Application Note #45
Input Power Requirements for AR RF/Microwave Instrumentation's Amplifiers

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A common concern when choosing an amplifier is, "How much input power is required to achieve full rated output power?" Here at AR this question is easily answered since we have always specified a maximum input of 1 milliwatt. Standardizing on 1 milliwatt precludes the need for an additional preamplifier, thus simplifying the overall test system. Over the years this feature has become an industry standard. While the rated input power is defined as 1 milliwatt, most amplifiers provide rated output power with less than 1 milliwatt input. This application note will discuss the importance of input drive and how to operate amplifiers to obtain optimum results.

Typical input levels

Signal Generator:	1 milliwatt which is equivalent to 0 dBm
Function Generator:	1 milliwatt or 224 millivolts into 50 Ω
Max input before damaging amplifier	+13 dBm or 20 milliwatts (20 times more power than 0 dBm)

Understanding amplifier output power levels - AR rates amplifier output power in a variety of ways.

1 dB compression point – this is the output power level where a 10 dB increase at the input produces a 9 dB increase in output power. (10 dB – 9 dB = 1 dB) Below this point the amplifier is said to be operating in the "linear region". In Figure 1 it can be seen that as input power increases from -18dBm to about -7dBm, there is a 1 to 1 ratio with the output power. For a 1 dB change in input, there is 1 dB change in output power. This is the linear operating region. See Figures 1 & 3.

3 dB compression point – the output power level where a 10 dB increase at the input only results in a 7 dB increase in output power. (10 dB – 7 dB = 3 dB) Above this point the amplifier is said to be in "saturation". See Figures 1 & 3.

Rated output power – the output power with a 0 dBm input. Also referred to as CW power. See Figures 1 & 2.

Saturated power – here an increase in input power will have no effect on the output power. At this point the amplifier is said to be in full saturation.

