5G The precarious promise

A lack of standards for 5G is threatening a move to faster data rates for mobiles, and could also hinder the growth of the internet-of-things and machine-to-machine communication

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The roll-out of 5G is anything but assured. According to speakers in the session entitled 'The Quest for 5 G' at this year's CS International, while there is substantial demand for a next-generation wireless network that sets a new performance benchmark, there is also a great deal of uncertainty that surrounds its deployment. Basic specifications, such as the operating frequency, are still to be nailed down. What's more, many operators are yet to start planning a build-out of the infrastructure, because they are yet to see an attractive return-on-investment.

Making a great case for the need for 5G networks was keynote speaker Michael O'Neal, Qorvo's Senior Director of Design and Advanced Engineering in the Infrastructure and Defense Products.

O'Neal kicked off his talk by arguing that there were three major market trends driving demand for 5G: a move to having everything on the Cloud, ubiquitous connectivity, and smart infrastructure.

The first of those, migration to data on the cloud, is well underway. After all, this is where many of us store our e-mails, access our music through the likes of iTunes, and watch movies through services such as Netflix. There are also tools in the cloud, such as those that enable GPS mapping on our phones.

O'Neal explained that is it the second major market trend, ubiquitous connectivity, that already allows gamers to play against peers over the ocean. It also underpins virtual reality and augmented reality.

The third trend, a smart infrastructure, is a key technology for connected cars − and eventually self-driving cars. "There are now 1 billion connected devices, and it's moving to 50 billion," remarked O'Neal, who explained that one of the numerous benefits of this will be the control of the heating in your home via a mobile.

According to O'Neal, migration to 5G should lead to: enhanced mobile broadband; massive machine-type communication; and ultra-reliable, low-latency communications. To make this happen, improvements associated with a shift from 4G to 5G will have to include a hike in cell edge data rates from 10 Mbit/s to more than 1 Gbit/s, a trebling of spectral efficiency, a 50 percent gain in energy efficiency, and an increase in mobility from 350 km/hour to 500 km/hour. "It's for high-speed trains − not for the autobahn," quipped O'Neal.

He does not expect 5G networks to operate below 3 GHz, due to a lack of available spectrum. Instead, he expects the use of millimetres waves, where there is more bandwidth, but a shorter reach. Data rates will also be increased by the use of multiple-input, multiple-output links, and advanced coding schemes. These 5G waveforms will be highly advanced, reducing the peak-to-average ratio of these signals, and demanding the use of high-efficiency amplification.

O'Neal concluded his talk by detailing the current status of wireless communication. The leading infrastructure of today is described as LTE Advanced, which operates below 6 GHz. It features carrier aggregation, with a few channels in a band – and can involve some channels in one band, and some in another.

Next up could be LTE-Pro, which some people refer to as 4.5G. It can operate at 3.4-3.8 GHz. "Systems are in field trials today," revealed O'Neal. "We are getting about 1 Gbit/s with these systems."

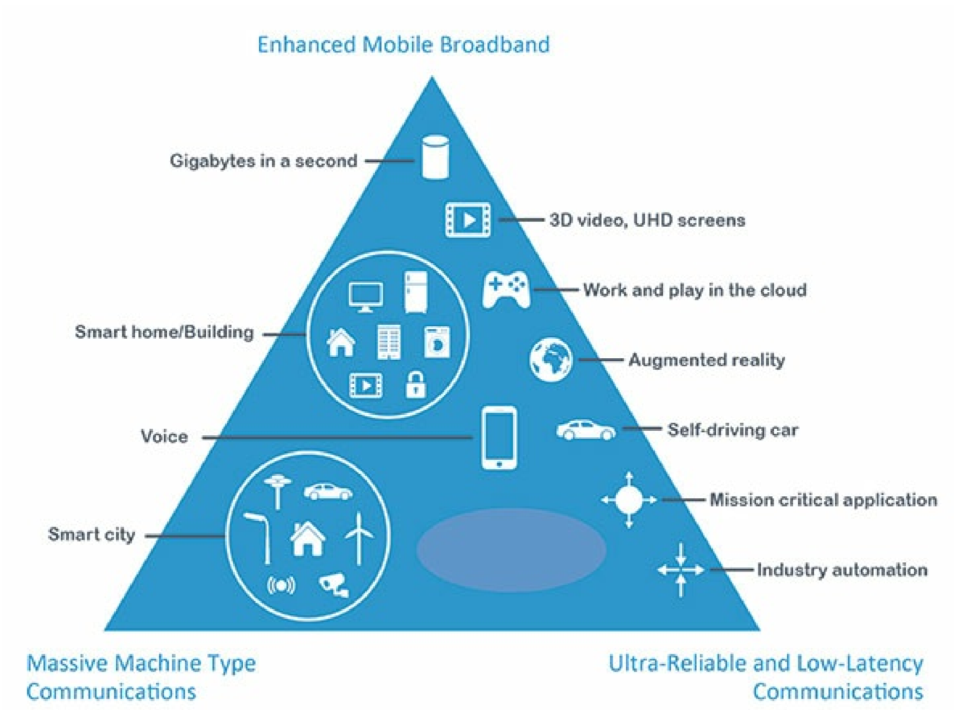
Over the years, significant progress has been made in the amplifiers for future mobile infrastructure, which could feature massive antenna arrays. O'Neal rammed home this point by comparing a 0.25 μm pHEMT technology from 2002 that delivered a power density of 650 mW/mm from a 4.3 mm by 3 mm chip, with a recent 2.6 mm by 0.9 mm GaN HEMT chip from Qorvo, made with a 0.15 μm process and delivering 2800 mW/mm. Advances included a slashing of size by 82 percent, and a fourfold reduction in power density.

