TECH BRIEF

Comparing Linearity Measurements in a GaN Ka-Band Satcom Power Amplifier

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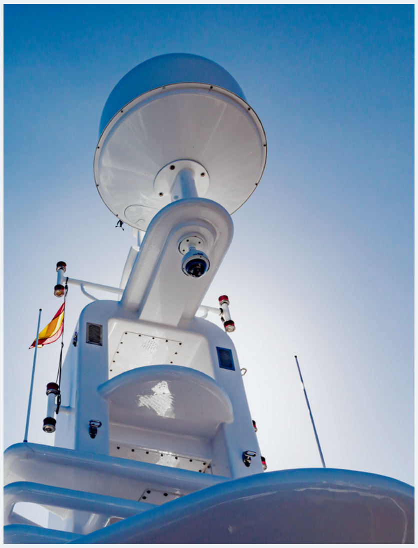
Introduction



Most modern Ka-Band Satellite Communication systems rely on solid state power amplifiers for their transmitters last stage. This item gives the transmitting signal the final power boost before being sent to the antenna, and its parameters are critical for the overall performance of the whole system.

The power amplifier's output power, linearity and efficiency are important variables to be considered for the final system design, which is normally based on wide-bandgap semiconductors like GaAs or GaN.

GaN based amplifiers are becoming more important due to their superior power density and power efficiency, which allows the manufacturing of smaller and more efficient transmitters. They are also much simpler and more reliable than other technology alternatives like tubes. However, this technology presents a non linear behavior on its maximum power areas, which can degrade the transmitted signal to a point where it is useless.

There are different methods to characterize the non-linearities of a given power amplifier. In this Tech Brief we focus on the Adjacent Channel Power Ratio (ACPR), that measures the amplifier behavior under a specific modulated input signal, giving a direct and clear indication of amplifier performance for a given application, and we compare this with classical RF parameters of the amplifier such us P1dB, Psat and OIP3. An ERZIA Ka-Band Satcom power amplifier has been used for this measurement.

DEVICE UNDER TEST

The device under test is a new COTS power amplifier designed for Ka-Band Satellite Communications applications, based on a GaN output stage to maximize power and size efficiency. **Table 1** shows Its main characteristics.

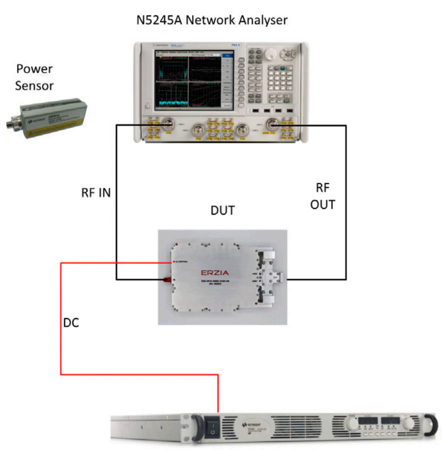
Table 1: *ERZ-HPA-2750-3100-46 Specifications summary*

	Min	Typ	Max	Unit
Frequency	27.5	—	31	GHz
Output Power (Psat) @CW	45	46	46.5	dBm
Output Linear Power @ACPR>25dBc (OQPSK Modulation)	—	44	—	dBm
Small Signal Gain	70	75	80	dB
Gain Flatness	—	±3	—	dB
VSWR input	—	1.5:1	—	—
VSWR output	—	1.5:1	—	—
DC Voltage	18	24	36	V
Power Consumption @Psat	—	210	240	W
RF Connectors	2.92mm (F) IN / WR28 OUT			—

DEVICE TEST SETUPS

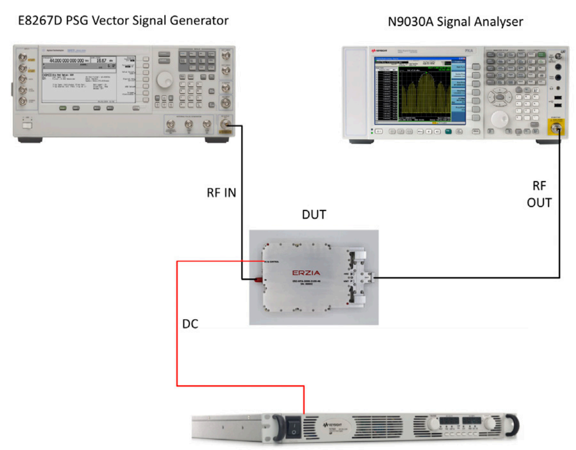
TEST SETUP 1

A PNA together with a power sensor for calibration purposes are used to perform S-parameters, P1dB and Psat measurements. A power supply is used to bias the device.



