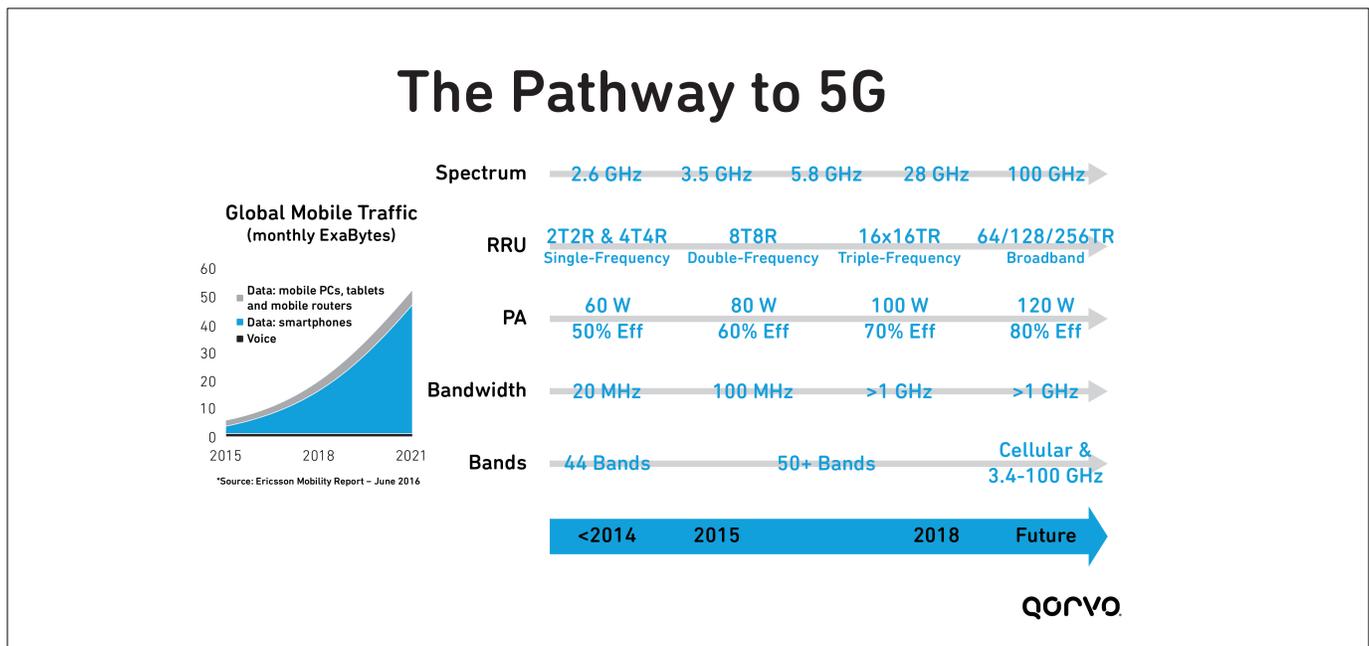# Gallium Nitride – A Critical Technology for 5G

By David Schnaufer and Bror Peterson, Qorvo

Introduction

Carrier providers talk a lot about how their individual networks provide higher capacity, lower latency, and ubiquitous connectivity. And, while today's networks certainly are better than previous generations, providers still have much to accomplish when it comes to the promises of 5G – less than 1 ms latency, 100x network energy efficiency, 20 Gbps peak data rates, and 10 Mps/m^2 area traffic capacity. Scheduled for commercial launch in 2020, 5G is expected to offer all of these significant advantages, including a more 'green' and efficient communication network.

