

TriQuint stretches the sweet spot

Paying great care to impedance matching has paved the way to production of incredibly wide bandwidth amplifiers with unprecedented efficiency, say TriQuint's **Mike Lincoln** and **Mark Andrews**.

Radio communication can provide a life-saving link between personnel in public safety agencies, the military and anyone in distress. The two-way radios that have been widely used since the end of World War II have enabled effective communication between personnel on countless occasions, using a specific frequency. Because different groups use different allocated frequencies, all users need wideband radio systems, which typically include high-power capability.

The unique challenges associated with high-power, wideband amplifier design leads to radios that are heavier, more costly and less efficient than those operating in narrowband applications, which have a far wider choice of high-efficiency RF transistors for amplifier construction. However, at TriQuint Semiconductor, we have developed a patent-pending technology that will revolutionize high-power wideband amplifier design. And best of all, it's not only applicable to two-way radio communications – it can also serve many other applications, including lab amplifiers, jammers and some forms of repeaters.

Our latest high-power transistor family has delivered a dramatic hike in wideband amplifier efficiency, and it is now being designed into broadband systems around the globe. The portfolio features discrete, 10–50 W output, RF transistors that can boost multi-octave (500 MHz–3 GHz) amplifier efficiency from 25–35% to 45–55%.

To fully appreciate the significance of our breakthrough, it is imperative to understand the elements common to wideband and narrowband systems.

Impedance issues

At the simplest level, an RF amplifier has to transform a small signal into a larger one. Typically, RF transistors produce 8–22 dB of RF gain, but this is inadequate for many RF systems that require a gain of 40 dB or more from the power amplifier (PA) section. Greater gain can be achieved by linking multiple amplifiers together, with one amplifier feeding the next. The signal increases at every stage, until it meets the required RF output power, and this can be transferred to an antenna or other final load.

As the signal travels from one amplifier stage to the next, impedance matching is needed at these interfaces to maximize energy transfer from the



A technician in TriQuint's Boulder, CO, Design Center inspects lead coplanarity of a prototype PowerBand device.

source of the signal to the load. Ideally, the amplifier circuits contain “matching networks” that match the source to the load at every stage. However, if the matching isn't perfect, some of the signal reflects off the load (known as the return loss) and is driven back towards the source, which reduces efficiency, gain and output power.

To meet the high-power requirements for applications such as two-way broadband radios and RF jammers, large RF power transistors need to produce between 10 W and several kilowatts. These transistors must be big enough to meet the RF power output requirement, but not so large that they hamper efficiency. As they get larger, impedance decreases, and this makes it harder to build matching networks that can transform this impedance to a higher level.

The transistor RF output power is calculated in the same way as DC power – it is simply the product of voltage and current at a given time. Consequently it is possible, for example, to produce a 120 W output from a 12 V, 10 A signal or a 28 V, 4.3 A signal. However, impedance matching is much easier with transistors that operate at higher voltages, such as 28 V compared with 12 V.

RF power transistor manufacturers provide

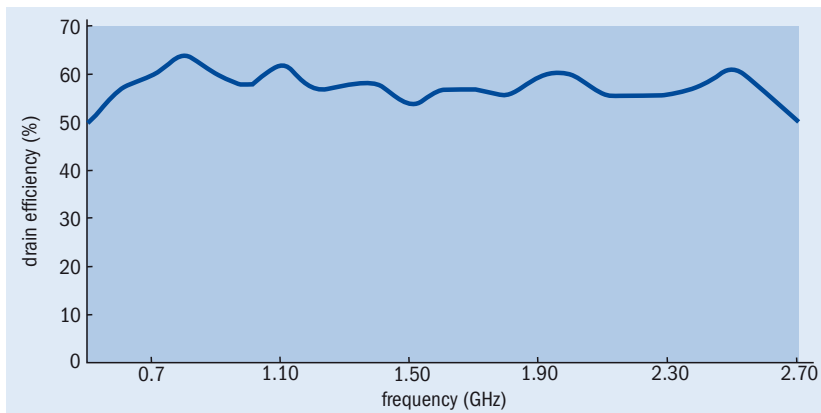


Fig. 1. Measurements in a broadband test fixture demonstrate that TriQuint's PowerBand devices deliver exceptional efficiency across an unprecedented bandwidth.

impedances and associated device performance in the form of load-pull and source-pull data tables and associated graphs. But engineers tackling these designs have discovered that gain, efficiency and output power require different impedances for peak performance. The challenge is to identify a “sweet spot” that offers the best trade-off in performance for a particular design goal.

