WHITE PAPER

How GaN is Changing the Satcom RF Front-End

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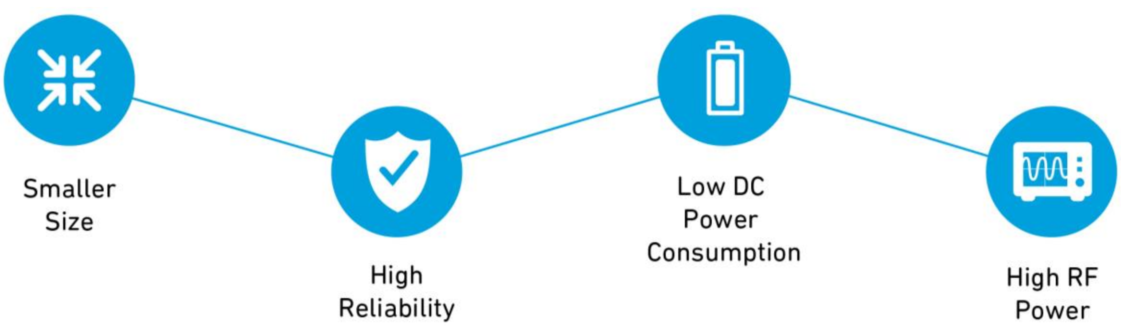
Introduction

Solid-state technologies such as gallium nitride (GaN) are transforming satellite communications (satcom). GaN's advantages of high RF power, low DC power consumption, high reliability and smaller size (which reduces system weight) are opening new markets and revolutionizing the RF front-end (RFFE) in existing satcom applications.

For many years the traveling wave tube amplifier (TWTA) and gallium arsenide (GaAs) were the go-to RFFE technologies for power amplification in satcom – with TWTAs used for high-power applications and GaAs employed in lower-power applications and as a pre-driver. But the situation has changed rapidly in recent years, due to advancements in GaN. Now, GaN and GaAs semiconductor technologies are becoming the go-to solutions; GaN has been replacing TWTAs due to its high-power performance and reliability combined with a small form factor. GaN and GaAs are enabling a wide variety of commercial and military satcom applications, such as 5G backhaul, ultra-HD TV transmission, satcom-on-the-move, internet access for aircraft passengers, and manpack (portable) terminals.