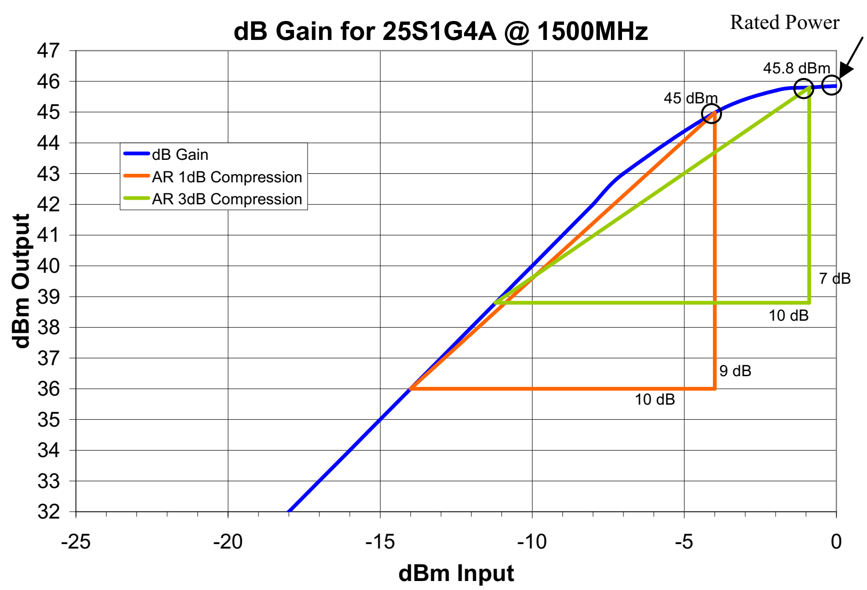

Figure 1: Compression points found at one frequency

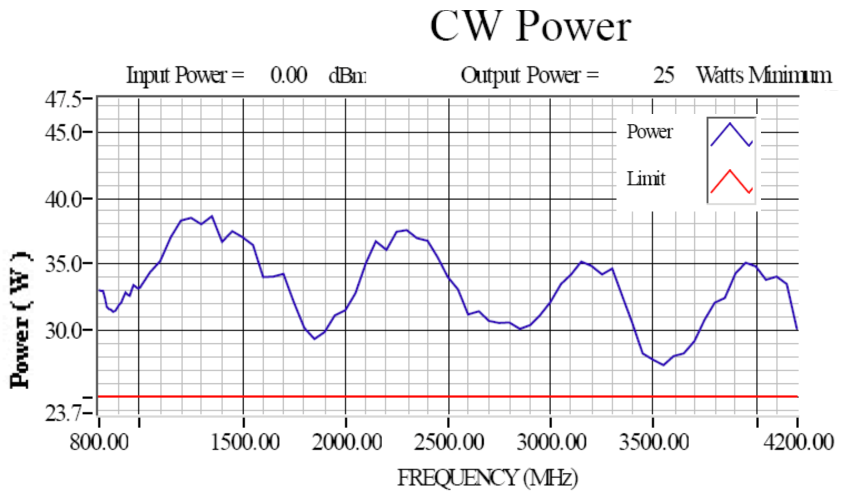

Figure 2: Production data of saturated power across the frequency band

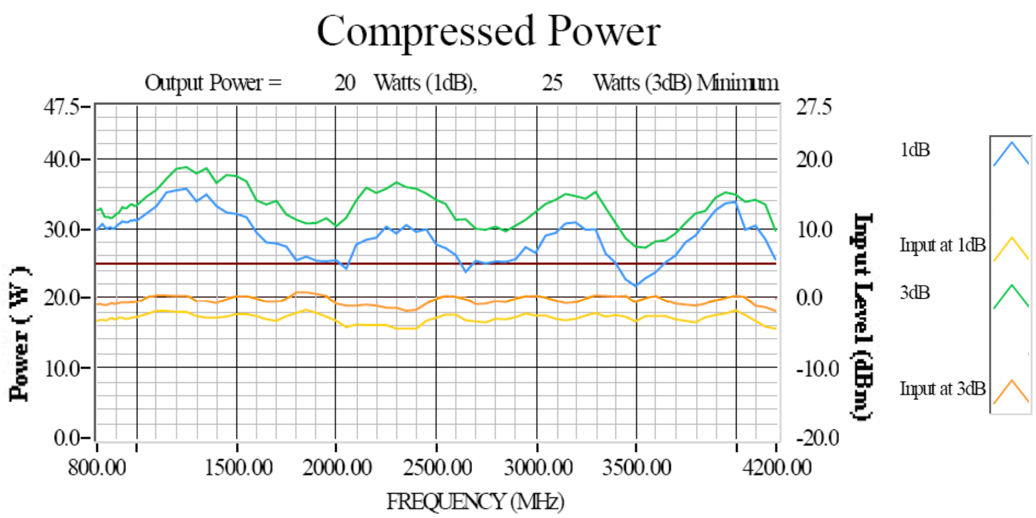

Figure 3: Production data of 3 dB and 1 dB compression points across the frequency band

How does the signal strength of the input signal affect the amplified output signal?

The input signal strength has a profound effect on the amplified output signal since it determines the operating region and thus, the degree to which the amplifier output is compressed. Ideally, an amplifier will simply amplify the input signal without adding any additional signals or artifacts. In reality, unless operated in the extreme linear region, amplifiers will distort the input to some degree. The extent to which the amplifier affects the input signal is a function of the output compression. This distortion can be seen in the time domain with an oscilloscope. At the 1dB compression point there may be a slight flattening at the top and bottom of a CW sine wave signal. As the amplifier is driven further into saturation, additional distortion will become apparent and eventually the CW input signal will approach a square wave output (See Figure 4). This distortion creates new unwanted frequencies not present at the input of the amplifier. This is best seen in the frequency domain with a spectrum analyzer. Figure 5 demonstrates the effect of driving an amplifier well into saturation. Note the addition of the harmonics to the output spectrum.

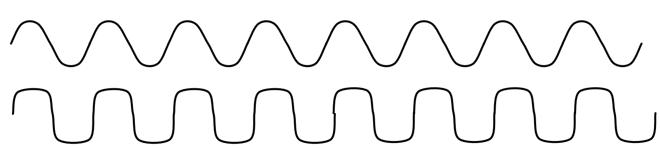
Figure 4: Sinusoidal CW signal compared to a signal in compression

The addition of modulation to the input signal further exasperates this problem resulting in additional signal artifacts.

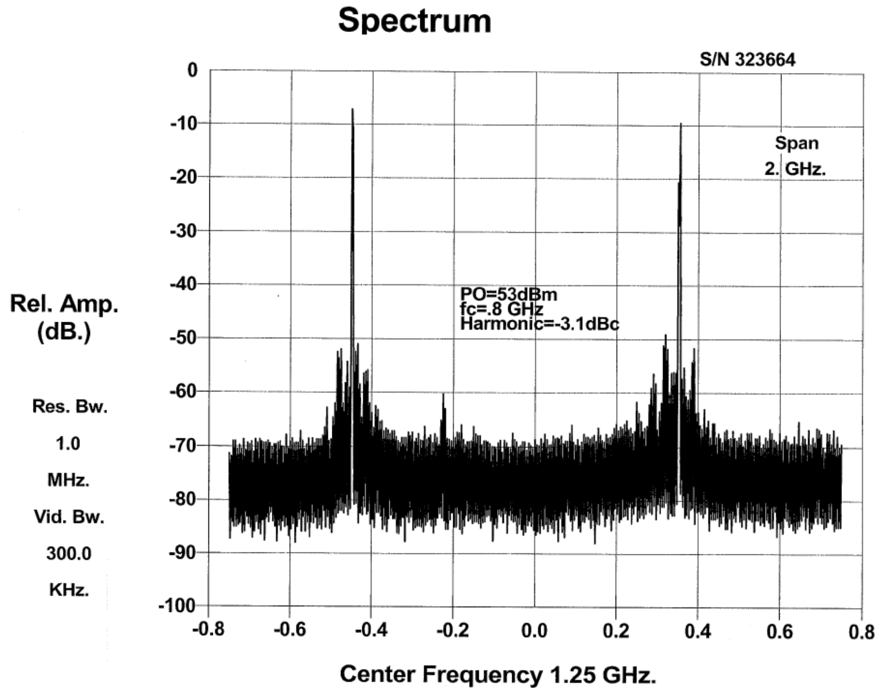

Figure 5: Amplifier output spectrum showing fundamental and harmonics present when operated in compression.

