

Gallium Nitride Amplifiers in Context

Applications & power levels for commercial & government satellite industries.

Terrasat Communications Inc

Our Ground-breaking IBUCs bring advanced features & performance to C-Band, X-Band, Ka-Band, Ku-Band earth terminals & VSATs worldwide.

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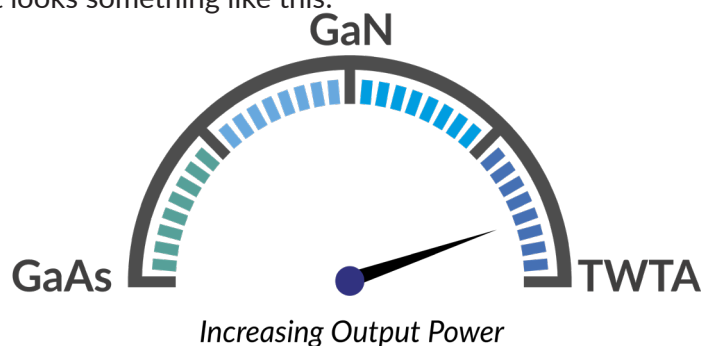
The evolution of the RF Amplifier landscape

Improvements in Gallium Nitride (GaN) devices & implementation of linearization techniques have changed the RF amplifier landscape. Customers have more choices than ever, which can lead to confusion. Here we will attempt to shed some light on GaN satcom implementation. The way we propose to do that is to consider GaN within the context of the adjacent technologies of Gallium Arsenide (GaAs) & Travelling Wave Tube (TWT) amplifiers. These technologies are commonly used in the applications & power levels in which our commercial and government satellite customers operate.

At the outset, let's be clear that none of these is an obsolete technology. And none has superpowers that render all other development futile. Each has characteristics that can optimize a customer's price/performance equation when matched to the application. There is competition at the edges where each manufacturer wants to extend their borders.

Raw Power

The history of our industry has been that SSPA manufacturers have continuously striven to increase output power in an effort to displace the market space occupied by tubes. Solid state power amplifiers deliver longer service life and are less delicate than tubes. GaAs devices are very linear. But they produce relatively low power per device. GaN technology, with higher power density characteristics, provides a path to higher power in a smaller package. However, combining losses at higher power levels & removing heat from devices limit solid state technologies in the power domain. We have an output power continuum then that looks something like this:



Linearity Clarified

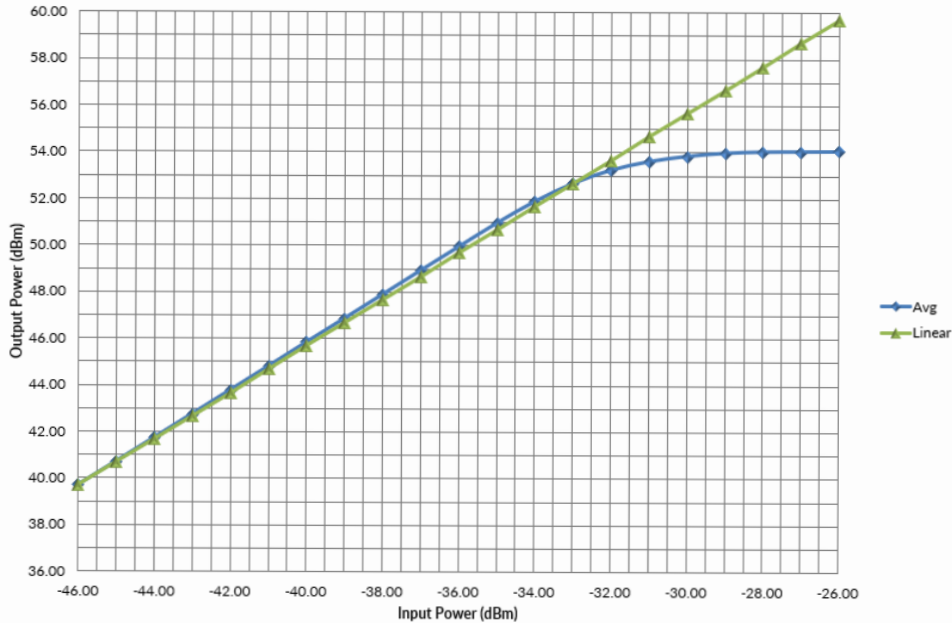
A key performance factor is linearity – defined as 1 dB additional input power resulting in an increase of 1 dB of output power. In the small signal linear region the power out vs. power in curve is a straight line. Signal distortion is minimal. A characteristic of GaAs amplifiers is that they are very linear – until they're not. A GaN amplifier is much less linear as can be seen in the two plots below. From information published by TWTA manufacturers you can see that a TWTA power transfer curve is linear until it approaches the P_{Linear} point, after which it degrades more gradually than a GaAs or GaN amplifier.