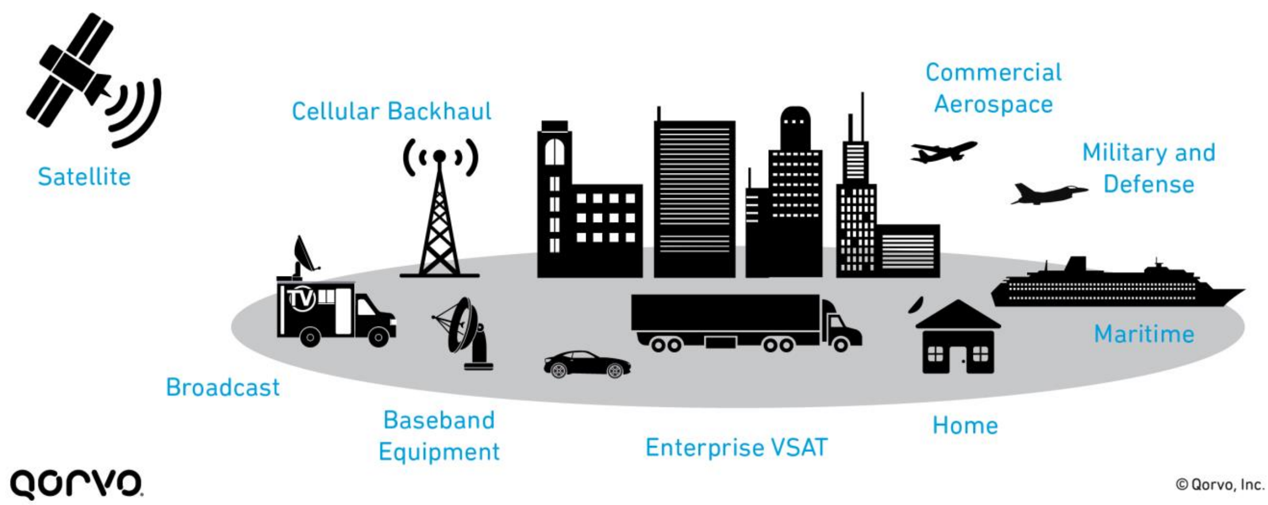
GaN Advantages



Satcom Trends

Satcom equipment plays vital roles in the global communications ecosystem and the daily lives of people across the world. It supports a broad and expanding variety of applications in telecommunications, weather monitoring, aeronautical communications, maritime applications, military uses and navigation (see Figure 1). According to **MarketsandMarkets research**, the satcom equipment market is projected to grow at about 8.5% a year to reach $30B by 2022. **Strategy Analytics** forecasts spending on global military communications systems and services will grow to over $36.7 billion in 2026, representing a CAGR of 3.5%.

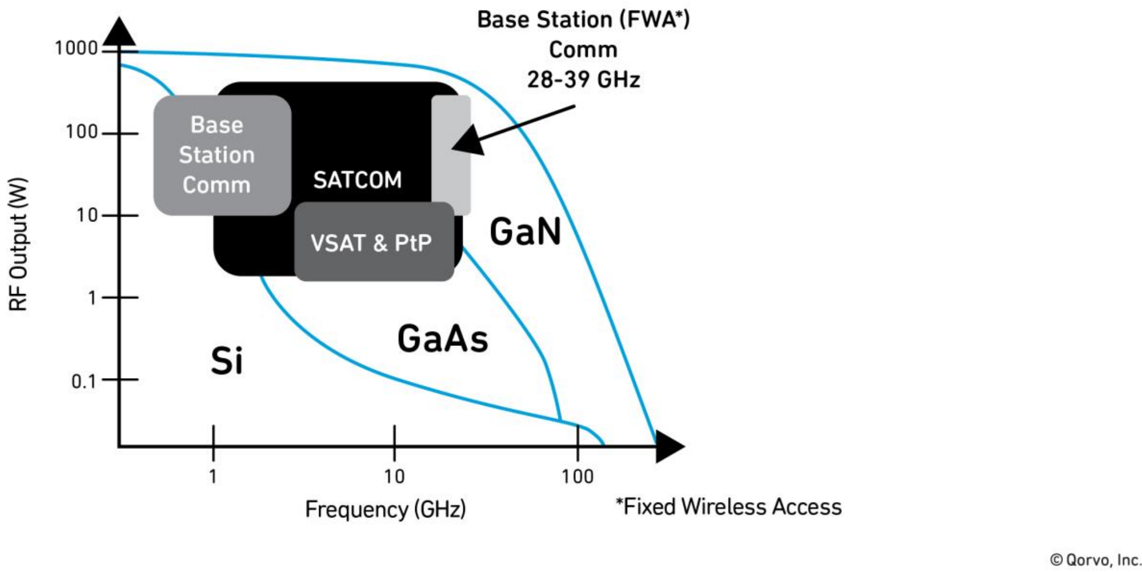
Figure 1. Satcom global markets.



Several broad trends are creating new and more challenging requirements for the RFFE in satcom equipment. The increasing use of smaller satellites and portable, mobile satcom devices is driving a need for more compact, lightweight components with lower power consumption. Additionally, components need to handle much greater bandwidth and data throughput to support advances such as 5G, ultra-HD TV, un-interrupted and secure communications. There's also pressure, to reduce development costs and increase reliability.

These trends are propelling the transition from TWTAs to solid-state devices that support higher data throughput and smaller form factors. Though GaAs and silicon (Si) have been used in some systems, GaN offers significant advantages for high-power amplification in satcom applications. Its high saturation velocity, high breakdown voltage, and thermal conductivity result in an order of magnitude improvement in power density and high reliability under thermal stress. As a result, **GaN** is uniquely suited to the high-power requirements of satcom, very small aperture terminal (VSAT), point-to-point (PtP) and base station applications, as shown in Figure 2.

Figure 2: Suitability of semiconductor technologies to different applications.



GaN's potential for the space and satellite communications sectors is only beginning to be realized. The high RF power, low DC power consumption, lightweight, small form factor and high reliability will enable manufacturers to downsize the RFFE. For example, GaN is expected to facilitate weight reduction in satellites and aeronautic applications.

Frequency Bands

The satcom industry has progressively moved to higher-frequency bands to support growing demand for bandwidth, including the X, Ku, K, and Ka-bands as shown in Figure 3. GaN easily supports high throughput and wide bandwidth across these higher frequencies. Today, many of the same satcom components are used across multiple military, space and commercial applications in these bands.