The graph below illustrates several 5G objectives, including increased power, frequency ranges up to 100 GHz and higher efficiency. Attaining these 5G objectives requires a progression of technology and system design.
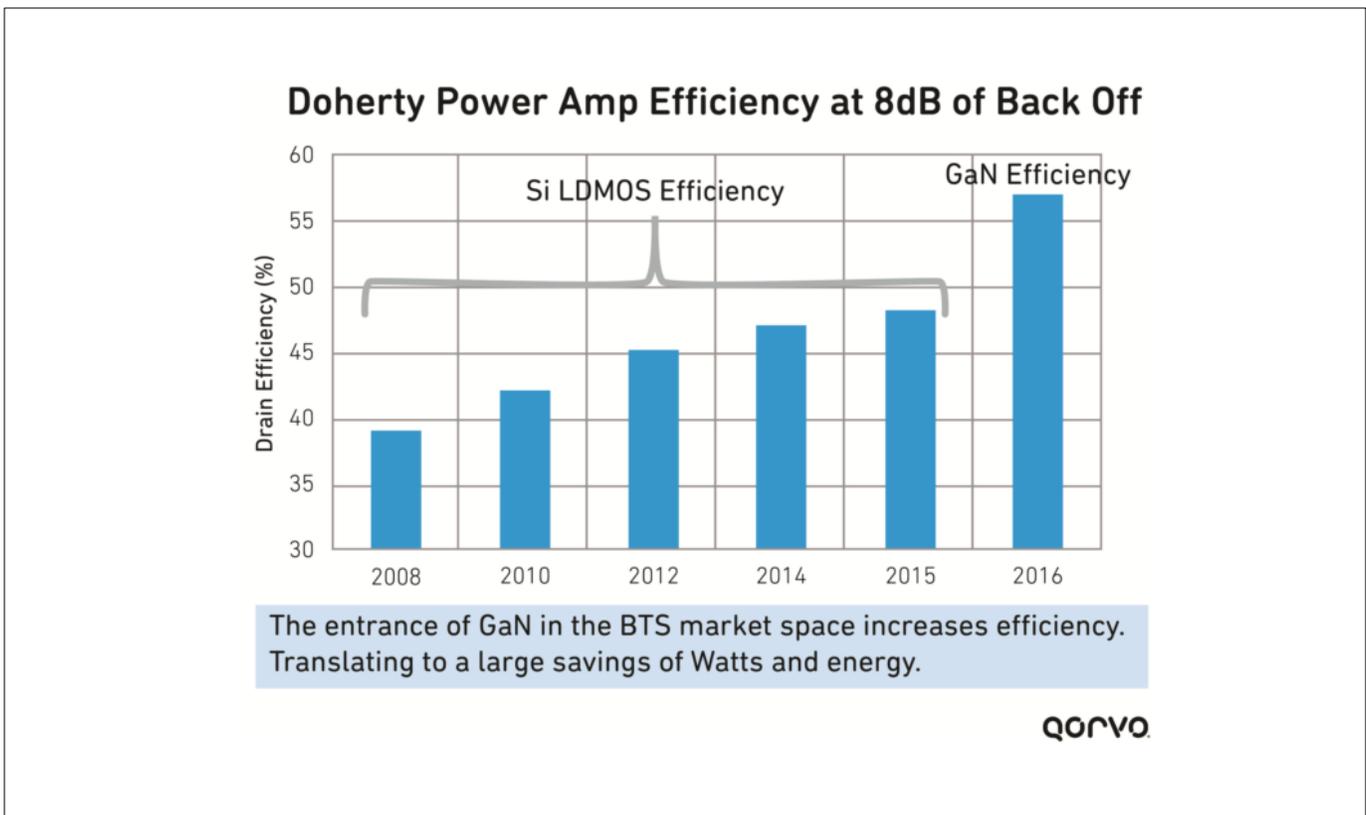
GaN's Superior Properties

In our **last quarterly article**, we discussed ways in which the telecom industry is focused on energy efficiency for 'green' communications. We explored how MIMO, beamforming, and small cells increase efficiency, making a telecom network that's more environmentally friendly overall. We also highlighted how much of the network energy consumption comes from the RF chain.

So, how do we achieve the RF chain 5G objectives and meet 'green' network goals?

Enter RF Gallium Nitride (GaN) – an efficient, wide-bandgap, reliable PA technology making year-over-year strides toward network efficiency. As displayed in the graph below, the introduction of GaN in the base transceiver station (BTS) ecosystem provides a sharp increase in front-end efficiency, making it a new go-to technology for both high- and low-power applications.

Doherty Power Amp Efficiency at 8dB of Back Off

The entrance of GaN in the BTS market space increases efficiency. Translating to a large savings of Watts and energy.