However, this is the first and very significant element of confusion. The output power of each of the three is measured & stated differently. And this has major implications in selecting which solution is appropriate in your circumstances. Understanding how output power is stated differently for each can make the difference between having enough power to close the link once the terminal is installed - or not. Briefly stated:

GaAs

A GaAs (Gallium Arsenide) amplifier is a very linear device. One dB additional input yields 1 dB output as shown in the plot below. Output power is measured at the P1 dB compression point at the output flange. It is defined as the point at which the gain of the device is reduced by 1dB as a function of the input power due to nonlinearity. Sometimes you will see a manufacturer specify P_{Sat} . It is necessary then to subtract about 1 dB (depending on how well-designed the amplifier is) to normalize to P1dB. Typically then it is necessary to back off output power about 1 dB to get to the P_{Linear} point as defined in MIL-STD 188-164B.

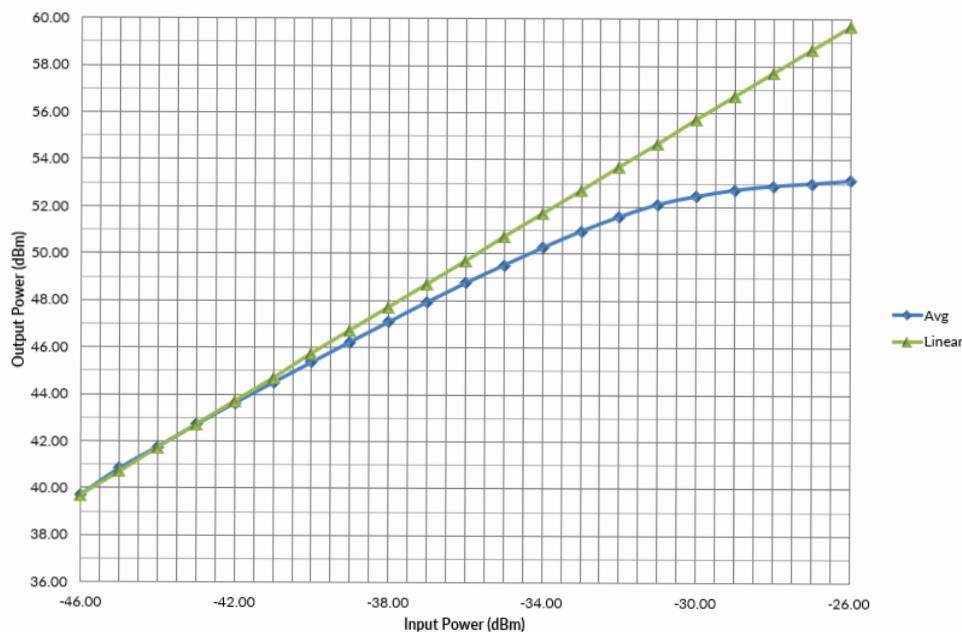
200 W IBUC \mathcal{R} Full Ku-band
 Pout (dBm) vs Pin (dBm)



GaN

The power transfer curve of a GaN amplifier shows it does not behave in a linear fashion (see plot below). The P1 dB compression is not meaningful. For the most part, the industry has settled on P_{sat} at the output flange as the convention for rating power. P_{sat} is the level at which any increase in input has no effect on output power. This is a reference point – and not a terribly useful one. At P_{sat} the signal is unusable. Therefore manufacturers also state P_{Linear} as defined in MIL-STD 188-164A. What this means is that it is necessary to back off the GaN amplifier by 1-4 dB (depending on quality of implementation) to get to P_{Linear} . So, a 200W GaN might be the equivalent of a 100-150W GaAs unit in useable power. Terrasat has implemented techniques that minimize the back-off in all models, delivering higher usable output power.