Going with GaN

Offering another perspective on how the compound semiconductor market will evolve with the emergence of 5G was Takahisa Kawai, general manager of RF device development at the Electron Devices Division of Sumitomo Electric Device Innovations.

Kawai began his talk by highlighting the dominant position that Sumitomo holds in the GaN power amplifier base station market. He first presented figures, based on ABI Research and internal estimates, that the base station RF power device market was worth $1.1 billion in 2014, with GaN taking an 11 percent share and silicon LDMOS 88 percent. He went on to predict that "GaN will overtake LDMOS within three years" and claim that Sumitomo is the world's leader in this wide bandgap technology. Sumitomo also produces GaAs devices for backhaul radio covering 4 GHz to 86 GHz, and it is developing GaN chips to supersede them.

According to Kawai, requirements for power amplifiers for 5G base stations include a low cost, RF power of between 0.2 W and 30 W, and operation in the 4 GHz to 6 GHz band and the 24 GHz to 86 GHz band. Additional requirements are low power consumption, small size, linear distortion and a broad bandwidth.



5G will not just improve smartphones; it will also enhance machine-to-machine communications and aid the growth of the internet-of-things.

Given these requirements, GaN is the technology of choice, claims Kawai. That's because it is superior to silicon and GaAs in the most important metric for judging these classes of device, the Johnson figure-of-merit.

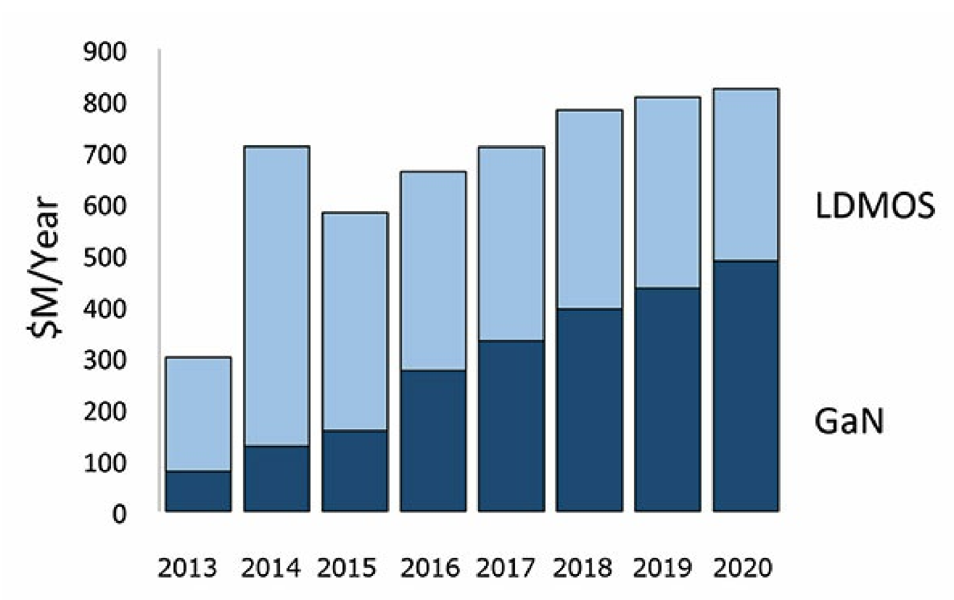
He noted that reductions in silicon devices to extend performance to higher frequencies lowered the operating voltage, leading to a diminished RF output power. Kawai pointed out that the biggest problem for 5G is that the specifications are still to be defined: "How do you know where to go if you don't have a roadmap?"

