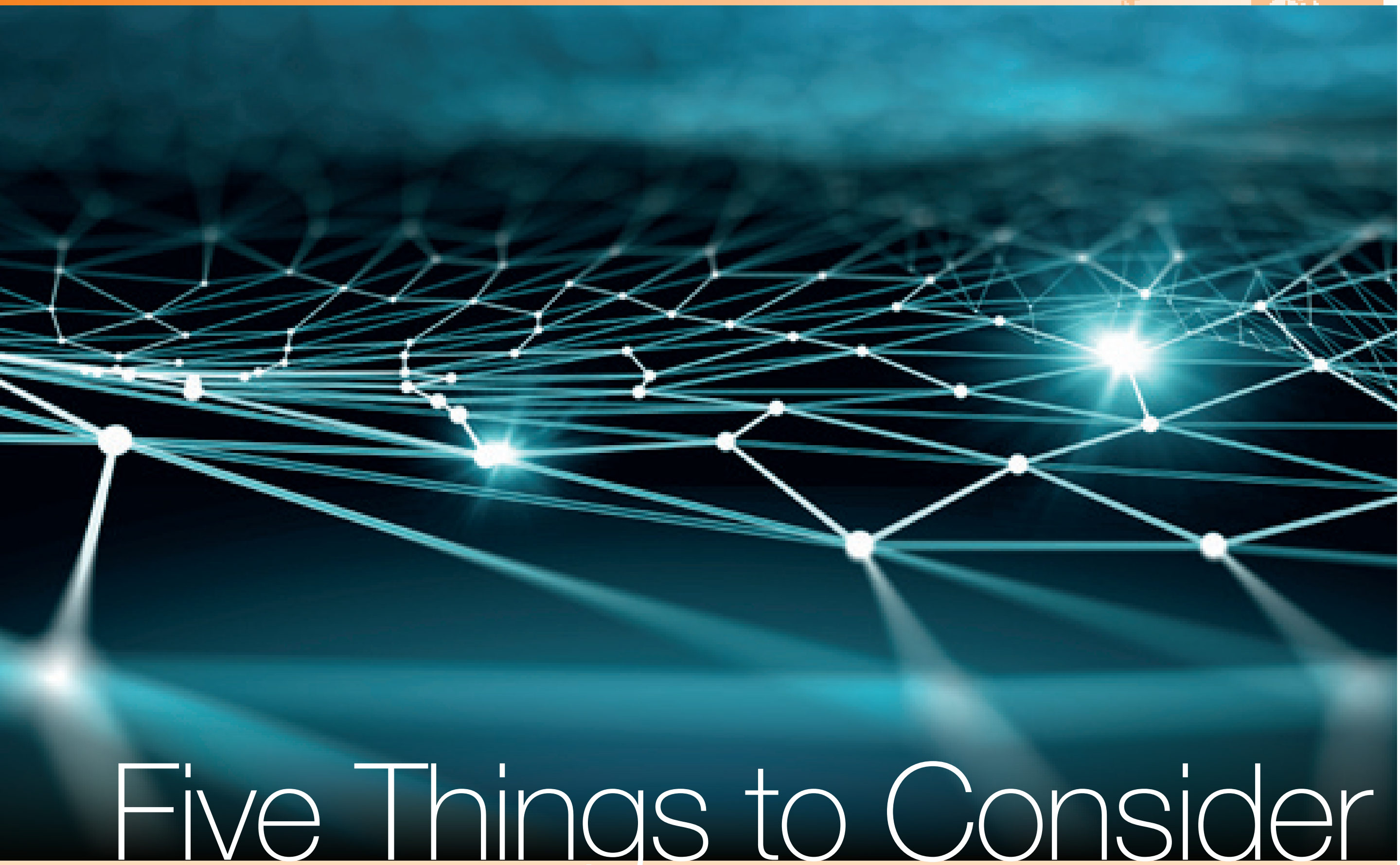

Five Things to Consider

When Designing Fixed Wireless Access (FWA) Systems

By David Schnaufer, Technical Marketing Communications Manager, Qorvo

FWA can be delivered to homes, apartments and businesses in a fraction of the time and cost of traditional cable/fibre installations. Here, we examine five key points to consider when designing FWA systems.

