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Understanding Amplifier specifications for EMC Applications
by
Pat Moore, Managing Director, MILMEGA

Amplifier Linearity

All linear systems, when given a sufficiently strong input signal, will reach a point where the system departs from a linear relationship between input and output. At this point the system is said to be going into compression or beginning to saturate.

An example of this would be the amplifier represented in the graph in Figure 1 (a MILMEGA AS0822-200). This is a plot of input power vs output power for a CW (continuous wave) input and a pulsed input at a spot frequency of 1900MHz.

In the example, the performance of the amplifier is linear up to an input signal of value –3dBm. This means there is fixed value relationship between the input power and corresponding output power, up to an input value of –3dBm. This fixed value is referred to as the gain of the amplifier. From Figure 1 it can be seen that an input power of -20dBm produces an output power of 35dBm i.e the amplifier gain is 35 – (-20) = 55dB. Similarly, for an input of –10dBm, the output is 45dBm i.e. the gain is 45 – (-10) = 55dB. The gain is therefore constant at 55dB up to the point when compression begins.

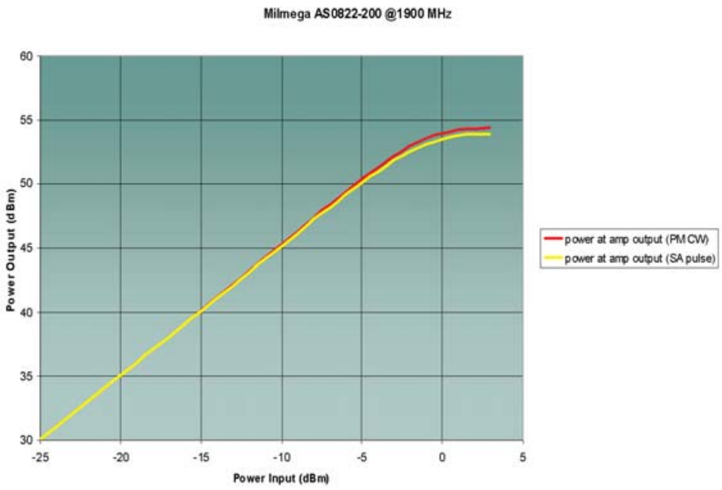

Figure 1: MILMEGA AS0822-200 input and output power at a spot frequency of 1900MHz

Beyond this point, the linear relationship between input and output is no longer valid and the amplifier is no longer considered to be linear. An internationally recognised figure of merit, used for defining the extent of linearity of an amplifier, is the 1dB compression point. This is the point of –1dB departure from linearity. In Figure 1, this will occur when (Pout –Pin) = 54dB. This corresponds, in this example, to an output power of approximately 53dBm. The output power of an amplifier cannot increase indefinitely and when an increase in input power generates no discernible increase in output power, the amplifier is said to be saturated, and by definition the output is not proportional to the input signal. This point is often referred to as Psat on a datasheet or sometimes P3dB. For the amplifier in the graph, this occurs at an output power of approximately 54.5dBm.

Generally, saturated power is of importance when considering the pulsed power requirements in something like automotive testing while linear power is of importance when considering the AM (amplitude modulation) waveform used in commercial EMC testing.

In the context of the test application, when looking at an amplifier datasheet, the first questions to ask are therefore:

- Does the frequency band of the amplifier meet the frequency response requirements of the test system?
- Is the power defined in terms of saturated (Psat or P3dB) or linear (P1dB) power?
- What power (saturated or linear) best suits my application?

2. Power related distortion products - the concept of useable power

All power transistors, used in the design of RF and Microwave amplifiers, are essentially non-linear devices. This non-linear behaviour causes distortion products to be generated as the amplifier compresses. As the amplifier approaches saturation, a sine wave at the input of the amplifier will be transformed into a square wave at the output. This gives rise to a rich harmonic content at the output - as would be expected from the mathematical analysis of a square or “close to” square wave. Typically the harmonics of interest are those that are twice and three times the fundamental frequency i.e. the second and third harmonic.

How harmonic content increases with input power can be seen in Figure 2. The diagram shows the level of second harmonic present in a MILMEGA 800MHz to 2200MHz, 200W P1dB amplifier at various drive levels. A +5dBm input power level corresponds to the amplifier being fully saturated. An input power level of minus (-)10dBm corresponds to the amplifier operating in a very linear manner. As an example, if you look closely at the data for the fundamental frequency of 1000MHz you will see that the 2nd harmonic increases by 20dB as the amplifier goes from linear operation to saturation.