Like O'Neal, Kawai spoke about a technology that could provide a stepping-stone to 5G, and will use the 3.5 GHz to 6 GHz bands. The Sumitomo spokesman believes that the technology will have similarities to LTE-Advanced, and feature a wide bandwidth, carrier aggregation, and a mixture of GSM, CDMA, WCDMA and LTE technologies.

Kawai described a few of the company's products, beginning with a 3.5 GHz GaN power amplifier for LTE-Advanced networks. It adopts a Doherty architecture to improve the overall operating efficiency. In base stations, the average power is typically one-fifth of the maximum – a conventional amplifier would not be that efficient when operating in that regime. When configured in a Doherty configuration, however, the efficiency at relatively modest output powers is far higher. For an average output power, the efficiency can be 43 percent.

For amplification at 30 GHz, Sumitomo has GaAs chips that can deliver a peak power of 200 mW at a 20 percent efficiency. For multiple-in, multiple out links that are expected for 5G, the size of these chips must be below 5 mm to ensure good beam steering. Sumitomo's devices fulfil this requirement, measuring just 1.8 mm by 1.6 mm. At frequencies of 30 GHz and above, wire bonding introduces variations that degrade yield. To address this, engineers at Sumitomo have developed a wire-free, direct-mount technology that uses solder balls to mount the chip to a printed circuit-board. This technology is also used for its 30 GHz GaN Doherty PAs that are currently under qualification. Built with a 0.15 μm process, two-stage prototype MMICs produce a peak power of 3W and 16 dB of linear gain at an efficiency of 26 percent.

Kawai revealed that in the company's research laboratory, engineers have fabricated InAlN/GaN HEMTs with a 0.1 μm process that have a cut-off frequency of 110 GHz. This technology is being transferred to the business group, where it will be used to develop 80 GHz power amplifiers for 5G base stations.



The superior power density of GaN, compared with silicon LDMOS, will help this wide bandgap technology to dominate the RF power amplifier base station market.

5G handset requirements

The impact of 5G on the handset was the focus of the presentation by Stephen Kovacic, Director of Technology at Skyworks Solutions. He began his talk by describing three of the biggest fears facing any teenager: that their mobile can't be connected, that it can't deliver an acceptable data rate, and that the battery will run out before it can be recharged. "We can't expect anything different when it comes to 5G,"claimed Kovacic.

According to him, one of the biggest differences between the development of 5G and its predecessors is that with this latest communication standard, the likes of Intel and Google are participating in attempts to define specifications. Like the other speakers in the session, he believes that progress is slow, citing issues that include the lack of a defined air-interface and uncertainties surrounding the frequencies used
for communication links. He believes that there are very significant challenges for the front-end of the mobile, which are not being discussed at the system level.

These challenges, and the lack of standards, will hamper progress with 5G. However, Kovacic believes this form of wireless must be introduced, backing up this view with figures based on data from Cisco. They showed that cellular traffic will double from 8 exabytes per month this year to 16 exabytes per month in 2018, creating traffic volumes that will challenge mobile infrastructure.

Kovacic, like his peers from Qorvo and Sumitomo, expects the introduction of 5G to involve the use of new millimetre-wave bands, and massive multiple-input, multiple-output links. He picked up on the point raised by O'Neal that the power-to-average ratio of waveforms is set to increase, given that it has already shot up from 2:1 for 3G (WCDMA) to 5:1 for 3.5G (HSUPA) and 7:1 for 4G (LTE/OFDM).

To meet these requirements, Kovacic and his colleagues believe that the handset front-end is best served with a system-in-a-package, which contains a variety of technologies. It is argued that this not only leads to the best overall performance – it is cheaper, and it leads to a quicker time to market than an approach based on just one type of material.

Kovacic claims that the optimum front-end for today's mobiles combines a power amplifier based on a GaAs HBT with silicon-on-insulator RF switches, filters based on SAW/FBAR technologies, and CMOS for other functions, such as the controller for the power amplifier. But when it comes to 5G, other materials will be considered. This includes InP, as HBTs made from this could replace those from GaAs, due to their faster switching time, higher power gain and superior efficiency. Note that all these benefits are available without an increase in power consumption.

The Skywork's spokesman concluded his presentation by revealing how quickly the company can respond to customer interest in new designs. Currently, following discussions, the first samples can be released in 6 months, compliancy with specifications met within 10 months, and a production ramp within just 12-14 months – and possibly sooner.

Kovacic expects these timings to not change when 5G modules are under development. That's clearly a strength for Skyworks, as given the great deal of uncertainty surrounding the specifications associated with 5G, it would not be surprising to find that its implementation will require chipmakers to rapidly move from sampling to high-volume production. Interesting times lie ahead.