High-voltage III-Vs, such as our GaN transistors, generally produce a far lower capacitance per watt of RF output power than those of devices fabricated using other process technologies. The lower capacitance translates into higher impedance and explains why high-voltage GaN-based power transistors are deployed in narrowband systems that require very high output power from a single-ended amplifier. Broadband designers also like to take advantage of the impedance benefits of GaN, which enable them to build matching networks operating over a greater bandwidth for a given output power.

On a per-device basis GaN is more expensive than incumbent technology, such as LDMOS, but its system-level cost savings are undeniable. In fact, turning to an advanced technology such as GaN is often the only sensible way to construct a system with aggressive design goals.

While advanced semiconductors have simplified wideband designs, and in many cases turned the impossible to the possible, performance is overshadowed by narrowband designs with far higher efficiencies. Even wideband GaN-based amplifiers only deliver 25–35% efficiency in the final PA stage.

Obstacles to going wide

Wideband designs face two additional challenges over their narrowband siblings. First, matching network impedance varies with RF signal frequency, and a circuit that works well at one particular frequency will deliver inferior energy transfer at higher and lower frequencies.

The other challenge is that device impedance changes with frequency and in the opposite direction. This leads the designer to see that as the signal frequency moves away from the center point – either

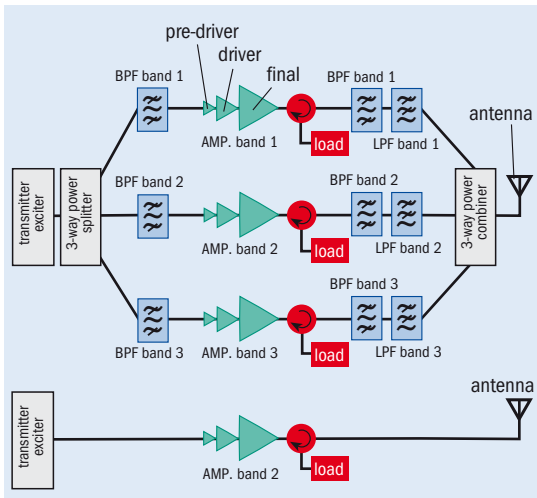


TriQuint's initial PowerBand family (top) consists of six devices that employ LDMOS and GaAs pHEMT technology, and offer an efficiency of 45–50% or more across a bandwidth that can span 500 MHz to 3 GHz. 100 W products based on GaN technologies will be added to the portfolio this year (bottom).

increasing or decreasing – differences between the impedance of the device itself and its matching circuit increase. Generally, gain is sensitive to the input match, while efficiency and RF output power tend to be more sensitive to the output match. The upshot is a very poor performance in all major areas, if the techniques of narrowband design are transferred to a wideband application.

Successful wideband amplifier designers address all of the challenges of narrowband designs, while simultaneously dealing with the added complexity of creating matching networks that continuously provide the RF power transistor with acceptable impedance over frequency changes of two octaves or more. If this wasn't enough, many RF power transistor manufacturers fail to provide load and source-pull data across the entire useful frequency band of a given device.

Designers in the rare position of having access to an automated source and load-pull tuner system can measure the device impedances across the entire band of interest. However, they will often find that impedances required for stable, high-performance operation are beyond the abilities of traditional matching networks. To address this, engineers tend to design smaller amplifiers (in terms of RF output power), which have adequate impedance to provide good performance. These are combined



Conventional designs (top) can be simplified with PowerBand technology (bottom). Although each design is unique, reduced part count, efficiency improvements and true wideband coverage – more than two octaves – is commonly achieved.

together to meet the desired RF output power. But this approach has high development and system costs, and produces large, heavy amplifiers. If the bandwidth is too great, designers resort to “channelizing” or breaking the frequency band into sections, creating amplifier stages that only target frequencies in a given range. Again, this comes with a huge financial, size and weight penalty.

