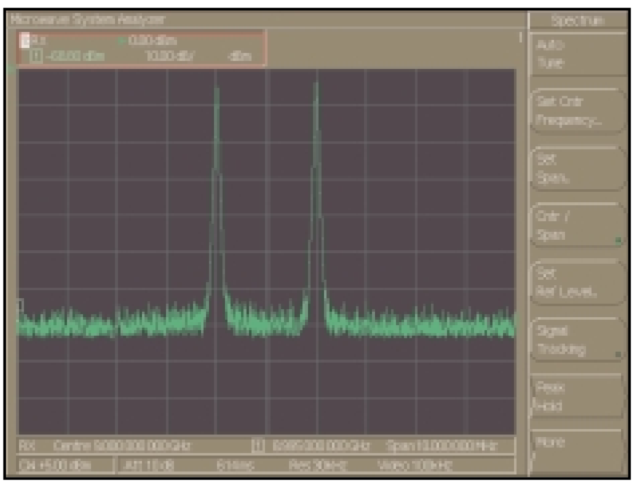


*Figure 12 : Intermodulation Performance of Test System*

Before testing the amplifier adjust the reference level to take account of the amplifier gain.

[**SPECTRUM**] [*Set Ref Level*] [10] [**ENTER**]

### 7.3 Example Measurement

Insert the amplifier to be tested between the splitter and the spectrum analyzer input. Turn on the amplifier. The display now shows the two tones as before (increased by the amplifier gain) with the two intermodulation products on either side.

To ensure that the displayed intermodulation products are real, and not produced by the spectrum analyzer, step the input attenuator up and down to see if the product values remain the same. If they change then the spectrum analyzer is being overdriven at those settings.

Set the attenuator at the lowest attenuator setting where the signals do not change.

To change the attenuator;

[**SPECTRUM**] [*More*] [*Coupled Functions*] [*Set Input Atten*] use the up and down arrow keys .

To determine the IP3 point use the markers as follows.

[**MARKERS**] [*Peak Search Functions*] [*Identify Peaks*]
Turn off markers 5 to 8 by [*Return to Marker*] [*More*]
[*Set-up Mkrs*] [⇩] [*Marker On* ○]
[*Return to Marker*] [*Return to Prior Menu*]
Note the levels of Marker 1 and Marker 2. In this instance 1.6 dBm
[*Mkr Functions*] [*Measure Rel to Carrier* ●]

The screen now looks like Figure 13.

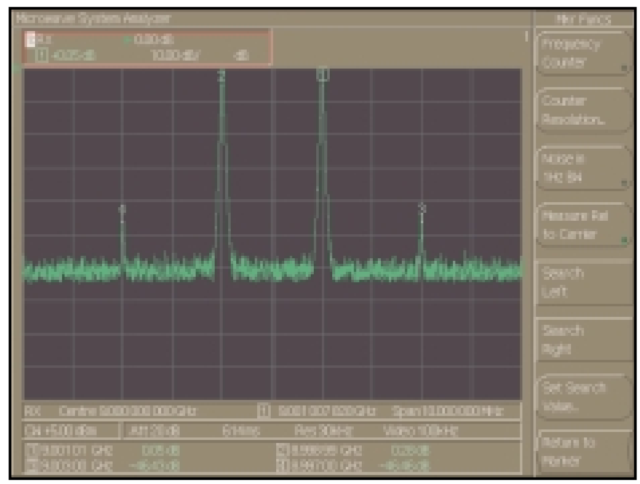


*Figure 13 : Intermodulation Response*

To determine the value of IP3

$$IP3 = \frac{\text{Magnitude of Marker 3 or 4}}{2} + \text{the absolute value of either of the carriers}$$

In this example Marker 3 = 46.4 dB

Therefore the output IP3 $= \frac{46.4\ \text{dB}}{2} + 1.6\ \text{dBm}$

$= 24.8$ dBm

## 8. CONCLUSION

An amplifier is commonly specified in terms of its frequency response, power response and signal purity. This application note has demonstrated how a 6840 series Microwave System Analyzer can be configured to make these measurements.

By using the tuned input, both network and spectrum tests can be performed and displayed simultaneously allowing real time tuning, a function not possible with separate units.

## APPENDIX : GAIN COMPRESSION, HARMONICS AND INTERMODULATION

The dynamic range of an amplifier represents the range of input signals over which the output will exhibit its intended function. The lower limit of the dynamic range will be determined by noise Figure and the upper limit will be determined by the allowable signal distortion.