GaN offers superior properties of high power density, power added efficiency (PAE), gain, and ease in impedance matching, which improves overall efficiency in the RF chain. Like designers of Formula One race cars, wireless engineers meticulously tweak and tune their RF systems to extract every ounce of performance. By starting with a fundamentally better semiconductor technology, performance targets can be achieved at vastly improved energy efficiency.
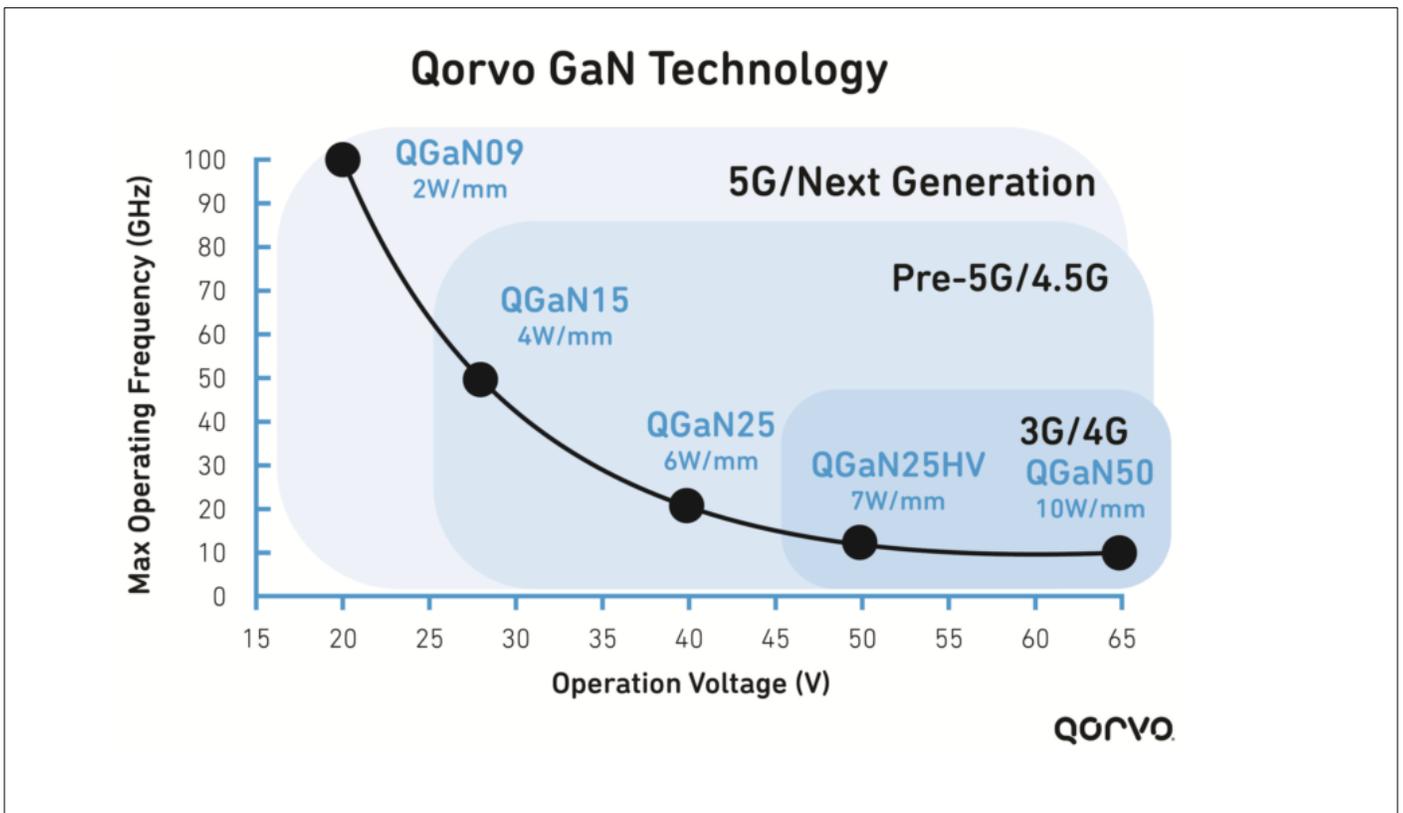
5G and GaN

The build-out of 4G LTE networks is maturing, but there are many upgrades that will bridge the gap to 5G. We currently are in the 5G definition and proof-of-concept phase, but **companies like Verizon** are accelerating the timetable for early deployments focused on fixed-wireless access.