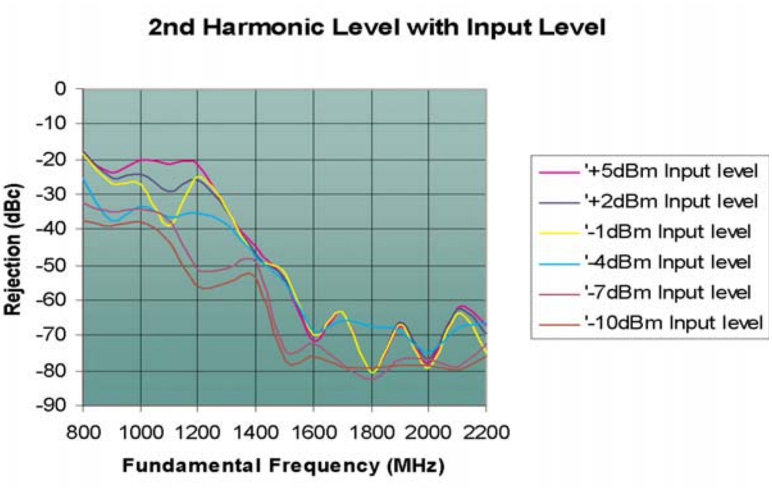

Figure 2: 2nd Harmonic Level with Input Level

There is therefore a 100 fold increase in harmonic power at Psat compared to the linear region. Ensure that the amplifier manufacturer defines where the harmonic level for the amplifier has been measured and satisfy yourself that this corresponds to the maximum power at which you intend to use the amplifier.

During a RF test scenario, the presence of harmonic power will distort the accuracy of the calibration results, as the test engineer cannot separate out the field of the fundamental frequency and the field created by harmonic power. As a rule of thumb, if the harmonic energy is 20dB lower than the fundamental energy, the impact of harmonic energy can probably be ignored. It is important to ensure that the maximum amplifier harmonic levels quoted by the manufacturer are referenced to a power that is either equal to, or greater than, the power you need to deploy in your test set up. You can then be confident that harmonics will not adversely impact on your test system.

We now have some further questions to ask when looking at an amplifier datasheet. These are:

- Is there a declared harmonic level specification? If not, then why not?
- Does the specification state at what power the harmonics were measured at?
- Is this power level either equal to, or greater than, the power you require for your test application?
- Is the amplifier power, from a harmonic perspective, therefore useable?

3. Spurious signal products

Spurious signal products are those introduced by the amplifier but which are non-signal related i.e. they are neither harmonics nor IM products. They may be caused by a low level instability in the amplifier (evidence of poor design) or they may be introduced into the amplifier from external sources e.g via the power supply, radiated interference or even local lighting. Spurious signal power is usually defined at a level relative to the fundamental signal and levels of minus 70dBc are typical for a good amplifier design. The most likely source of spurious in a well designed amplifier will be the switching power supply, generating spurs at it’s operating frequency – which is usually 100’s of kHz. Figure 3 shows an example of power supply induced sidebands.

The area between the maximum spurious power level and P1dB, is the usable range over which the test engineer can be confident that the device under test is subjected only to an amplified reproduction of the input signal i.e. that it is not being modulated by the presence of spurs or high harmonic levels.

We now have another question to ask to further determine the impact of distorting products likely to be present in an amplifier:

- Does the level of spurious defined for the amplifier ensure an adequate operating power range for the test system application?

4. The use of the descriptors “rated” and “typical”

Having ascertained the definition of power, in terms of Psat and P1dB, and determined the potential usability of the product (with respect to harmonic distortion), the next area requiring attention are the parameter qualifiers attached to the data entries on the amplifier data sheet. There are several qualifiers of particular interest that are in general usage. These are rated, typical and guaranteed minimum The qualifier “rated” is essentially meaningless from a user perspective – it is the descriptor that the manufacturer has assigned to a product and it comes with no guarantees of performance. It is a term that is best ignored when making a purchasing decision.