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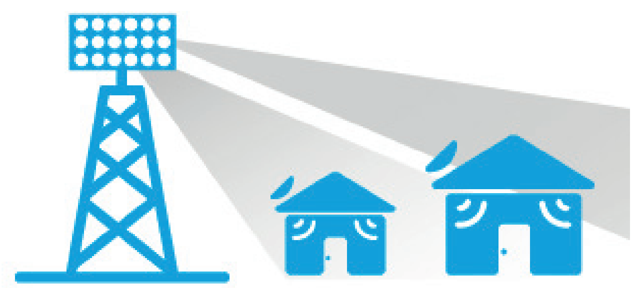
David is the public voice for Qorvo's applications engineers. He provides technical insight into RF trends as well as tips that help RF engineers to solve complex design problems.



One of the earliest uses of 5G will be fixed wireless access (FWA), which promises to deliver Gigabit internet speeds. FWA can be delivered to homes, apartments and businesses in a fraction of the time and cost of traditional cable/fibre installations. As with any technological advance, FWA brings new design hurdles and technology decisions. Let's examine five things to consider when designing FWA systems:

- The choice of frequency spectrum: millimetre wave (mmWave) or sub-6GHz.
- Achieving higher data rates with antenna arrays.
- All-digital or hybrid beamforming.
- Power amplifier (PA) technology choices; silicon germanium (SiGe) or gallium nitride (GaN).
- Choosing components from today's RF front-end (RFFE) product portfolios.

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#1: Spectrum choice: mmWave or sub-6GHz?

The first decision is whether to use mmWave or sub-6GHz frequencies for FWA:

- **mmWave.** These higher frequencies offer a large amount of contiguous spectrum available at low cost. mmWave supports component carriers of up to 400MHz wide and enables Gigabit data rates. The challenge is path loss due to obstacles such as vegetation, buildings and interference. However, do not assume that FWA is useful only in clear line-of-sight settings between the base station and the home — FWA can actually perform very well in both urban and suburban settings. It is true that vegetation and interference are challenging, but these can be overcome with antenna arrays that provide high gain.
- **Sub-6GHz.** This lower-frequency spectrum helps to overcome the problems caused by obstructions, but at a cost. Only 100MHz of contiguous spectrum is available, so data rates are lower.

The efficient use of frequency range (sub-6GHz or mmWave) is critical to scaling deployments. The choice for any situation will depend upon balancing the goals of speed and coverage.

#2: Achieving higher data rates with antenna arrays

An FWA system will also need to employ active antenna systems (AAS) and massive MIMO (multiple input/multiple output) to deliver Gigabit service.

- **AAS** provides many directional antenna beams. These beams are re-directed in less than a microsecond, enabling beamforming that offsets the greater path loss associated with high frequencies.
- **Massive MIMO** uses arrays of dozens, hundreds or even thousands of antennas, allowing simultaneous transmission of single or many data streams to each user. The results are improved capacity, reliability, high data rates and low latency.

Beamforming also enables less inter-cell interference and better signal coverage.

#3: All-digital or hybrid beamforming

A third element to consider is the type of beamforming to employ — all-digital or hybrid.

All-digital approach

The most obvious choice in mmWave base station applications is to upgrade the current platform. You could explore extending all-digital beamforming massive MIMO platforms used for sub-6GHz frequencies, but this isn't a plug-and-play solution.

Remember: An array's size is dependent upon:

- The scanning range (azimuth and elevation).
- Desired EIRP.

EIRP is the product of:

- The number of active channels.
- Conducted transmit power of each channel.
- Beamforming gain (array factor).
- Intrinsic antenna element gain.