Early 5G trials began in 2013, and data from these and more recent experiments are now frequently published.
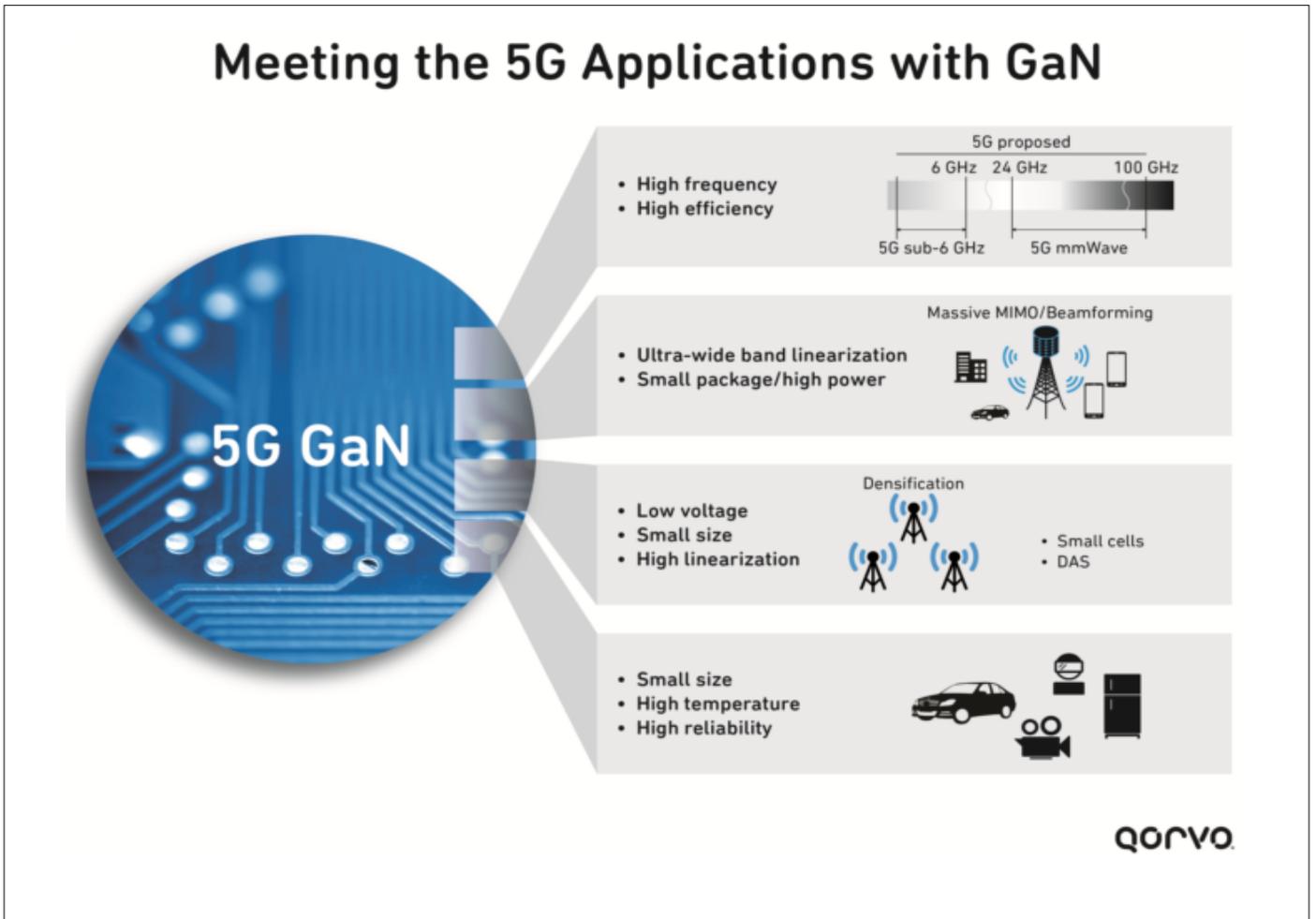
Key technologies offering promising results in mmWave, massive MIMO antenna arrays, and beamforming are already in pre-commercial development. All of the base station OEMs are in the product trial mode. Companies like Qualcomm and Intel are testing 5G-enabled modems, such as the **X50 modem**, which works in the 28 GHz band. **Qorvo and NanoSemi** have published demonstration data on ultra-wide linearization of GaN devices for massive MIMO applications.