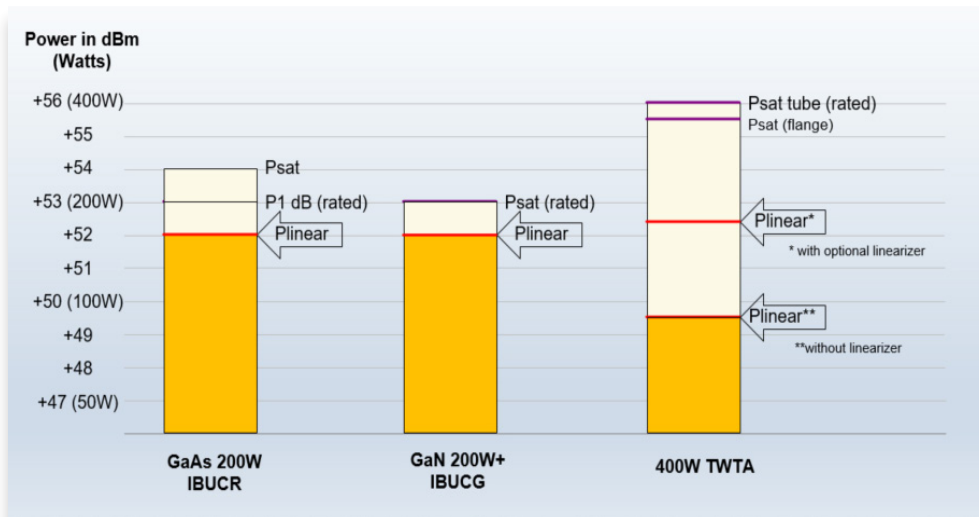
200 W IBUC \mathcal{G} Full Ku-band
 Pout (dBm) vs Pin (dBm)



TWTA (HPA)

TWTA output power is measured in yet another manner. The industry convention is to name an HPA unit by the saturated output power of the tube rather than at the unit output flange. The TWTA is even less linear requiring 6-7 dB of output power backoff to meet the standard of P_{Linear} . For example, a 400W TWTA without a linearizer produces about 100W at P_{Linear} . By comparison, a 100/125W GaAs unit would produce about the same useable power. It is possible to improve the linearity of a TWTA by adding a linearizer – a form of pre-distortion. That adds cost & complexity, which may be justified in the circumstances.

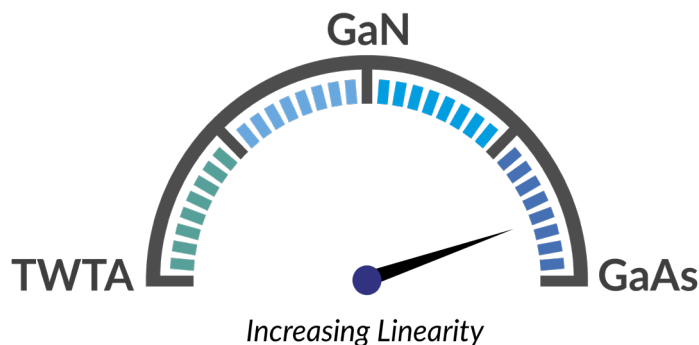
The following chart shows the interrelationships of the rated output power, P_{sat} , & typical P_{Linear} output power performance for each of the three technologies.



It is necessary to normalize to P_{Linear} in order to compare alternatives.

Non-Linear Distortion

As a device is driven into saturation, the transfer characteristic becomes increasingly non-linear & signal distortions become evident. But this happens very differently with each of the technologies under consideration. Looking at the three technologies in context, now we get a very different progression.



The two primary measurements of non-linear distortion are Spectral Regrowth & Intermodulation Distortion (IMD). Spectral regrowth is the intermodulation products of a single carrier while IMD measures intermodulation of two carriers. The reference is MIL-STD-188-164 which defines P_{Linear} in these terms – Spectral Regrowth better than -30 dBc & IMD3 better than -25 dBc relative to the combined power of two carriers. (Equal to -22 dBc with reference to one of the two carriers as is more commonly stated).

What we see in IBUC performance and collected data from published data sheets is that there is a significant variability in the amount of output power backoff (OBO) required to achieve P_{Linear} performance in GaN products:

	GaAs OBO	GaN OBO	TWTA OBO
C-Band	1 dB	1-3 dB	6-7 dB
Ku-Band	~1 dB	1-4 dB	6 dB

The less backoff, the higher the output power. This leads to the critical point:

Two amplifiers with the same rated output power can be up to 3 dB different in usable power. The better the implementation of the amplifier, the more usable output power you will have.

TWTA performance can be improved by approximately 3 dB by adding a linearizer, which is a cost factor to consider.

Summary

The objective here is to give you some information for drawing your own conclusions. Each satellite operator has their own definition of acceptable levels of out-of-band interference & it is imperative to understand those limits when planning the link. A customer would be well-advised to consider all of the data in relation to the specific link requirements in order to make a wise choice.

Terrasat uses both GaAs & GaN technologies in IBUC products.