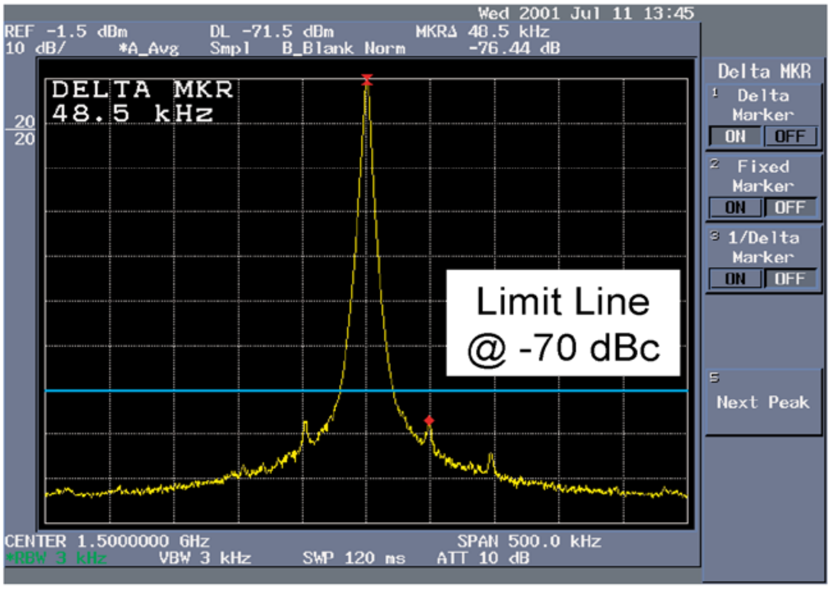

Figure 3: an example of power supply induced sidebands

The descriptor “typical” (or “nominal”) has widespread usage. In general terms it describes the most likely occurring value within a process which outputs a product of naturally occurring variances. The output variation of such a process can be described in terms of a distribution around a mean (or typical) value. Figure 4 shows the most commonly occurring distribution in processes with natural variations. This is often referred to as a Bell Curve. On a Bell Curve, the vertical axis is scaled appropriately to reflect the sample size so that a user can determine the cumulative values within a particular range or a sum of ranges. The horizontal axis maps the process variation, centred on a mean or typical value, in 6 equal steps – called standard deviations. There are 3 negative values to get from the minimum value outputted by the process to the typical value and 3 positive values to get from the typical value to the maximum value outputted by the process.

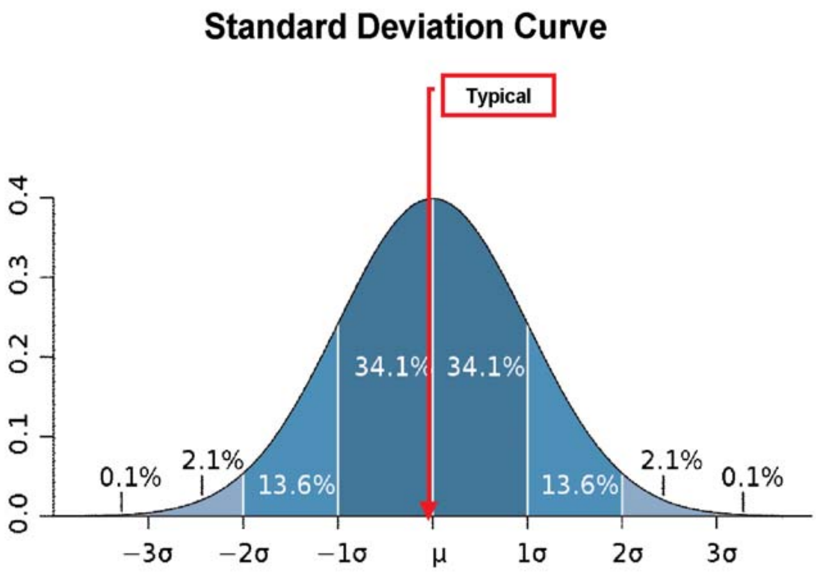

Figure 4: Standard Deviation Curve

The curve shows that for a standard industrial process a manufacturer can expect 50%of their output to be above an average level (the typical value) and 50% to be less than average. The lower the deviation value, the more tightly controlled the process. In an amplifier these deviations (the horizontal axis) would be in watts. As an example, suppose we had a process that produced an amplifier of output power 200W typical and the deviation step size was 10 Watts. From these numbers we could determine facts such as the following:

1. The minimum value (or minimum power amplifier) produced by the process would then be 200W minus (3X10) = 170W.
2. The maximum value (or maximum power amplifier) produced by the process would be 200W plus (3X10) = 230W.