Figure 3. IEEE microwave bands.

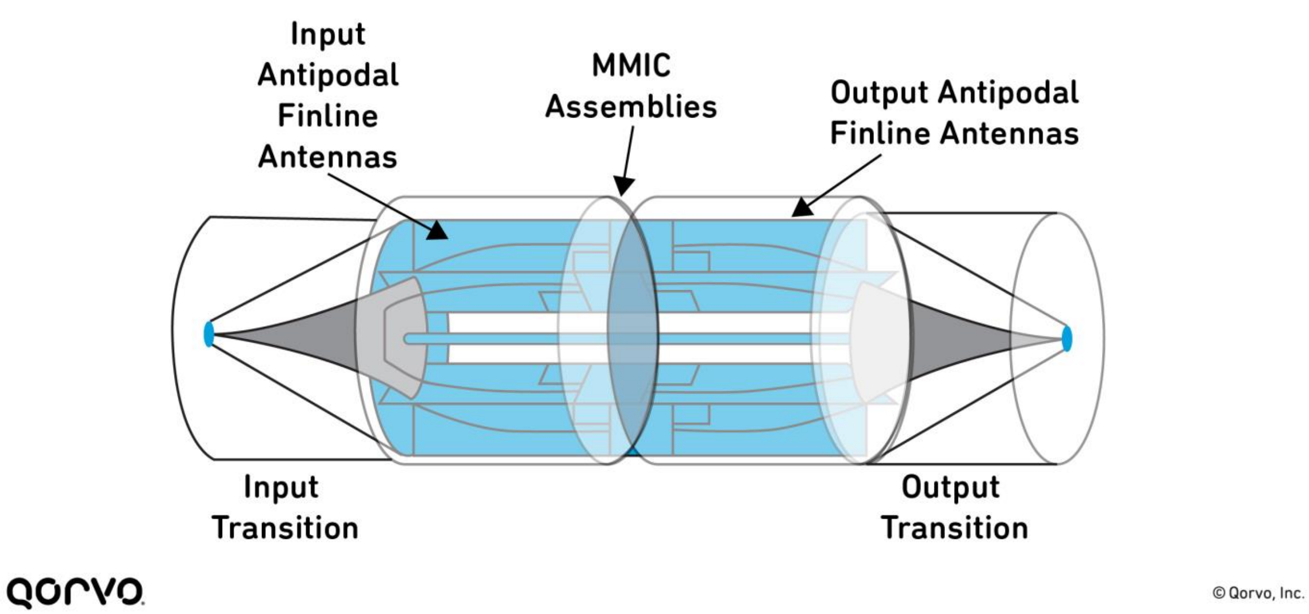
IEEE Microwave Band	Frequency Range	Description
L-Band	1 GHz – 2 GHz	Global positioning system (GPS) carriers and also satellite mobile phones, some communications
S-Band	2 GHz – 4 GHz	Weather radar, surface ship radar, and some communications satellites
C-Band	4 GHz – 8 GHz	Primarily used for satellite communications, for full-time satellite TV networks or raw
X-Band	8 GHz – 12 GHz	Primarily used by the military, also used in radar applications
Ku-Band	12 GHz – 18 GHz	Used for satellite communications, fixed satellite services and broadcast satellite services
K-Band	18 GHz – 26 GHz	Used for fixed satellite services and broadcast satellite services
Ka-Band	26 GHz – 40 GHz	Communications satellites, uplink in either the 27.5 GHz and 31 GHz bands, and high-resolution, ctlose-range targeting radars on military aircraft

Replacing TWTAs

Until recently, TWTAs were the mainstay in many satcom applications because solid-state devices weren’t capable of producing similar power levels. However, power combining techniques now make it possible to generate much higher power using GaN, enabling the replacement of TWTAs with more-reliable solid-state devices.

The GaN power-combining approach aggregates the output power from several single power amplifier MMICs using fully isolated coupling networks. An example is Qorvo's **Spatium**®, which is a spatial combining product that uses a patented spatial combining technique to offer high RF power, high efficiency and broadband operation. Spatium uses broadband antipodal fin-line antennas as the launch to and from the coaxial mode, splitting into multiple microstrip circuits (see Figure 4). It then combines the power from these circuits after amplification with a power MMIC. A typical Spatium design combines 16 devices, with a combined loss of 0.5 dB. Spatium is used in Ka-band satellite earth stations that operate at 100 Watts and 27-31 GHz, covering both military and commercial bands. Within these stations, it is used in the transmitter side at the antenna hub in block up-converters (BUCs).