TEST SETUP 2

A signal generator with vector signal generation capabilities and a spectrum analyzer with complex signals measurements capabilities is used to perform two-tone and ACPR measurements.

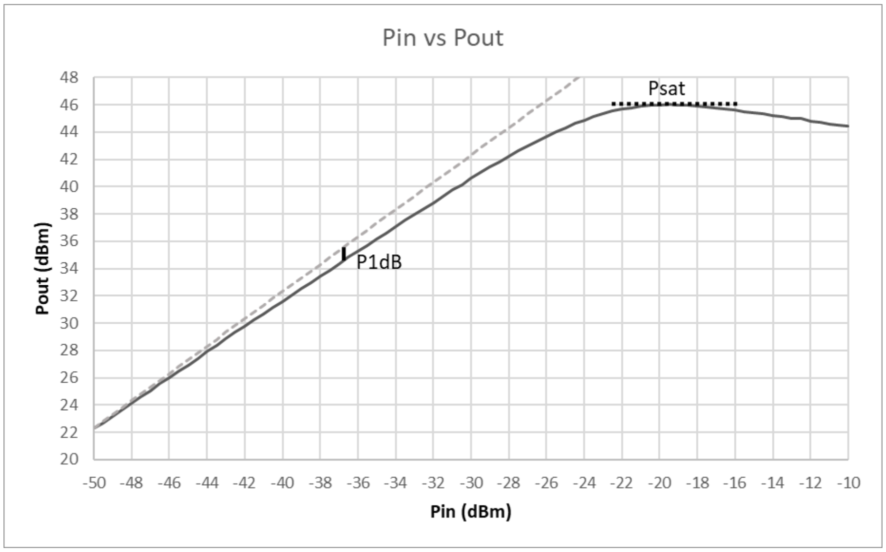


RESULTS

P1dB & PSAT

An input power sweep between -50 to -10 dBm was executed to the amplifier at 29.3 GHz obtaining the response in **Figure 1**.

Figure 1: Pin vs Pout



A Psat of 46 dBm is obtained with a P1dB of 34.8 dBm. This big difference between P1dB and Psat is normally an indicator of bad linear behavior at the high-power areas of GaN amplifiers when compared with normal differences of less than 1 dB in GaAs equivalents. Although those values indicate the maximum power levels that the amplifier can deliver, it is a weak indicator from a linearity point of view, as it only gives an idea of how the amplitude of the signal would behave in these areas, not taking into account phase variations and thus overall distortion.

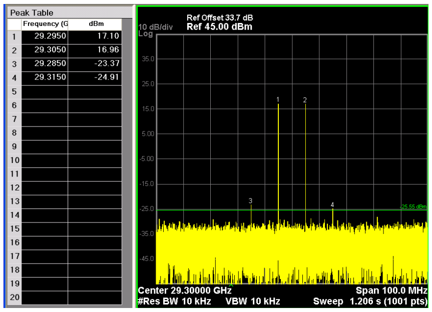
IMD3

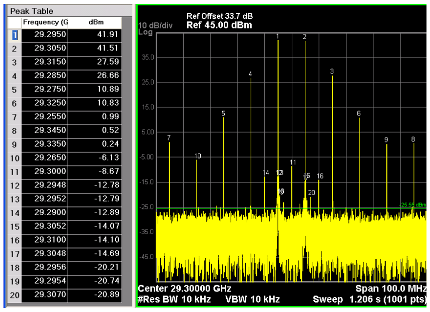
A two-tone test has been executed at 29.3 GHz center frequency with output power levels increasing between -20 dBm and 45 dBm in order to see the transition between linear regions and full compression.

Figures 2 & 3 present the two tones at the output of the amplifier for a given power. The intermodulation products can be also observed.