An all-digital approach faces these design constraints:

- **Power consumption.** Digital beamforming uses many low-resolution analogue-to-digital converters (ADC). But ADCs with a high sampling frequency and a standard number of effective bits of resolution can consume a large amount of power. This power consumption can become the bottleneck of the receiver. A large AAS with massive bandwidth presents a huge challenge for an all-digital beamforming solution. Essentially, the power consumption will limit the design.
- **The need for two-dimensional scanning in dense urban environments.** The required scanning range depends upon the deployment scenario, as shown in Figure

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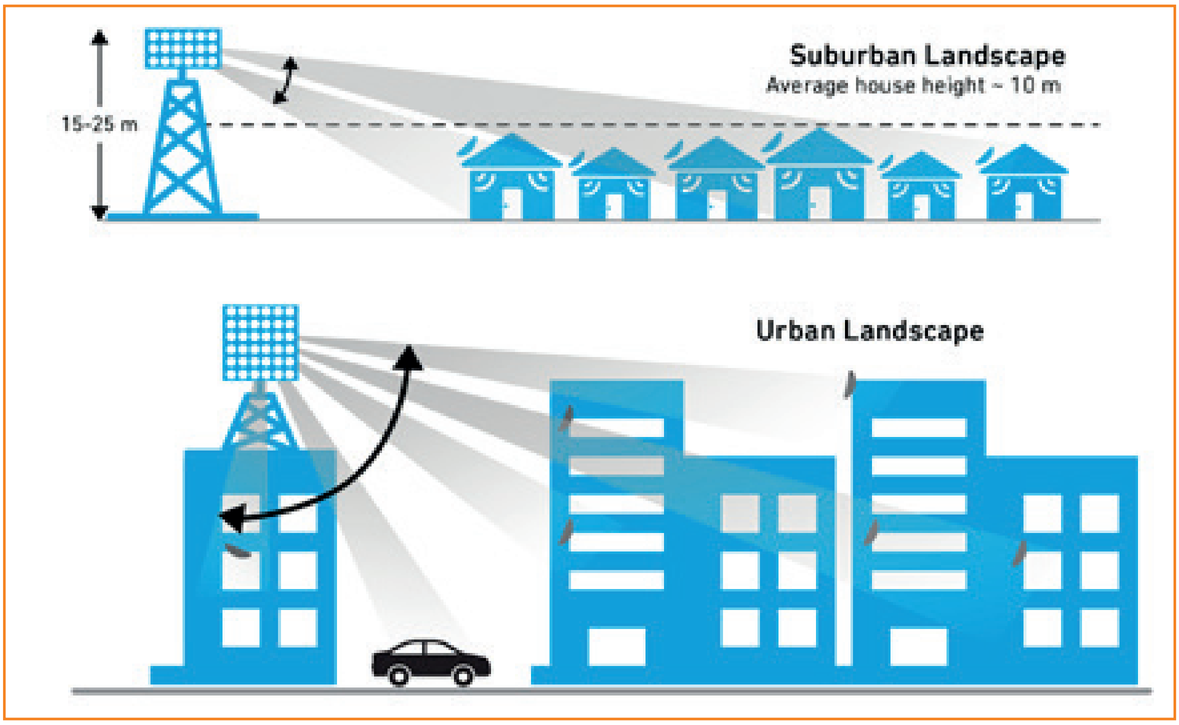

Figure 1: FWA array complexity depends upon the scanning range needed for the deployment scenario

1 above. In a dense urban landscape, wide scan ranges are needed in both azimuth (~120°) and elevation (~90°). For suburban deployments, a fixed or limited scan range (< 20°) in the elevation plane may be enough. A suburban deployment requires limited scan range or half as many active channels to achieve the same effective isotropic radiated power (EIRP), which reduces power and cost.

To achieve the target EIRP of 75dBm and beamforming gain, an all-digital solution using today's technology would need 16 transceivers. This would equal a total power consumption of 440W. But for outdoor passive-cooled, tower-top electronics, it is challenging to thermally manage more than 300W from the RF subsystem. We need new technological solutions.