These forward-looking companies are dialing in major 5G system architectures, frequency bands, and enabling technologies to find the proper balance of cost, performance, and complexity.
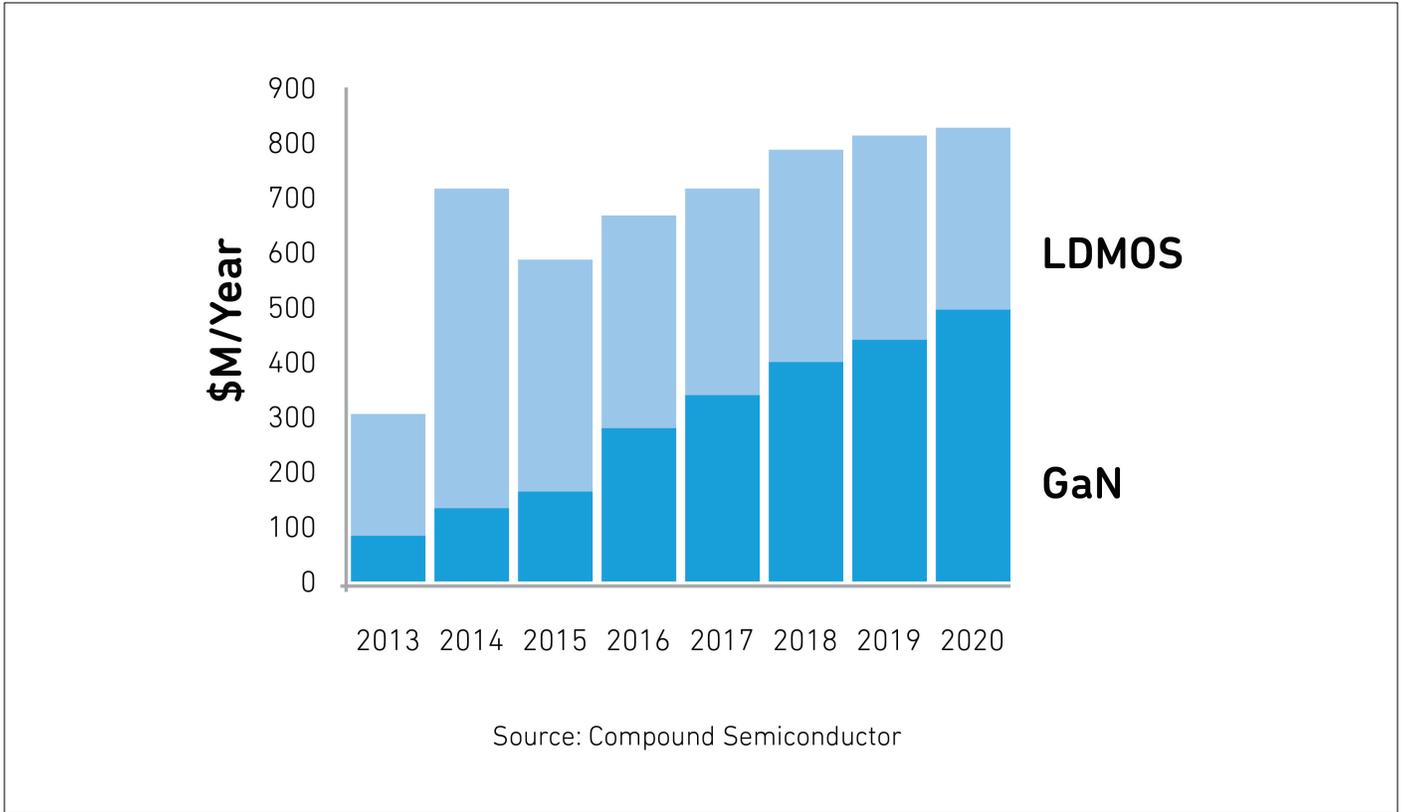
To meet the diverse set of 5G requirements, GaN manufacturers need to offer several variations that span a broad range of frequencies and power levels. With more than one GaN process to choose from, a designer can optimally match a GaN technology to an application. The graph below examines Qorvo's capabilities in this realm.