The mechanism for the generation of distortion in an amplifier comes from the non linearity of the amplifying device itself and limitations of the bias supplied to it.

These distortion effects will occur, to some extent, at all input powers.

There are three main types of distortion that the designer should take into account when designing an amplifier; gain compression, harmonic distortion and intermodulation distortion, and depending upon the particular application, their relative levels may or may not be an issue.

As an amplifier is driven towards saturation, the level of the harmonics will increase at the expense of the desired output, and the gain will subsequently decrease in magnitude to a point where the output power is almost constant as a function of input power.

The output power level at which the gain has decreased 1 dB from its small signal gain is known as the 1 dB compression point.

Figure 14 is a graph of an amplifier's transfer function for any given frequency on a logarithmic magnitude scale. The output power levels of the second and third harmonics are also plotted.

We can see that they have a different slope to that of the fundamental. In fact they rise at a rate of 2 dB/dB for the second and 3 dB/dB for the third. Therefore, for a 10 dB increase in output power, the second harmonic will rise 20 dB and the third harmonic will rise 30 dB.

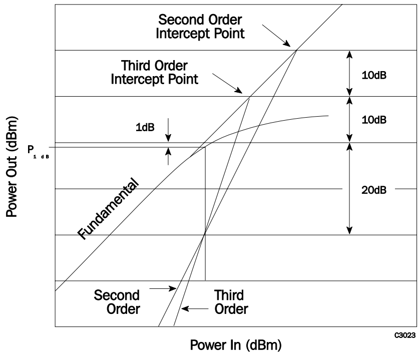



*Figure 14 : Amplifier Performance Characteristics*

In reality the harmonic levels will not continue to rise indefinitely but will saturate in much the same way and at a similar input level to that of the fundamental.

This type of harmonic distortion of the CW signal is problematic in wideband systems and systems which are measured using broadband detectors, as all additional signals will be summed with the fundamental. (See section Reducing Harmonic Errors in Amplifier Measurements Using Scalar Analyzers)

However in narrowband systems, especially those used for communication channels, bandpass filtering is used after the receiver input amplifier and harmonic distortion is no longer a problem. These channels are generally used to carry multitone signals. If an amplifier is used to transmit these signals then the individual components of the signal will interact to produce new intermodulation products at the frequencies $mf_1 \pm nf_2$

where m and n are any integers and $f_1$ and $f_2$ are any simultaneous input frequencies.

Many of these products occur at frequencies well outside the passband of the receiver, however the third order products, which occur at $2f_1 - f_2$ and $2f_2 - f_1$ are very close in frequency to the signals that created them and so cannot be removed by filtering. This problem is compounded because the multitone third order product is closely related to the single tone third harmonic and also rises at a rate of 3 dB/dB of wanted signal.

Intermodulation products are usually much weaker than the signals that generate them and appear as spurious signals; however, a situation can arise where two or more strong signals in one channel create an intermodulation product, maybe the fifth or seventh order, that falls within an adjacent channel's passband and this can swamp a weak desired signal. For this reason strict guidelines exist on the levels of adjacent channel intermodulation.

Referring back to Figure 14, if the linear responses are extrapolated we find an imaginary point of intersection between the fundamental and the third order/harmonic level. This point is known as the third order intercept point or IP3 and is particularly useful because knowledge of its value enables the intermodulation levels to be calculated.

### Intermodulation Distortion Test System Setup

When measuring intermodulation distortion, two tones are combined and input simultaneously to the device under test. It is important that during the signal combination the two sources do not interact with each other and generate third order products themselves. The way to ensure that this does not occur is to isolate the sources from each other. Three schemes are presented below;