Figure 2: Left—2 tone test for 20 dBm output

Figure 3: Right—2 tone test for 45 dBm output

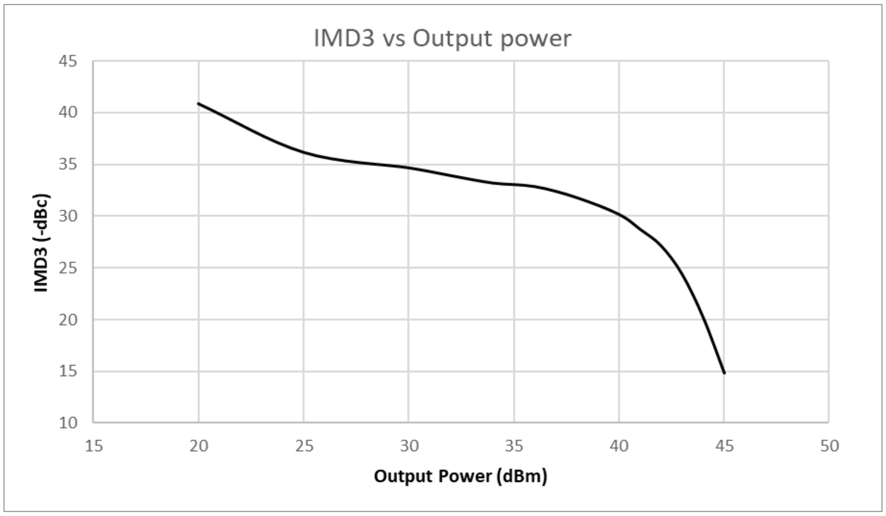




As expected, at 20 dBm output a very clean response is obtained while at 45 dBm (1 dB back off) there is an important mix of tones, with the highest ones at only about 14-15 dBc from the main tones.

Figure 4 presents how this IMD3 evolves with output power.

Figure 4: *2 IMD3 vs Output Power*



A low distortion response can be observed at the lowest power, with more than 40 dBc between the main tones and the intermodulation products, slightly decreasing down to 30 dBc at 40 dBm output power, and quickly decreasing afterwards until a minimum of 15 dBc at 45 dBm.

This test is a more reliable indicator compared to the P1dB and Psat as it presents the real distortion of the amplifier when working at compression regions. Its advantage is that is a pure RF indicator, not including any modulation scheme, but it can still be pessimistic if we compare it with real behavior of communication signals.

Adjacent channel power ratio (ACPR)

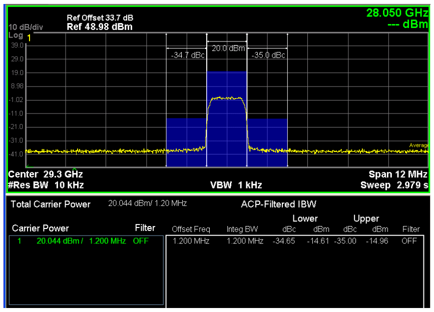
A test with a real communication signal is performed. The Adjacent Channel Power Ratio gives an indication of the distortion of the signal when real modulation schemes are injected to amplifier. In this case a BPSK and QPSK signals where used.

Figures 5, 6 & 7 present modulated BPSQ and QPSK signals with a bandwidth of 1.2 MHz centered at 29.3 GHz. The adjacent channels are also monitored with a 1.2 MHz bandwidth at each side of the main channel.

Figure 5: *Left—ACPR for BPSK @ 20 dBm output*

Figure 6: *Middle—ACPR for BPSK @ 43 dBm output*

Figure 7: *Right—ACPR for BPSK @ 45 dBm output*



With a BPSK signal, a good response—better than 35 dBc (real signal is below the noise) is observed at the linear region (20 dBm output) while a strong deterioration down to 18.6 dBc is measured for 45 dBm output. At 43 dBm output (3 dB back-off) the ACPR is still 25 dBc.

Figures 8, 9 & 10 show the QPSK results:

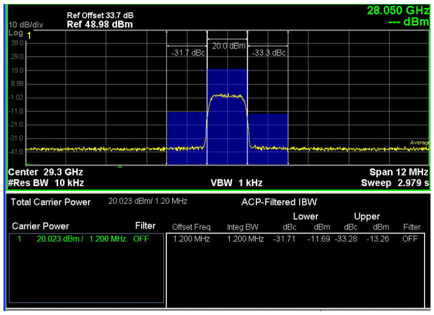


Figure 8: *Left—ACPR for QPSK @ 20 dBm output*

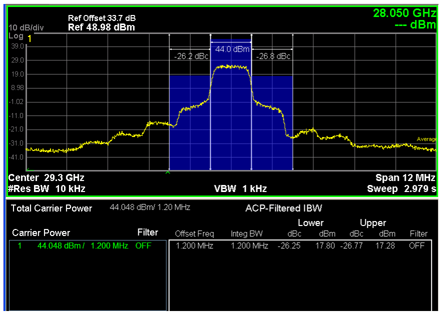


Figure 9: *Middle—ACPR for QPSK @ 44 dBm output*

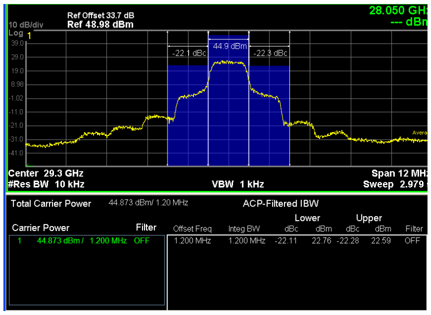


Figure 10: *Right—ACPR for QPSK @ 45 dBm output*

With a QPSK signal, a good response of 33 dBc is observed at the linear region (20 dBm output) while a strong deterioration down to 22 dBc is measured for 45 dBm output. At 2 dB back-off (44 dBm) the ACPR with QPSK is still greater than 26 dBc.