A purchaser can expect that 34% of amplifiers produced, using this process, to have values between 200 and 190W (i.e. within one standard deviation from the mean) It can be seen that purchasing a product on typical values, without knowledge of the process variations, is a high risk strategy. It is essentially a gamble that you will get what you need. In the above example if you require 200W for your application but the manufacturer delivers you a 170W amplifier (the minimum value for the process) then you have a problem and the manufacturer does not If you purchase typical performance, the area smaller than typical value in Figure 4 is the area of risk that you are operating in. If the amplifier you buy was sold on typical performance and you need typical performance then you are likely to be disappointed.

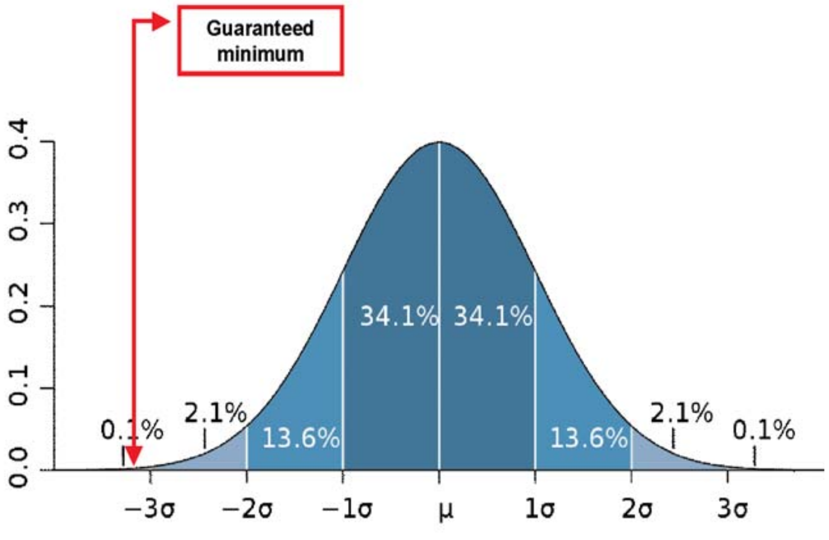

Figure 5: Ways to choose guaranteed minimum value

The way to avoid disappointment is to work with guaranteed minimum values (see Figure 5). By doing this you can be certain that what you will purchase will meet all aspects of your test system power amplifier requirements. Good advice would be to avoid making a large capital purchase based on typical data. Asking the following questions though will help de-risk the process:

- What is the sample size on which the stated typical power is based? If it is 1000 then it represents a mature process. If it is smaller than 10 it is evidence of an immature or statistically inadequately defined process.
- What is the standard deviation step size for the process?
- Given the step size, what is the probability that I will be disappointed if I purchase using typicals?

5. Checklist

Prior to making your decision on your capital equipment purchase, a decision which you will have to live with for up to 5 years, review each amplifier manufacturer's specifications carefully. The following is a summary of the questions you should ask both yourself and the manufacturer of the product you are hoping to procure. Questions 1 to 6 are technical related questions ranked in order of importance. Questions 7 to 9 relate to risk and obtaining answers to these questions is fundamental to ensuring that the manufacturer accepts the risk in delivering what you require. The questions are:

1. Does the frequency band of the amplifier meet the frequency response requirements of the test system?
2. Is the power defined in terms of saturated (Psat or P3dB) or linear (P1dB) power?
3. Does my application require saturated power or linear power?
4. Are the harmonics defined at a power that is useful in the system?
5. Does the level of spurious defined for the amplifier ensure an adequate operating power range for the test system application?
6. For the parameters important to my application, has the manufacturer defined guaranteed minimum performance levels or have they described performance as typical?
7. Am I prepared to take the risk that I may get a typical amplifier?
8. If I am prepared to take the risk, can the manufacturer help to mitigate the risk by defining the probability that I will be disappointed?

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MILMEGA Limited Ryde Business Park Nicholson Road Ryde, Isle of Wight PO33 1BQ United Kingdom
Tel. +44 (0) 1983 618004 Fax. +44 (0) 1983 811521 sales@milmega.co.uk www.milmega.co.uk