1. Using attenuator pads; broadband but high loss.

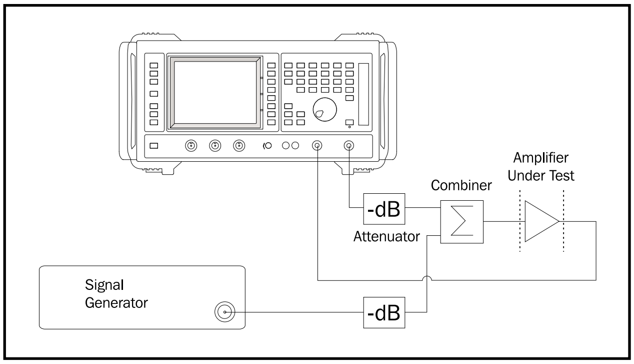



*Figure 15 : Intermodulation Test Setup*

2. Using isolators; narrowband, low loss.

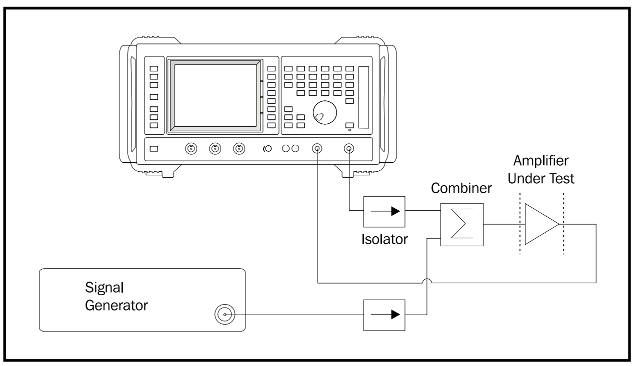



*Figure 16 : Intermodulation Test Setup*

3. Using amplifiers and attenuators; this combination should be used if the MSA cannot produce enough output power to determine the third order products. Ensure the amplifier outputs have low harmonic levels.

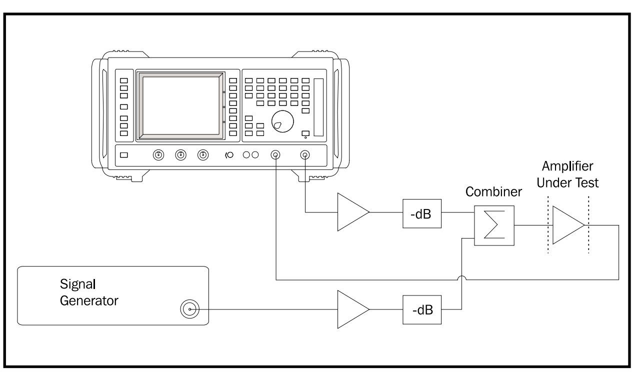



*Figure 17 : Intermodulation Test Setup*

## Reducing Harmonic Errors in Amplifier Measurements Using Scalar Analyzers

In both the gain compression and frequency response measurements, the definition of the measurement requires that only powers at the fundamental frequency should be measured. At the 1 dB compression point the amplifier harmonics may typically be only -20 dBc, which means that the measured output power may be higher by 0.043 dB. Not only does the presence of power at harmonically related frequencies cause an error, but the use of diode detectors can magnify their effect.

At power levels below -30 dBm, a diode detector is considered to be in its square-law region, which means that the detected voltage is directly proportional to the input power. It can be shown that the detected response to harmonics is similar to that of a true thermal sensor. However at high power levels, the square-law approximation is not valid, and it is necessary to use software correction to enhance the detected reading. Although measurement accuracy of pure signals is very good, the non-linear characteristics of the diode cause it to respond to the voltage amplitude of the harmonics, rather than their power level. The following practical measurements illustrate the problem:

| *7 GHz Fundamental Error* | *14 GHz Harmonic* | *Thermocouple Error* | *Diode* |
|---|---|---|---|
| +3 dBm | -30 dBc | 0.0043 dB | 0.16 dB |
| -7 dBm | -20 dBc | 0.043 dB | 0.45 dB |
| -7 dBm | -10 dBc | 0.41 dB | 1.74 dB |

In order to minimize this effect, an attenuator can be inserted between the output of the amplifier and the detector. A value between 10 and 30 dB is appropriate. This will reduce the diode detector error towards the level of true power measurement.

If this level of uncertainty is unacceptable, then the amplifier output must first be low pass filtered. The passband match must be sufficiently good to avoid raising the mismatch uncertainty of the measurement. If this is a problem, a well matched 10 dB attenuator can be fitted between the amplifier output and the filter.

The loss of the filter and attenuator must be characterized as before so that the output power level of the amplifier can be calculated.

## NOTES

IFR Americas, Inc., 10200 West York Street, Wichita, Kansas
67215-8999, USA. E-mail: info@ifrsys.com
Tel: +1 316 522 4981 Toll Free USA: 1 800 835 2352 Fax: +1 316 522 1360

IFR Ltd, Longacres House, Norton Green Road, Stevenage, Herts
SG1 2BA, United Kingdom. E-mail: info@ifrinternational.co.uk
Tel: +44 (0) 1438 742200 Freephone UK: 0800 282 388 Fax: +44 (0) 1438 727601





http://www.ifrinternational.com

Part no. 46891-841
Revision A