APPLICATION NOTE

GaN MMIC PAs Support the Rapid Growth of Ku Band Applications

INTRODUCTION

In the 22 years since it was opened for satellite communications, Ku Band (13.75-14.50 GHz uplink, 10.7-12.75 GHz downlink) has become an essential part of the radio spectrum. Today, there are systems in place that provide video and data distribution for internet access, television news gathering, home radio and television programming, in-flight Wi-Fi and cellphone networks, plus high capacity data networks for commercial and government applications.

Commercial satellites now provide worldwide coverage, which is especially attractive for government and military communications. These in-place systems are available to support control and communications for unmanned aerial vehicles (UAV) operations, en route briefing for special forces, and in-flight communications for diplomats and other government officials.

Figure 1. Satellite systems can provide worldwide control and communications for UAVs such as this Global Hawk, which has just returned to Edwards Air Force Base after a three year deployment. (U. S. Air Force photo by Chad Bellay)

The future of Ku Band is a matter of high interest. At the time this story is being written, the International Telecommunications Union (ITU) is holding its 2015 World Radiocommunication Conference (WRC), where mobile satellite allocations at many different frequencies dominate the WRC agenda, including proposals for expanding primary allocations in the 10-17 GHz Ku Band frequency range. Further demonstrating the future vision for Ku Band, at least one entrepreneur has proposed a low earth orbit (LEO) satellite network to provide low cost internet service. A few airlines are planning free Wi-Fi for passengers, which is expected to accelerate growth beyond previous estimates.
GaN Leads the Way for Reliable Ku Band Power Amplifiers

Wolfspeed, a Cree company, offers Ku Band power products using their proven fabrication process of GaN on silicon-carbide substrates. GaN supports wide-band-gap RF operation, in combination with the inherent thermal advantages of SiC versus traditional silicon substrates. GaN-on-SiC has high efficiency and high power density, with the result that less energy is dissipated as heat and smaller-sized transistors can provide the same output power. Less heat and smaller size means smaller heat sinks, PCBs and PA enclosures.

Packaged Power Amplifier

Wolfspeed’s CMPA1D1E025F is a power amplifier MMIC based on GaN HEMT technology, fabricated on a silicon carbide (SiC) substrate, using a 0.25 µm gate length process. This PA MMIC is intended for commercial Ku Band applications, which are primarily satellite communications systems operating at 3 dB back off from saturated power output (P_{SAT}).

The CMPA1D1E025F is a 50 ohm, class A/B PA with performance optimized for the 13.75-14.5 GHz band. The device operates with V_{DD} up to 40 volts, providing 40 watts saturated power output (P_{SAT}) with a typical small-signal gain of 24 dB and power added efficiency (PAE) of 18-22 percent. Input and output matching achieves S11 and S22 of -7 dB. Under OQPSK operating conditions, it will withstand a VSWR of 5:1 at all phase angles. The MMIC is provided in a 10-lead, 25 x 9.9 mm metal/ceramic flanged package for convenient implementation.

Figure 2 includes the schematic and photo of the test/demonstration circuit. Performance in the test circuit is shown in Figures 3 and 4, which show the small-signal S parameters and spectral mask performance with OQPSK modulation.

Figure 2. Schematic diagram and photo of the CMPA1D1E025F test and demonstration board.
PACKAGED POWER AMPLIFIER PERFORMANCE

Wolfspeed’s CMPA1D1E025F is a power amplifier MMIC based on GaN HEMT technology, fabricated on a silicon carbide (SiC) substrate, using a 0.25 µm gate length process. This PA MMIC is intended for commercial Ku Band applications, which are primarily satellite communications systems operating at 3 dB back off from saturated power output (P_{SAT}).

![Small Signal S-parameters](image1)

**Figure 3.** Small-signal S parameters at Ku Band.

![Spectral Mask](image2)

**Figure 4.** Spectral mask of a communication channel with OQPSK modulation.
Power Amplifier MMIC Die

The PA MMIC is also offered in die form, part number CMPA1D1E030D, for construction of assemblies using eutectic die attach techniques and gold bond wire connections to external components and transmission lines. Figure 5 is a photo of the die, along with a block diagram of the MMIC equivalent circuit and recommended external coupling and decoupling capacitors. Overall die size is 5000 × 6000 microns (+0/-50 microns), with a thickness of 100 ±10 microns.

