Applications for Milmega Amplifiers in the Communications Industry

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Milmega amplifiers are popular amongst communications companies where the benefits of their high reliability, industry leading power density, and class leading performance are widely accepted. This paper describes some of the many uses that Milmega amplifiers are put to in this sector, and the key features that a customer looks for.

Typical Tests requiring Milmega Amplifiers

- ✓ Passive Intermodulation Testing, PIM
- ✓ Intermodulation Testing, IM
- ✓ Adjacent Channel Power Testing
- ✓ Multi-tone testing
- ✓ Power handling
- ✓ EM Immunity Testing
- ✓ High Signal Level Testing

Some of these tests are fairly self evident from their titles as to their application. Others require more explanation either because of their complexity, or their recent introduction in to the field of microwave tests.

<u>Definitions</u>

Intermodulation: Inter-Modulation Distortion (IMD) is a phenomenon that occurs in any non-linear junction. This could be as simple as the junction of two metals in a component, for example between the base metal and its plating. Absolute linearity exists only as a mathematical idealisation – passive elements are all weakly non-linear. IMD exists when more than one signal is present, and should not be confused with harmonic generation. It is related to harmonic generation as the intermodulation products are produced by a mixing effect between the fundamental signals, and the harmonics. For most communications systems it is the third order products that are the most critical, as they fall closest to the carriers, see figure 1.

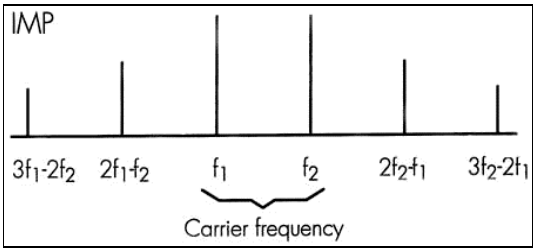

Figure 1 Intermodulation Products

$2f_1$-f_2 & $2f_2$-f_1 are 3rd order products

$3f_1$-$2f_2$ & $3f_2$-$2f_1$ are 5th order products

Adjacent Channel Power: This is closely related to IMD, and is its digital 'cousin'. Many modern communications systems use digital modulation schemes such as BPSK (Binary Phase Shift Keying) or QPSK (Quadrature Phase Shift Keying). Instead of the 'normal' signal frequency spectrum of AM or FM, these modulation methods produce an occupied bandwidth of noise like power. The frequencies within this bandwidth intermodulate and create sidebands. As the carrier is spread over the bandwidth so the sidebands are spread. The measurement of these sidebands is made relative to the power in the wanted band and is referred to as ACPR (Adjacent Channel Power Ratio) or ACPL (Adjacent Channel Power Level).

Multitone: One of the main differences between WCDMA (Wideband Code Division Multiple Access) and cdma2000 is that the former uses a Direct Sequence (DS) mode, whilst the latter uses a Multi-Carrier mode. Visually the difference can be seen in the wavy pattern in

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pass band for MC mode modulation. Multitone testing is one in which a number of tones are generated within a bandwidth.

Passive Intermodulation (PIM) Testing

This is largely the domain of the cable, filter and antenna manufacturers. Although as has been said earlier IMD will occur in any component where there is a non-linear junction, in reality the problem with PIM is only serious where:

- there are high transmit levels
- – the receiver sensitivity is high
- – there are several transmit channels
- where only one antenna for transmission and receive path is used.

Once in receive band, PIM cannot be reduced by filtering as it is 'on' frequency, hence the efforts to minimise it in the first place.

In passive elements there are some dominant contributors of non-linearity:

- dissimilar metal-to-metal joints
- plasma effects (local high fields causing corona)
- magnetic non-linear effects
- high-current density

For cable and connectors the metal-to-metal joints are the most significant PIM contributors. Gold, silver, copper, brass and copper-beryllium joints generate low PIM; steel, aluminium, stainless-steel-joints generate higher PIM.

PIM testing therefore tends to be carried out in the presence of high signal levels, e.g. 2 tones at 20W each, with IM Products (IMP) specified at very low levels, e.g. <-120 dBm. For such testing very high quality components are required. To calibrate the system IMP generating elements, i.e. parts generating a calibrated IMP level, can be used. These are available with levels such as –80, -100, and –110 dBm. For accurate system measurements the IMPs produced by the system need to be of the order of –130 dBm.

There are a number of practical difficulties with repeatability in the measurements.

- The IM level generated over the whole signal path is a result of many IM sources. The value of the resulting IM level depends on the phase relation of all these sources (constructive or destructive interference). This phase relation varies with frequency.
- IMP's of different order have different frequencies, and hence the resulting product does not have a constant amplitude.
- PIM's of different measurement setups are not exactly comparable (because of the different phase relations).
- It is not possible to measure a single connector. Only assemblies can be measured.
- The measured level can vary up to 40 dB by vibration or bending of the cable. It is necessary to know if the application of the assembly is mechanically static or dynamic.
- All connections must be carefully made. The use of torque spanners and careful inspection of connectors is essential, (these are the most vulnerable metal-metal junctions).