Efficient GaN Doherty PAs with digital pre-distortion (DPD) may provide the required margin, but these devices are still in

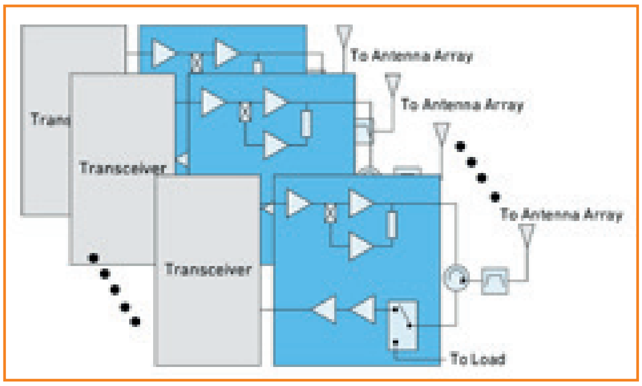

Figure 2: Integrated FEM with GaN Doherty PA and Switch-LNA

development for mmWave applications. But it won't be long before we see an all-digital beamforming solution. Several developments will make it a reality:

- Next-generation digital-to-analogue and analogue-to-digital converters which save power.
- Advances in mmWave CMOS transceivers.
- Increased levels of small-signal integration.

Hybrid approach

An alternative is hybrid beamforming, where the precoding and combining are done in both baseband and RF front-end module (FEM) areas. By reducing the total number of RF chains and analogue-to-digital and digital-to-analogue converters, hybrid beamforming achieves similar performance to digital beamforming, while saving power and reducing complexity.

Another advantage of the hybrid approach is the ability to meet both a suburban fixed or limited scan range (<20°) and dense urban deployments with wide scan ranges in both azimuth (~120°) and elevation (~90°).

The bottom line; all-digital and hybrid approaches both have advantages and disadvantages. We believe that the hybrid approach is more appealing and 'doable' today, but new products on the horizon could make the all-digital approach equally appealing in the future.

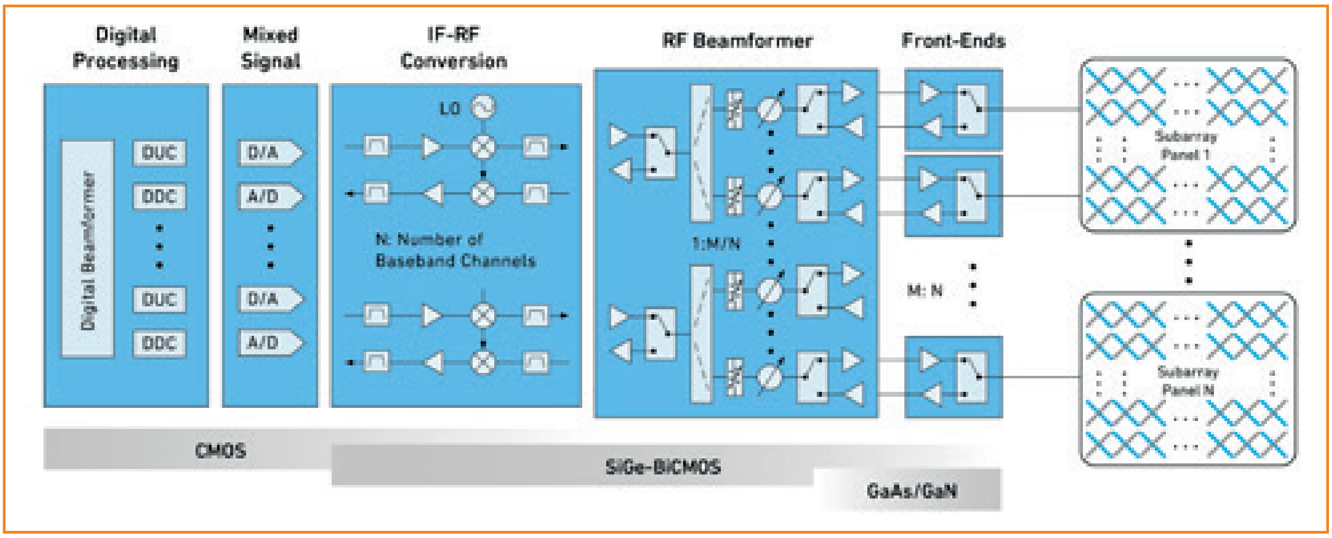

Figure 3: Hybrid beamforming Active Antenna Systems (AAS) block diagram

#4: PA technology choices: SiGe or GaN

The technology that you choose for the FWA front-end depends upon the EIRP, antenna gain and noise figure (NF) needs of the system. All are functions of beamforming gain, which is a function of the array size. Today, you can choose between a SiGe or GaN front end to achieve your desired system needs.