Figure 4: Spatium spatial combining patented design.



This solid-state power-combining approach offers several performance advantages over TWTAs.

- TWTAs need to warm up before they can attain stable RF performance. Warming the tube can take a few minutes. Mitigating the problem requires backup systems running in hot standby. This results in large energy costs. These back-up systems are not required when using Spatium, as no warm up is required.
- TWTAs require high voltage power supplies, typically in the multi-kV range, thus increasing system power consumption. GaN devices do not require high-voltage power supplies.
- Solid-state GaN generates lower noise and has better linearity than TWTAs. Noise figures for medium power TWTAs can be around 30 dB, versus about 10 dB for a solid-state GaN monolithic microwave integrated circuit (MMIC) PA. Another operational benefit of the GaN transmitter is the reduced harmonic content in the output signal.

GaN Advantages for Satcom

GaN offers a range of other advantages over both TWTAs and other solid-state technologies for satcom applications.

Reliability and ruggedness. Reliability is extremely important in satcom applications. GaN offers much higher reliability than TWTAs for several reasons. With TWTAs, a failure in the tube causes a total performance breakdown. In contrast, a spatial combining technique like Spatium increases robustness and reliability. The failure of one transistor does not mean the entire unit shuts down; instead it continues to function using the remaining GaN amplifier MMICs. Each solid-state device is also highly reliable: although the lifetime of a transistor is limited due to electromigration, time-to-failure is typically over 100 years.

The higher power-efficiency of GaN also reduces heat output, which further contributes to higher reliability. Furthermore, wide-bandgap GaN tolerates much higher operating temperatures, so the cooling requirements in compact areas may be relaxed without compromising performance and reliability. This reduces the need for cooling fans and heatsinks, which reduces the weight and size of satellites and therefore the cost of launching them into orbit.

Small, lightweight devices. Weight and size are becoming critical factors in satcom applications, with the trend to smaller satellites and the growth of other on-the-move satcom applications. GaN's high power output and on-resistance and breakdown voltage allows satellites and other applications to reach target power output levels with smaller devices. Higher power density results in less weight and size per given unit of power output. The high breakdown field allows higher voltage operation and increased efficiency and helps to ease impedance matching requirements, reducing the need for tuning components and helping to decrease board size.

Low current consumption means lower operating costs and less heat to dissipate. Lower currents also helps to reduce system power consumption and demand on power supplies. The result is reduced expense for manufacturers and operators.

Reducing the thermal rise in a system makes it easier to increase performance and cuts cost for the application. Because GaN technology is highly power-efficient and tolerates higher operating temperatures, GaN technology can help system designers work within tighter thermal related margins, allowing extra performance to be delivered from the RFFE.

Frequency bandwith. Increased bandwidth is being used across the entire communications industry to provide greater capacity to support the ever-growing number of users and insatiable demand for data. The high power density of GaN and its lower gate capacitance enables greater operational bandwidth and higher speeds. Today's GaN modules and power amplifiers deliver broadband operation to support the unprecedented bandwidth requirements of 5G and other emerging applications.

Integration is now appearing in **satcom RFFEs**. Demand for smaller solutions for aeronautic applications and satellites is prompting suppliers to replace large multi-technology discrete RF front-ends with monolithic fully integrated solutions. GaN manufacturers are catching this wave, and are developing fully integrated solutions that combine the transmit and receive chain in a single package. This will further reduce system size, weight and time to market for manufacturers.