![Figure 5. Die photo and block diagram of the CMPA1D1E030D.](image)

In a properly constructed circuit, the CMPA1D1E030D provides 27 dB typical small signal gain and 30 watts $P_{\text{SAT}}$. At saturation, PAE is 22-24 percent; or 20-22 percent at 3 dB backoff. In die form, better matching

Which is better — Ku Band or Ka Band?

Satellite service providers have made significant investments in ground and space hardware, and can be expected to make competitive claims. One example is that growth at Ku Band has been criticized by companies specializing in Ka Band (26.5-40 GHz) satellite operations. Some marketing arguments suggest that users considering Ku Band operation should wait until higher-performance Ka Band systems are deployed.

These criticisms are based on the way Ku Band has been used, with satellites that provide a broad footprint for regional, or even continental coverage. Antennas with wide beamwidths for such broad coverage have lower gain than narrowly focused “spot beams” that are more common in Ka Band systems. Lower gain leads to reduced link margins, requiring higher gain receiving antennas or higher power transponders to achieve equivalent performance.

This issue is studied in a 2012 paper by McLain, et al [1], in which the authors concluded that the primary factor is antenna gain, and that claims of lower performance at Ku Band were based on the specific systems in use (or preparing for deployment), not any inherent performance characteristic of either band.

A more realistic comparison should be based on the frequency difference, which affects antenna gain versus physical size, propagation path loss, and the noise figure performance achievable in each band (Ka Band is an octave higher in frequency than Ku Band). First, Ku Band has approximately 4 dB better downlink carrier-to-noise ratio (C/N) than Ka Band, mainly due to the higher noise figure of Ka Band receivers. However, for the same gain, a Ku Band antenna will be larger than a Ka Band...
is achieved than the packaged part, achieving S11 of -16 dB and S22 of -9 dB. These products from Wolfspeed provide higher gain and better linear efficiency than competitive GaN MMICs, and have as much as 14 dB linear gain improvement over GaAs IMFET PAs. Higher gain simplifies implementation of multi-device power amplifier assemblies, allowing relaxed specifications for combining circuits and, in some cases, reducing the number of stages required.

**Technical Issues**

Despite the well-established performance and reliability record of solid-state PAs (SSPAs) using high performance GaN technology, the discussion of SSPA versus TWTA (traveling wave tube amplifier) continues. Both technologies are capable of delivering the required power, have demonstrated reliability, and have clearly identified ranges of performance. This should result in a straightforward choice between them.

For those system designers who have limited experience with SSPAs, here is a reminder of the specific advantages they offer:

- GaN-on-SiC has been an enabling technology for RF/microwave power, compared to earlier device fabrication materials and methods.
- SSPAs do not require a high voltage power supply, as needed for TWTAs.
Technical Issues Continued

- Methods for combining multiple devices to achieve the required power output are well-established, using coaxial, microstrip and waveguide lines, whichever best suits the required power level, loss performance and cost.

- Combiners can be designed to provide redundancy (soft failure), where the loss of a single module simply reduces power output without shutting down the system.

- Combiners may also include the ability for “hot swap”, where a module may be replaced while the remaining PA modules continue to operate.

Summary

High power SATCOM earth station design can benefit from the advantages of solid state power amplifiers using Wolfspeed’s GaN-on-SiC power devices. Past limitations on SSPAs have been overcome, mainly through the development of GaN, but also with refined PA design techniques, incorporating high performance combiners with soft fail and hot swap of individual amplifier modules. The two Wolfspeed products described above are ideal for Ku Band aeronautical satellite systems that are now enjoying a time of significant growth.

Resources

CMPA1D1E025F [Data Sheet](#) (Packaged GaN-on-SiC Power Amplifier MMIC, 25 W, 13.75 - 14.5 GHz, 40 V)

CMPA1D1E030D [Data Sheet](#) (GaN-on-SiC Power Amplifier MMIC Bare Die, 30 W, 13.75 - 14.5 GHz, 40 V)

[Video](#) Introduction of the CMPA1D1E025F