In the U.S., the Federal Communications Commission (FCC) has set high EIRP limits for 28GHz and 39GHz spectrum, as shown in Table 1 opposite.

To achieve 75dBm EIRP with a uniform rectangular array, the PA power output required per channel reduces as the number of elements increases (i.e. the beamforming gain increases). As

Equipment Class	Power (EIRP)
Base Station	75 dBm/100 MHz
Mobile Station	43 dBm
Transportable Station	55 dBm

Table 1: FCC power limits for 28GHz and 39GHz bands

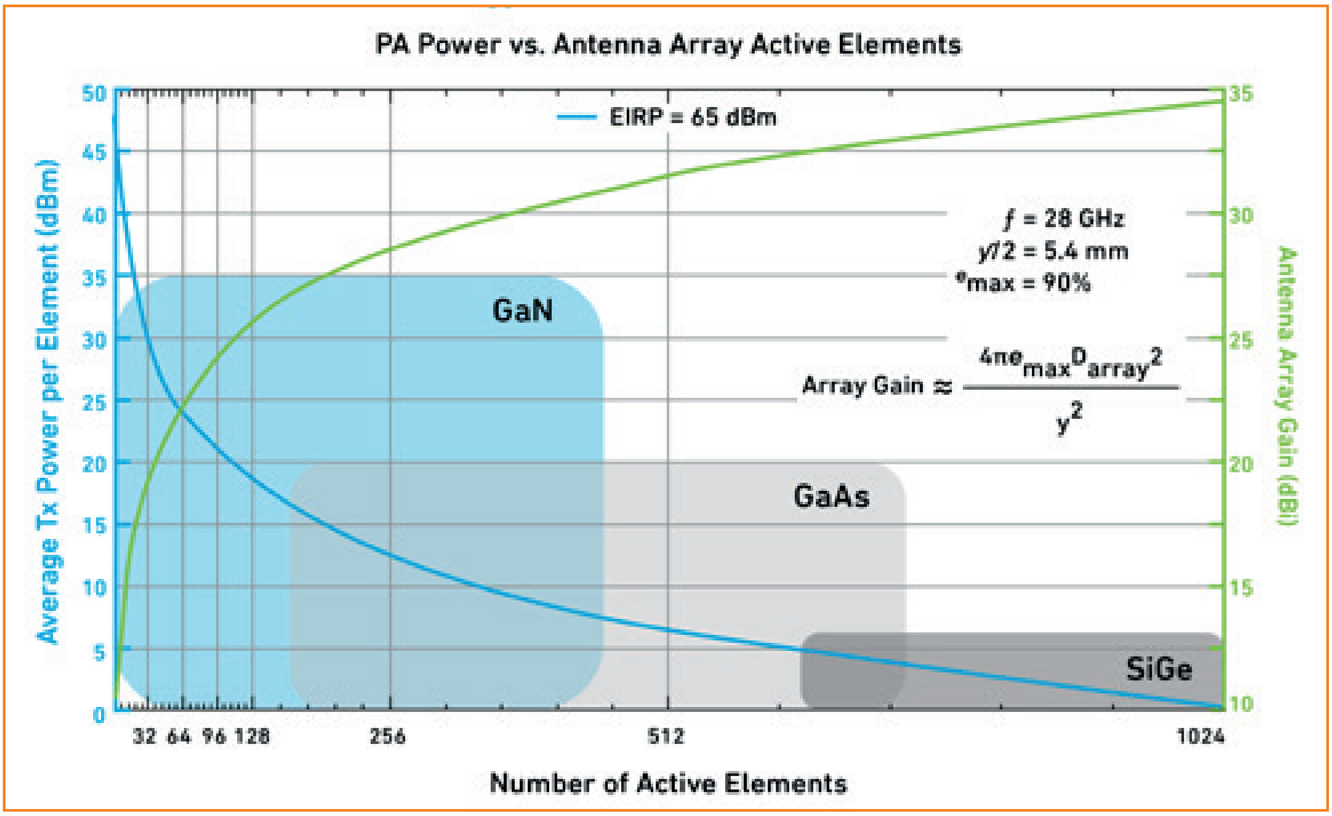

Figure 4: Trade-offs between the number of Antenna Array elements and RFFE process technology

> A third element to consider is the type of beamforming to employ — all-digital or hybrid.