Key GaN Satcom Applications

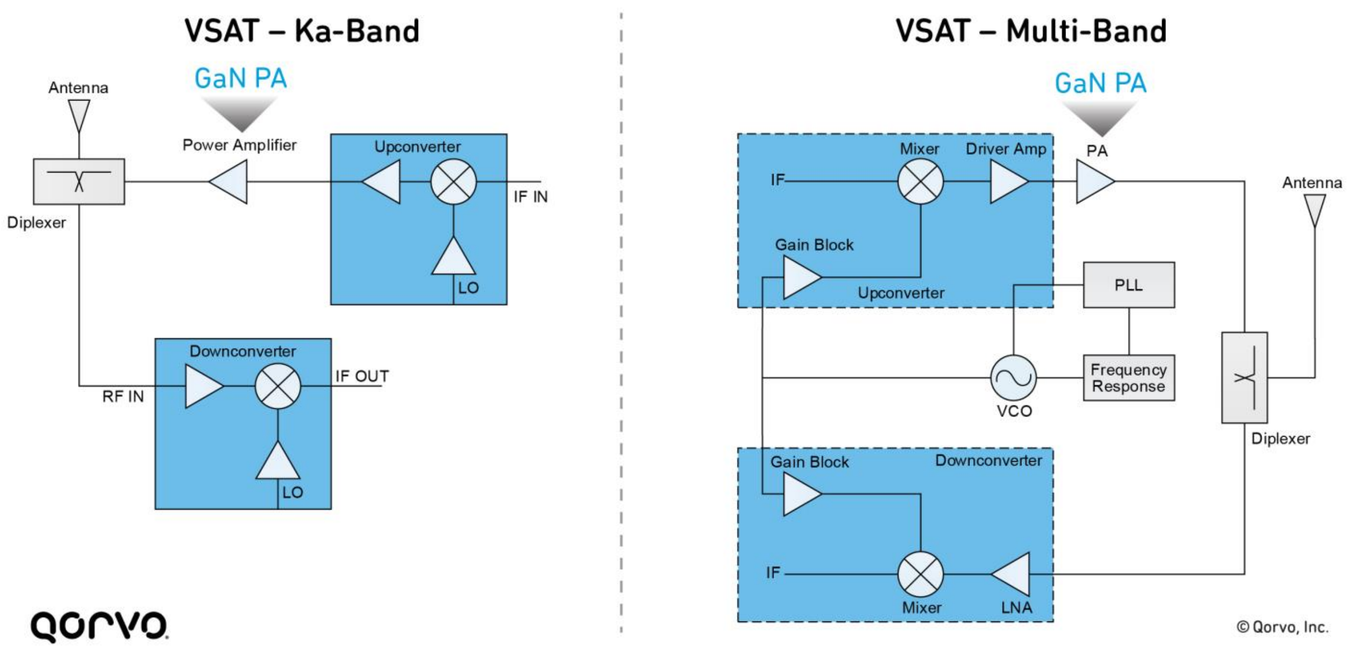
GaN is making its way into many commercial and military satcom applications, including satellites, manpack, satcom-on-the-move, commercial aircraft, and VSAT terminals. In the space industry, GaN is replacing Si and GaAs due to advantages such as size, weight and efficiency. The smaller die size of a GaN device, compared to Si, enables performance improvements in power-switching applications. Parasitics such as output capacitance and layout inductance are reduced, resulting in lower switching insertion loss and higher-frequency operation.

Moreover, new all-electric satellites are currently under study. GaN will be a key enabler in these developments as size reduction, weight and low power consumption are important for success. Some GaN suppliers like Qorvo have space-qualified their technology, underlining the clear opportunities for GaN in this sector.

GaN is also poised to transform the lower-power very small aperture terminal (VSAT) satcom sector. The use of VSAT systems is expanding: they are employed for a wide variety of applications including fixed and portable wideband systems for consumer, commercial, defense and maritime communications, as well as transaction processing, data acquisition and remote monitoring. GaN is replacing and teaming up with traditionally all GaAs systems used in VSAT due to its ability to provide higher output power, which supports higher speeds and increased bandwidth allowing greater data throughput. This accelerates demanding applications, such as commercial two-way data transfers of video and other large files. GaN also outperforms Si in PA-related applications.

GaN's reliability under harsh environmental conditions is also important in this sector. VSAT devices are typically used in environments where they are subjected to harsh conditions. Advances in thermal management using unique packaging are further enhancing GaN's high reliability under these conditions. A two high-level VSAT applications using GaN PA are shown in Figure 5.

Figure 5. Satellite terminal system, **VSAT block diagrams**.



Conclusion

GaN is transforming the RF front end across multiple satcom application sectors. GaN is replacing incumbent technologies such as TWTAs, GaAs, and Si, because it is more reliable, more efficient, smaller, and offers higher power density and lower power consumption. Satcom manufacturers are using GaN to improve current satcom products – and to explore new developments and potential new applications.

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