Figure 2 PIM Test Station

Typical PIM Testing station
(courtesy of Huber & Suhner)

2x Signal Generators
Spectrum Analyser
Power Meter
2x Milmega AS0822-100 SSPAs
Control PC
Duplexer and filters (hidden)
Clamps to secure cable under test.

Figure 2 shows a Through Passive system. Other systems include Reflection Passive (where the created intermods are measured reflected back from the unit under test e.g. an antenna), and Through and Reflected Active systems. These tests are generally conducted at relatively low levels, although new test procedures are now under consideration for both high power 2 tone testing and multi-tone testing.

Choosing the right Milmega amplifier for an IMD test set-up

When deciding on the amplifier for an IMD system there are two way of specifying the performance. In terms of either;

i. The 3rd Order Intercept point (IP3)

ii. The two tone intermodulation level (IM3) at a specific output power.

It should be noted that the IP3 is a theoretical number that is derived by extrapolating the amplifiers performance. To add to the confusion this can be specified either in terms of an output or an input power. On figure 3 the IP3 point is at the intersection of the Ideal Pout and the Theoretical Response curves. This point is never reached in practice as the amplifier reaches saturation. In many ways the

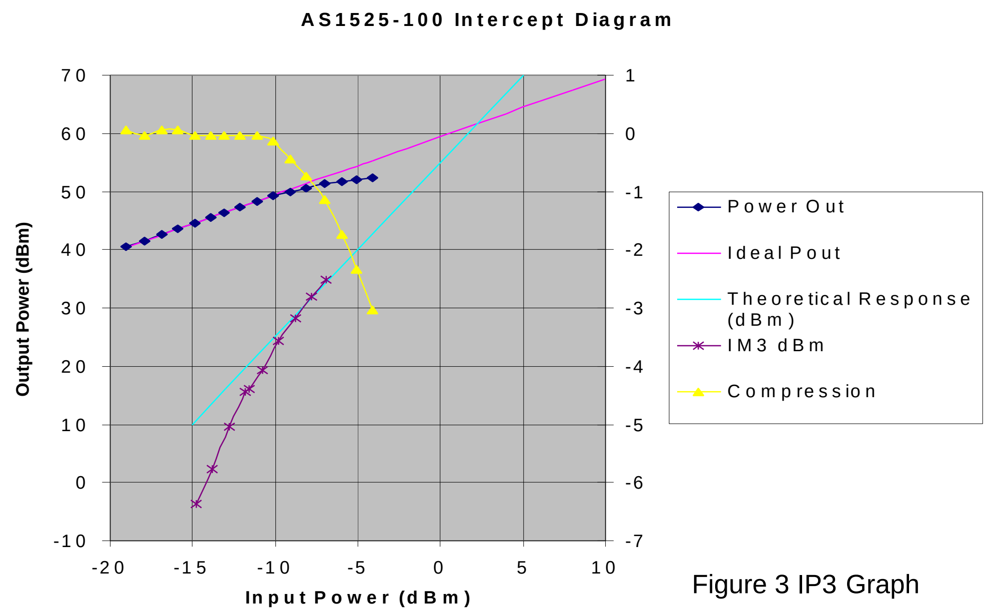

Figure 3 IP3 Graph

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better measure is actual intermodulation product levels at the specified power levels. In this case two tones at a fixed frequency offset (e.g. 1 MHz) are injected into the amplifier, and the resulting 3rd order products are measured on a spectrum analyser, in dBc. The signal sources and spectrum analysers can be locked together, and as the frequencies are known exactly very low levels can be measured. It is very important that either signal sources with very low harmonic content are used, or that their output are filtered. The use of ferrite isolators/circulators is not recommended as these have poor IM performance.

Adjacent Channel Measurements

These measurements are often difficult to make because of the system (WCDMA) requirements compared to the capabilities of available test equipment. Also as with any newly introduced concept there is a great deal of confusion as to what is actually required, (i.e. how the overall system budget is divided between the various components). ACP measurements are not limited to WCDMA systems, but are probably most likely to be first encountered with such, due to the current high level of interest. WCDMA employs Quadrature Phase Shift Keying (QPSK) modulation. QPSK carriers have constant amplitude, however to reduce the occupied bandwidth wave shaping filters are employed, and this creates a signal of varying amplitude. The extent of this variation, or the ratio of the peak to the average power, is called the Crest Factor (CF). Gain and phase variations in the signals, produced by these parameters varying in the amplifier under different input signal conditions, cause distortion. These are seen as 'shoulders' appearing on either side of the band. In CDMA systems the CF is usually between 8 and 12 dB, for TDMA the requirement is lighter, ~3.5 dB.

The general requirement is for ACP ('shoulder') levels on the unit under test to be below ~-45 dBc. This means that the test equipment used to drive the UUT be less than –55 dBc. High quality signal generators are be able to produce levels of –65 dBc, however their average output power levels are very low ~5 dBm, compared to measurement levels ranging from 1 to 10's of watts. Hence the need to use a driver amplifier.