We have approached the challenges of wideband design from a different perspective. Our starting point was a study of the various approaches to broadband matching and the resulting impedances across a given frequency band. We set a goal of creating an RF power transistor that would perform well in such an impedance environment, and placed an emphasis on output power and efficiency.

The results are dramatic: we now have a range of six products that are based on GaAs and LDMOS process technologies, which can deliver 45 and 55% efficiency over bandwidths of up to 500 MHz–3 GHz (figure 1 and table 1). These can utilize more than 75% of the devices’ rated narrowband P1dB output power capability, which is three times that of most transistors built with traditional approaches.

Missing data

The challenges of wideband design are often compounded by a lack of data provided by RF transistor manufacturers; data provided rarely reveal how devices would perform in a wideband application. Yet there are many instances where narrowband devices are marketed as suitable for broadband use, even though the data supplied fail to accurately characterize the performance for applications requiring greater than 2 GHz coverage. In many cases, narrowband data is only published at the high and low ends of the device’s intended frequency range.

It is far more useful to publish gain, efficiency and output power at the “instantaneous bandwidth”, which

Table 1. TriQuint’s PowerBand portfolio

Part number	Technology	Operating voltage (V)	Bandwidth (GHz)	Power P1dB (W)
T1P2701012-SP	pHEMT	12	0.5–2.7	10
T1P3002012-SP	pHEMT	12	0.5–3.0	20
T1L2003028-SP	LDMOS	28	0.5–2.0	30
T1P3002028-SP	pHEMT	28	0.5–2.0	20
T1P3003028-SP	pHEMT	28	0.5–2.0	30
T1P3005028-SP	pHEMT	28	0.5–2.0	50

More information is available at www.triquint.com/prodserv/markets/military/powerband.cfm.

is the device performance in an RF fixture with bias circuitry and matching network in place. The device can then be tested from one end of the frequency band to the other, with no changes required to the circuit or device. This differs from testing a device at a range of frequencies in various test fixtures, each attuned to work well at a single frequency.

Our PowerBand data sheets list instantaneous bandwidth RF performance and narrowband RF performance in the RF specifications section. Source and load impedances are also provided along with RF gain, efficiency and P1dB output power performance levels in the form of a table. These data have been generated by placing a given device in the stated impedance environment across the entire band of operation in 100 MHz increments. In addition, optimal input and output impedance of the matching network from the low end to the high end of the band is provided graphically on a Smith chart.

Broadband designers benefit from narrowband data, because they expose the degree of trade-off between wideband and narrowband performance. They also allow engineers to design narrowband amplifiers and exploit the benefit of greater flexibility compared with internally matched devices, thanks to the application of a single device to multiple product platforms. For example, two-way communication radio manufacturers produce a family of radios operating at different frequencies. In this case, one PowerBand device can serve three or more designs, whereas the traditional approach requires a different internally matched transistor for each application variation. Broadband amplifiers can also aid non-telecom systems designers, which often struggle to source internally matched RF power transistors that can operate in their band of interest.

There is no getting away from the fact that high-power amplifier design is difficult, and high-power, broadband design pushes that even farther. Until now, performance-reducing compromises were inevitable to meet the operating goals. But thanks to PowerBand, breakthrough levels of efficiency plus greater bandwidth coverage are now possible from RF transistors with output power levels of 10 W (P1dB CW) and 50 W (P1dB pulsed). We are aware that many applications require even higher output power and we plan to introduce a GaN-based 100 W P1dB CW device to the PowerBand portfolio. ●



About the authors

Mike Lincoln (left) is the original founder of Colorado-based Peak Devices, which was acquired by TriQuint in 2007. He is currently TriQuint’s PowerBand marketing director for the company’s portfolio of high-power, wideband RF transistors. **Mark Andrews** (right) is TriQuint’s strategic marketing communications manager for networks and defense/aerospace product marketing.