	SiGe	GaN	Units
Average Output Power/Channel	0	18	dBm
Power Dissipation/Channel	150	840	mW
Antenna Element Gain	5	5	dBi
Number of Active Channels	1024	128	Channels
EIRP	65	65	dBm
Total Pdiss	154	127	W

Table 2: Assumptions and total dissipated power for SiGe versus GaN FWA front end

shown in Figure 4 (previous page), as the array size gets very large (>512 active elements), the output power per element becomes small enough to use a SiGe PA, which could then be integrated into the core beamformer RFIC.

As you can see from Table 2 above, a SiGe PA can achieve 65dBm EIRP using 1024 active channels. However, by using GaN technology for the front-end, the same EIRP can be achieved with 16 x fewer channels.

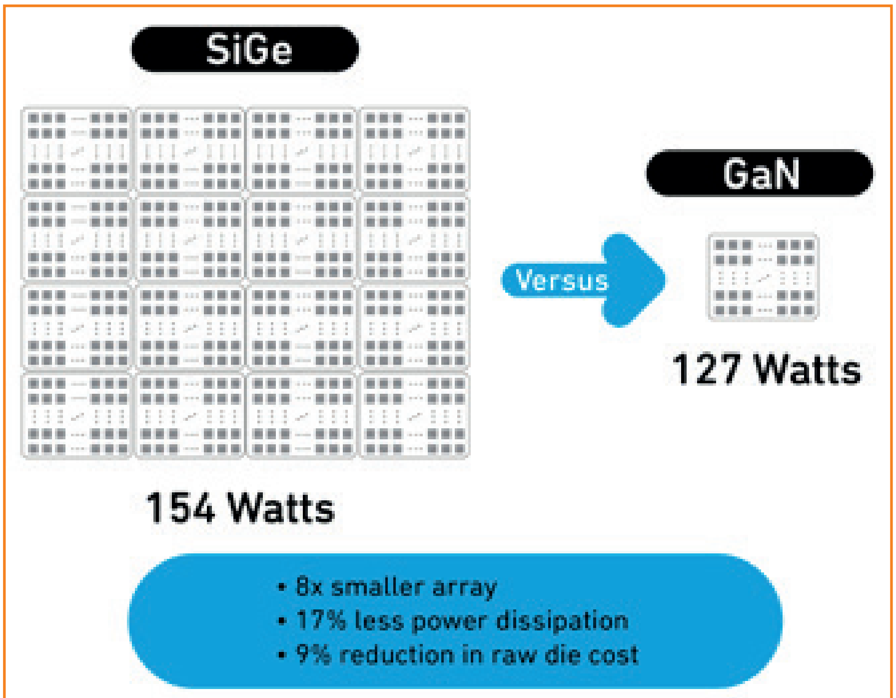

Figure 5: Comparing an All-SiGe FWA system to a combination of SiGe beamforming with GaN front ends

A GaN FWA front-end provides other benefits:

- **Lower total power dissipation.** To ensure an accurate comparison, the GaN power dissipation includes an extra 19.2 watts, to account for the 128 beamformer branches needed to feed the front ends. As shown in the following figure, at the target EIRP of 65dBm, GaN provides lower total power dissipation (127Pdiss) than SiGe. This is better for tower-mounted system designs.
- **Better reliability.** GaN is more reliable than SiGe, with >107 hours MTTF at 200°C junction temperature. SiGe's junction temperature limit is around 130°C.
- **Reduced size and complexity.** GaN's high power capabilities reduces array elements and size, which simplifies assembly and reduces overall system size.