QPSK response is 3 dB better than the one obtained at 45 dBm with the BPSK modulation scheme. The complete power sweep is presented in **Figure 11**.

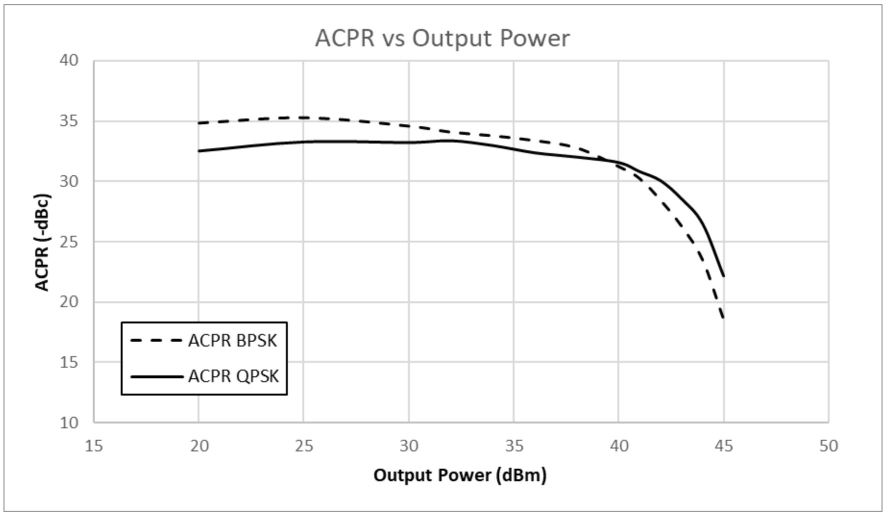


Figure 11: *ACPR for BPSK and QPSK versus output power*

It can be observed how at linear regions both ACPR are well above 30 dBc, but when entering in compression regions both are quickly decreasing, arriving to 22.2 dBc for QPSK and 18.6 dBc for BPSK. For a given output power and with the same amplifier, QPSK performs about 3 dB better than BPSK, which is consistent with the fact that QPSK contains the information in both phase and amplitude, while BPSK is only phase modulated.

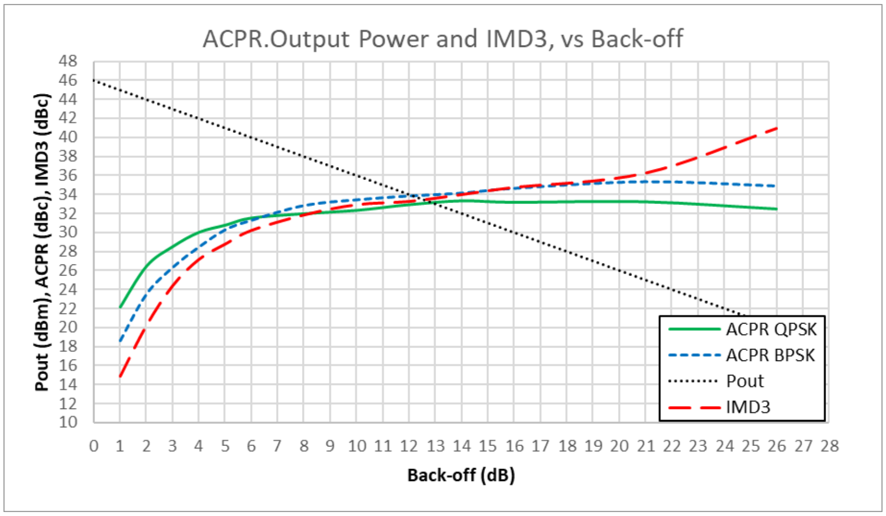
DISCUSSION

It has been observed in previous sections how the linearity measurement is different depending on the parameter observed. The P1dB and Psat measurements are needed to understand which is the maximum power level that the amplifier can deliver (Psat) and where the non-linear region begins (P1dB), but additional data is needed to correctly dimension and design the amplifier performance in the system as the amplifier will need to work at a certain back-off (dB down from max output power), with the trade-off between delivered output power and linearity.