Why should amplifier compression be limited?

As discussed above, the output signals from "real life" amplifiers are somewhat compressed resulting in some distortion of the input signal. The amount of distortion is directly proportional to how far the amplifier is driven into compression. Depending on the application, this distortion can present a serious problem.

For testing applications involving complex waveforms and modulation schemes such as WiMAX and WiFi where signal integrity is of paramount importance, the input signal must be reduced well below 0 dBm to insure that the amplifier operates in the "extreme linear" range. While the output power is quite linear in this region, the output level may be reduced as much as ½ to ¼ of that available at the 1 dB compression point. The obvious trade-off here would be the requirement for a much larger amplifier throttled back to yield the necessary linearity for this specialized application. Some high quality amplifiers apply advanced design techniques to improve linearity for output power levels up to and in some cases greater than ½ the output power at the 1 dB compression point.

When conducting an EMC immunity test, distortion is not as much of a concern as noted in the above applications. Nevertheless, it must be considered since it will adversely affect repeatability. It is vital that immunity testing yield repeatable tests and every effort must be made to insure repeatable results. Some EMC standards do not specify linearity and only require a specific test level be used. The problem with this approach is that if the amplifier is allowed to operate well into saturation the immunity test is severely flawed, even though the required test level seems to have been achieved. You might ask how this can be. As it turns out, there are two main causes. 1) The harmonic content of the distorted output will add to the reading of a broad band field probe resulting in a false reading. For example, you might think you are subjecting your Equipment Under Test (EUT) to 10 V/m at the specific test frequency, but you are actually testing at 7 V/m with the remaining 3 V/m comprised of higher frequency harmonic energy. 2) The problem is that a high harmonic content can have an unwanted adverse effect on the EUT. The harmonic could be at a frequency that causes the EUT to fail. A failure at a test frequency of 300 MHz might actually result from a 600 MHz sensitivity of the EUT to a very strong harmonic. Since test personnel are testing at the fundamental frequency, they will naturally assume the EUT failed at the fundamental frequency, which in this case clearly would be in error.

To preclude this uncertainty, the newer EMC immunity standards mandate amplifier linearity and allowable harmonic levels. For example, the latest version of IEC 61000-4-3, Ed. 3 Electromagnetic compatibility (EMC) Immunity test and measurement techniques basic standard mandates a maximum harmonic content of -6 dB in the test field. Considering a 5 dB maximum antenna gain variation between the harmonic and fundamental frequencies and factoring in a 3 dB safety factor for unknown setup and room effects, a maximum allowable harmonic content of -14 dB should be adequate.

For most EMC immunity test applications as well as general purpose usage, operating at the 1 dB compression point seems to an appropriate compromise. The amplifier is slightly compressed but the distortion is minimal.

Basic amplifier setup:

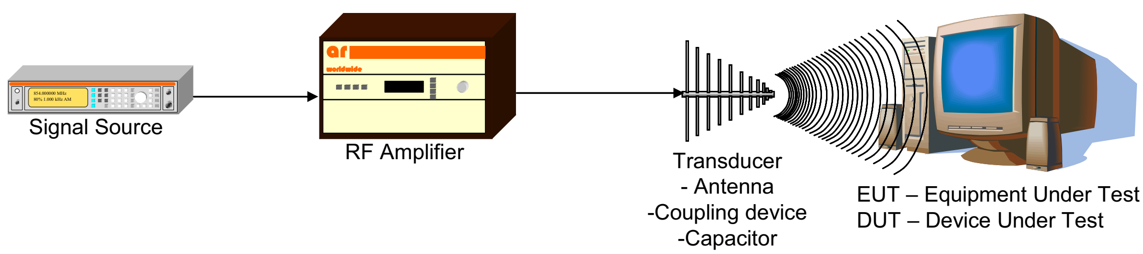

Figure 6: Basic amplifier setup diagram

What is the best way to control the output power of an amplifier?

This application note has shown that the signal output of an amplifier must be considered if accurate, repeatable tests are desired. Guidelines have been established to achieve these goals. Now the remaining issue is how to insure the amplifier is adjusted for optimum performance. There are two basic methods used to control the output of an amplifier. One can either adjust the gain of the amplifier or vary the output level of the signal source. While most amplifiers have a front panel gain adjustment, remote interface gain adjustment capability, or possibly both, the simplest and most accurate approach is to set the amplifier at maximum gain and control output power by controlling the output of the signal generator.

Example: (refer back to Figure 3)

In the production test data, output power at both the 1 dB and 3 dB points are shown across the frequency band along with the required input to reach these levels. This amplifier specific test data can be used to make sure you either don't exceed the amplifier output level or the signal generator input level, depending on your testing method. As an example, to insure an output signal with no greater compression than 1dB, the input must not exceed -4.5 dBm over the entire frequency range. If an output compression of 3 dB can be tolerated, the input signal can be as great as -2 dBm.