The takeaway; In wireless infrastructure applications, reliability is imperative because equipment must last for at least ten years. For FWA, GaN is a better choice than SiGe for reliability, cost, lower power dissipation and array size.

#5: Choosing from today's RF technology

The last consideration is selecting product solutions that are being used in

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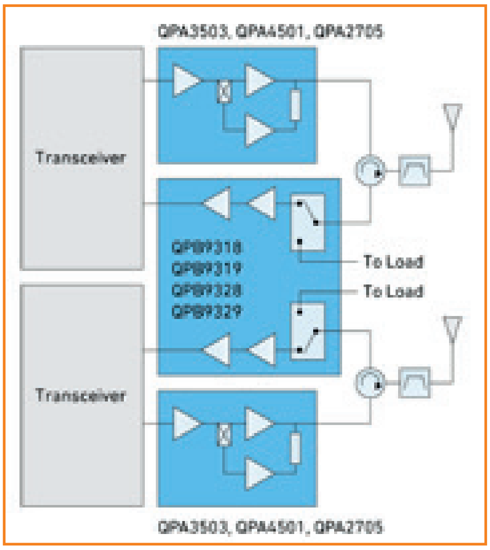

Figure 6: Qorvo FWA solutions: Sub-6GHz Massive MIMO GaN front ends

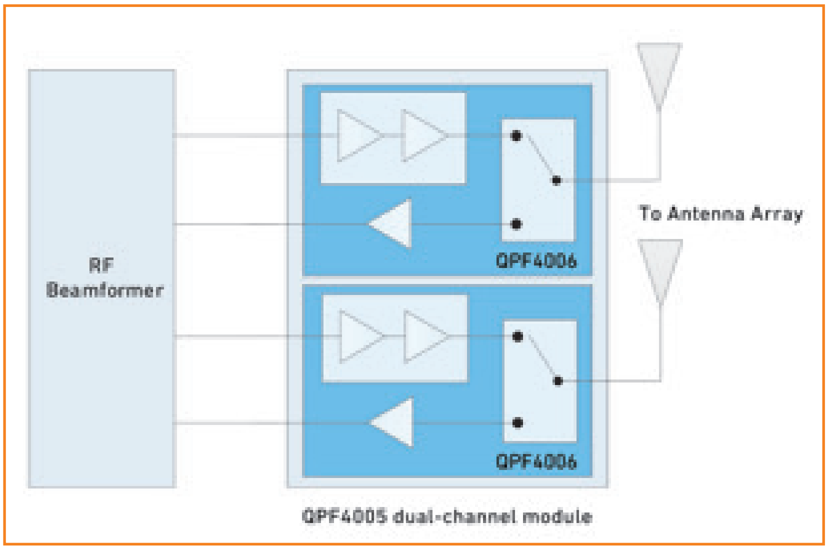

Figure 7: Qorvo FWA solutions: mmWave Massive MIMO GaN front ends

real-world applications. Several RF companies are positioned to support the development of sub-6GHz and cmWave/mmWave FWA infrastructure. Qorvo, for instance, is already supplying products for many Tier 1 and Tier 2 supplier field trials. Across the RF industry, examples of products for FWA include:

- **Sub-6GHz products:** Dual-channel switch/LNA modules and integrated Doherty PA modules.
- **cmWave/mmWave:** Integrated transmit and receive modules.

Additionally, in the 5G infrastructure space, several things are imperative:

- Integration.
- Meeting passive cooling requirements at high temperatures.

To support these trends, Qorvo has created integrated transmit and receive modules for cmWave/mmWave, as well as integrated GaN FEMs. These integrated modules include a PA, switch and LNA, and have high gain to drive the core beamformer RFICs. To meet the infrastructure passive-cooling specification, we use GaN-on-SiC to support the higher junction temperature.

FWA is approaching — fast

FWA implementation has begun, and full commercialisation is approaching rapidly. Today, we believe hybrid beamforming is the best approach. Additionally, GaN, along with SiGe core beamforming, meets FCC EIRP targets of 75dBm/100MHz base station targets. This approach also minimises cost, complexity, size and power dissipation.

For more information, see www.qorvo.com

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