Figure 12 gives a good understanding of how the amplifier performs and how to select the best back-off for each case.

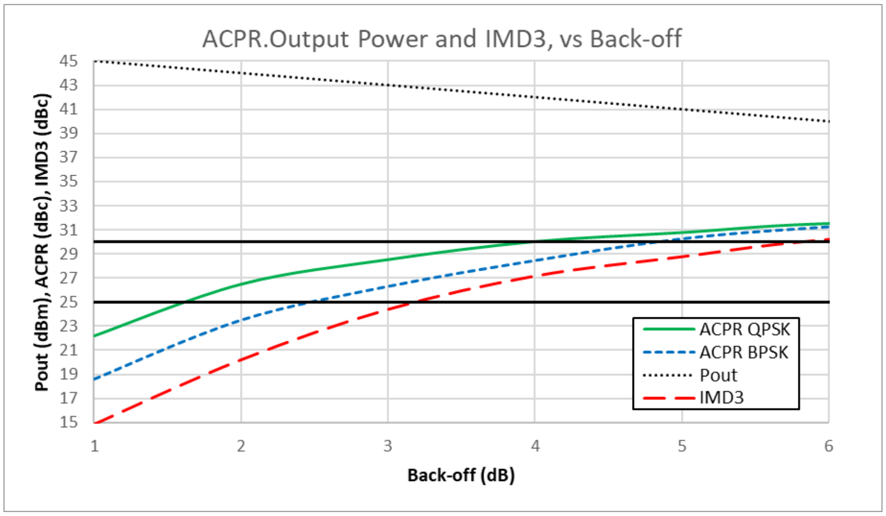
The X-axis represents the back-off in dB from the maximum output power (46 dBm). For example, if we work at 6 dB back off we will have a 40 dBm output power (black dashed line) we will have an ACPR for BPSK of 31.25 dBc (green line), an ACPR for QPSK of 31.55 dBc (blue dashed line) and an IMD3 of 30.19 dBc.

Figure 12: *ACPR for BPSK and QPSK, IMD3 and Output Power, versus back off*



It can be observed how the IMD3 is a very good indicator of the distortion generated by the non-linearities, but still can give to pessimistic indications when we compare it with real measured modulations, especially at points of low back-offs and highest output powers, which is the area of biggest interest. **Figure 13** presents the same chart but focuses on the high power area and highlights two typical linearity thresholds of 30 dBc and 25 dBc.

Figure 13: ACPR for BPSK and QPSK, IMD3 and Output Power, versus back off (zoomed version)



It can be observed how if a designer that desires to maintain a transmitter linearity of 30 dBc, and he or she only takes into account the IMD3 data of the amplifier, the needed backoff is almost 6 dB, with the amplifier delivering around 40 dBm - 10 W. However, if the modulation scheme is taken into account, for a 30 dBc ACPR, the selected point would be a back off of 4.8 dB for BPSK and 4 dB for QPSK, which means much higher output power. If the system can be pushed to the limit and 25 dBc is the threshold, then the IMD3 will be indicating a back-off of 3.2 dB (42.8 dBm output power) while BPSK would indicate 2.45 dB and an output power of 43.55 dBm and QPSK 1.6 dB and an output power of 44.4 dBm. This means that only with IMD3 data, the system would be delivering much less output power, while when using the specific data for each modulation, the system can be optimized for the desired output power and linearity values.

Conclusion

P1dB, Psat, IMD3, ACPR for QPSK and for BPSK have been measured in a GaN based SSPA designed for Ka-Band Satellite Communication applications, reaching to the following conclusions:

- P1dB and Psat give valuable information about amplifier maximum output power capabilities, but they are very weak indicators of linearity performance.
- IMD3 is a modulation-independent indicator of distortions caused by non-linearities, but it can underestimate the performance of the amplifier in the real application.
- ACPR is the best parameter to optimize the amplifier working point to deliver the maximum output power for a given linearity, but it must be measured for each specific modulation.
- The GaN Ka Band Solid State Power amplifier measured is able to provide a maximum output power of 46 dBm, with good linearity values at very low back-off without the need of additional or externals linearizers.

NEXT STEPS

Download the data sheet for the High Power Amplifier in this tech brief:
ERZ-HPA-2750-3100-46 Ka band High Power Amplifier

ERZIA catalog of High Power Amplifiers:
High Power Amplifiers | Compact Solid State Low Noise Amplifier RF/Microwave

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