As Qorvo's Doug Reep mentioned in a **previous article**, GaN will overtake traditional semiconductor materials for 5G network applications like small cells, which require higher frequencies, tight integration, and minimal implementation cost. He also goes on to proclaim that the efficiency offered by low-voltage GaN will inevitably make its way into the mobile handset. With properties including operating in high-temperature environments, GaN is well suited for passively cooled, all-outdoor tower-top base station electronics and automobile applications. Overall, having a wide array of GaN technology choices will mean more applications being serviced.
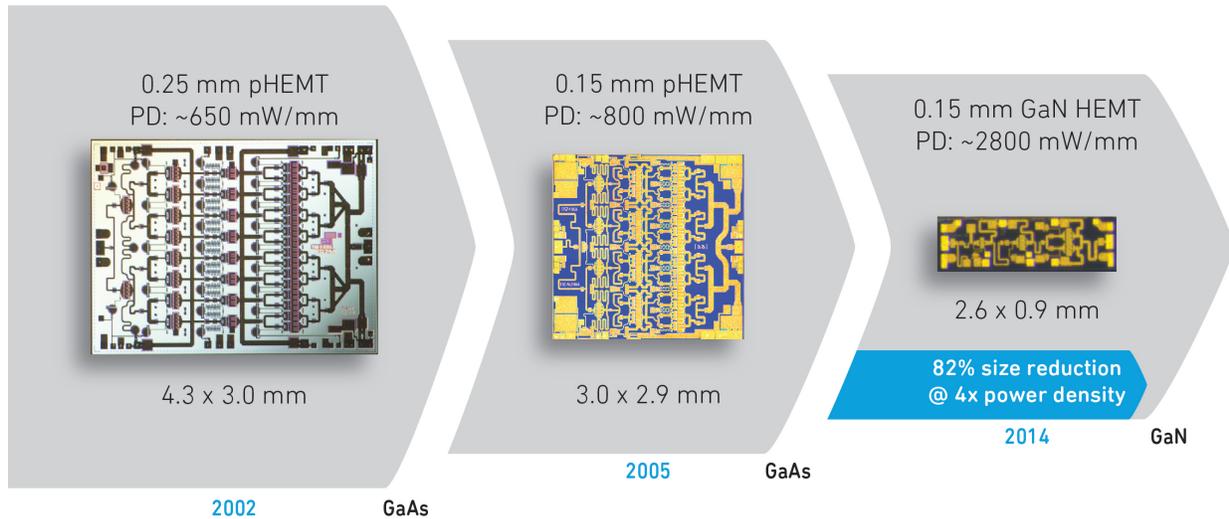

Today, GaN is heavily used in the small cell and BTS market space and continues its upstream ascent in 2016. **GaN shipments** are estimated to reach near $300M in 2016, well above the 2015 mark of $150M. Small cell, distributed antenna system (DAS), and remote radio head network densification deployments play a big role in this trend.

Source: Compound Semiconductor

The incentives of untapped spectrum, high throughput, and low latency goals are enticing developers to migrate toward higher mmWave frequency bands. The mmWave spectrum bands provide 10-30 times the bandwidth of current 4G frequency bands (<4 GHz), and network capacity is directly proportional to the available bandwidth.

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GaN Enabling Monolithic Front-End Solution for 5G

Higher Power Density ➜ Small Size ➜ Miniaturization & Easy Integration

0.25 mm pHEMT
PD: ~650 mW/mm

4.3 x 3.0 mm

2002   GaAs

0.15 mm pHEMT
PD: ~800 mW/mm

3.0 x 2.9 mm

2005   GaAs

0.15 mm GaN HEMT
PD: ~2800 mW/mm

2.6 x 0.9 mm

**82% size reduction
@ 4x power density**

2014   GaN

- **GaN technology reduces design complexity**
- **Essential for success of high-frequency commercial markets**

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GaN is well suited for both the high frequency and the wide bandwidth required in the mmWave arena. It can fulfill the performance and small size requirements, as illustrated above. Applications using mmWave frequency bands will require highly directional beam-forming technology (beam-forming focuses the radio signal into a highly directive beam, which boosts power and minimizes interference at the user device). This means that the RF subsystems will require a large number of active elements driving a relatively compact aperture. GaN is ideally suited for these applications, since powerful performance in a small package size is one of its most notable traits.

When 5G comes to fruition in 2020, we will all find out what capabilities and advantages follow. Today, the trials, initiatives, discussions, and demonstrations continue to aid in defining the 5G standard. But tomorrow, the reality of ubiquitous, sub-1-ms latency and extremely high capacities will be in our everyday lives. Whatever the outcome, it is apparent that GaN will be a critical technology in 5G applications.

About the Authors

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David Schnaufer is Qorvo's technical marketing communications manager. Over the last 15 years, David has worked for Qorvo. From 2013 to 2015, David served as product marketing manager for the Advanced Filters group in Qorvo. Prior to 2013, David worked as a senior manager of strategic marketing, global applications engineering, and global customer quality engineering manager. He earned an MBA in technology and business management from the University of Phoenix, a BA in business administration from Belmont Abbey College, and an electronics engineering degree.

Bror Peterson
Bror Peterson is a principle systems engineer with Qorvo Inc. located in Richardson Texas. He is currently focused on mmWave 5G base-station RF system analysis and product development. He received a Master of Science in Electrical Engineering degree from Virginia Tech in 2000. He has been involved with research, design, and development of wireless infrastructure systems for over 17 years with a broad background in communications theory and systems analysis.