Ideally an amplifier would have the famous 'Bart's Head' shape, touted by a certain amplifier company. In fact

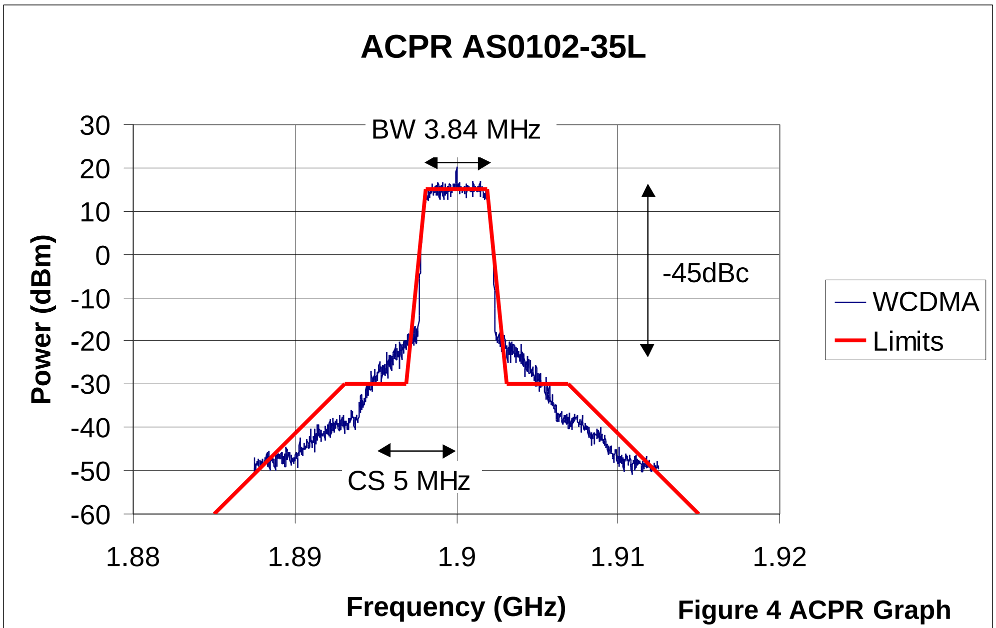

Figure 4 ACPR Graph

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all amplifiers do produce this performance, if backed off into the linear region sufficiently. Hence this graph is actually meaningless. The trick is to produce the most efficient amplifier for the application, i.e. the one that has to be backed off the least.

The need for efficient amplifiers capable of handling high CF is what has lead to the development of 'Linearised' Amplifiers. These are very complex amplifiers that employ either a method of deliberately distorting the signal (pre-distortion), or compensating the output to remove the distortion, (feed-forward). However these are narrow band and very complicated to manufacture and especially test. For most general-purpose test instrumentation requirements a higher power SSPA is the best solution.

When selecting a power amplifier for testing with digitally modulated signals the important criteria are:

- Frequency (range)
- Modulation format
- Crest factor
- Test power level
- Rejection criteria.

For example:
- Frequency 2.11-2.17 GHz
- WCDMA 3GPP, BW 3.84 MHz, CS 5 MHz
- Crest factor 11 dB
- 3W average output power level
- -45 dBc ACR

As already mentioned above, to minimise distortion it is important keep gain and phase variations to a minimum. Hence although the specified band is only 60 MHz wide the actual performance bandwidth may be greater, in order to minimise gain and phase variations across the band. It is also usually important that these do not vary with temperature and time, as test systems will be calibrated to reduce their effects, and drift with temperature or time will require a longer calibration time.

The following graph and tables show actual ACP performance of a standard Milmega amplifier at two frequencies across its operating band.

Reference Power		**Frequency: 900 MHz**			
Watts	**dBm**	**LC1**	**UC1**	**LC2**	**UC2**
10	40	-32.3	-31.8	-56.2	-53.3
5	37	-43.7	-43.3	-60.3	-60.0
3.5	35.4	-51	-51	-60	-60.0
3	34.8	-52.7	-54.2	-61.5	-61.5
1	30	-59	-59	-59	-59

Reference Power		**Frequency: 1900 MHz**			
Watts	**dBm**	**LC1**	**UC1**	**LC2**	**UC2**
10	40	-31.0	-30.1	-52.5	-52.0
5	37	-41.8	-41.7	-58.0	-58.0
3.5	35.4	-48.0	-48.0	-60	-60.0
3	34.8	-51.3	-51.3	-60	-60.8
1	30	-59	-59	-59	-59

BW = BandWidth, CS = Channel Space, LC = Lower Channel, UC = Upper Channel.

At both frequencies it is necessary to back off the amplifier by about 10 dB to achieve the basic system requirements, and by a further 2 dB to

meet the –55 dBc for test system amplifiers.
Milmega amplifiers inherently have the flat phase and gain performance required for digital modulation test schemes. However ACP is not a parameter regularly tested in production. When a customer specifically requires an amplifier for such systems Milmega should be informed so that the appropriate tests can be agreed and arranged. A problem with these measurements is that –55 dBc is getting close to the limits of Milmega's test system, and consequently measurement accuracy is low. It is therefore common for measurements to be carried out at a higher level and the performance to be extrapolated back.

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