INTRODUCTION TO ALL SILICON MILLIMETER-WAVE 5G ARRAYS

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mmW Solutions. Enabling a new world

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“5G has arrived. One consequence will be the largest volume of millimeter-wave (mmW) ICs ever produced. A radical use case evolution is happening to make ubiquitous 5G possible by harnessing mmW spectrum to increase data speeds by orders of magnitude.”

mmWave Active Antenna Overview

by Alastair Upton, David Corman, Ian Gresham, Anokiwave, Inc.

Active millimeter-wave (mmWave) antennas will be deployed in unprecedented volumes over the next few years, fueled by the rapidly emerging 5G wireless (fixed wireless access and enhanced mobile broadband) and satellite communications systems. Millimeter-wave spectrum is attractive for telecom and satellite network operators due to the availability of large bands of contiguous spectrum, allowing for increased capacity, lower latency, and the ability to offer more services.

Unlike some of the early mmWave ICs used in military phased arrays, multi-channel silicon beamformer ICs are now recognized as being fundamental to reducing the cost of the active antennas as the way to commercialize phased arrays. The combination of high-performance silicon processes together with advanced analog and digital design techniques has accelerated the adoption of mmWave ICs to the extent that advanced 5G and SATCOM networks are now anticipated several years earlier than the industry originally projected.

Additionally, there are several antenna system architectures being adopted for 5G, depending on fixed wireless access, traditional radio access networks, CPE and UE applications. In this paper, we will discuss some of the key considerations for active antennas for multiple applications and discuss how silicon ICs are addressing the needs to make the deployment of commercial phased arrays successful.

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Growth in mmWave Market

The explosive growth of RF communication systems has made spectrum a scarce resource. The drive for more bandwidth has saturated the frequency bands from 700 MHz to 5.8 GHz. The only way to fuel the future demand for bandwidth is to push into the higher frequency bands – what we loosely term the millimeter-wave (mmWave) range of 15-70 GHz. This shift to higher frequencies, as well as advances in technology, will see the largest volume of mmWave ICs ever produced.

The 5G market has launched in the U.S. with Verizon launching its fixed wireless access (FWA) service, "5G Home" in four US cities. AT&T recently made the first mobile 5G browsing session on commercial 5G network equipment, and plans to rollout 5G service to 19 cities in 2019. Just as the industry was starting to slow down for the holiday season, AT&T announced that it has turned on its mobile 5G network in parts of a dozen cities via connections to a portable hotspot. T-Mobile has also announced multibillion-dollar agreements with OEM manufacturers for deployment in 2019. This is only the beginning; a number of market segments such as high power gNodeB antennas, fixed wireless access, small cell access points, indoor/outdoor CPE, as well as automotive will drive a radical use case evolution making ubiquitous 5G possible by harnessing mmWave spectrum to increase data speeds by orders of magnitude.

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At the same time, traditional satellite communications companies as well as some newcomers are scrambling to offer data services in the already licensed SATCOM Ku and K/Ka bands. In parallel with this are some new proposed "Stratelite" systems. Instead of space-based satellites, a network of balloons or drones can be created to produce a similar data communications system.

Another trend is being driven by advances in technology. The ability to create planar phased arrays that are much lighter than traditional systems is creating growth opportunities in the more traditional Aerospace and Defense market. Lighter and smaller arrays mean that RADARs can be

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deployed more easily and cost effectively and new applications are being developed to exploit this benefit. The remainder of this paper will focus on the 5G market, as the explosive growth of this market will drive the volume and innovations of mmWave active antennas.

Figure 1: 5G Market Use Cases

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Key Considerations for mmWave Active Antenna 5G Design

We are now beginning the multi-year rollout of 5G NR that should take us to through the next decade. For this market to realize its huge potential, and to develop as promised, OEMs, and RF component suppliers like Anokiwave need to not only address the technical challenges, but also consider the economic factors that will ensure the success of 5G.

One example of where these technical and economic factors overlap is at the active antenna air interface, where the link budget determining the user experience and Quality-of-Service is largely determined. Here, the most important factors determining the performance of active antennas – and consequently the radio link – are the observable sensitivity and radiated power. While transmitting enough signal power is critical, it is also essential that it must be developed efficiently. Excessive power dissipation not only results in economic consequences from the obvious increase in operating costs, but also to larger size and weight, reduced reliability, and more restrictions in unit deployment, all resulting in increases in the total cost of ownership. Figure 2 summarizes the important factors to consider.

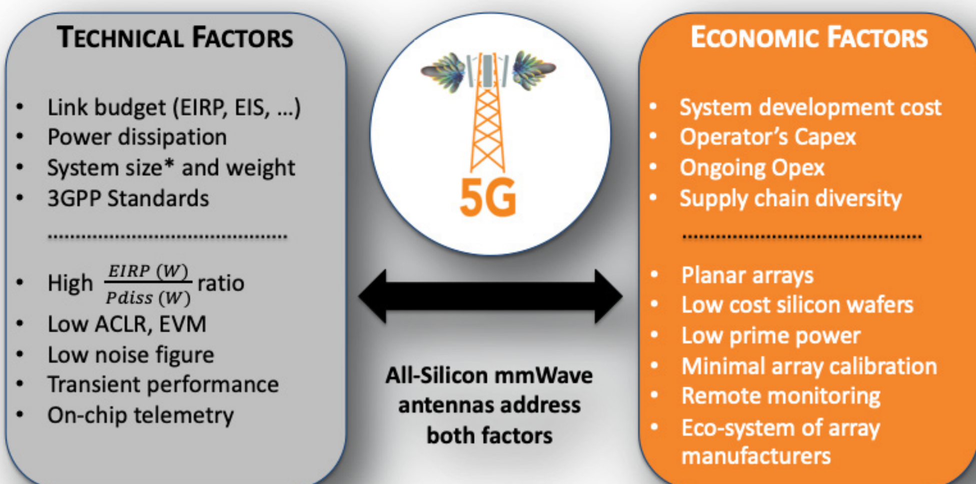

Figure 2: Technical and Economic Factors to Determine the Success of 5G

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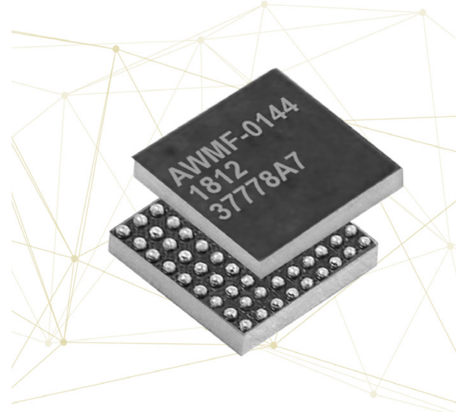
A key performance indicator of the air interface is the antenna consumption factor or the ratio of the EIRP to dissipated DC power of the antenna (both in Watts). Keeping that ratio high is critical in addition to continuing to meet the 3GPP and regulatory standards.

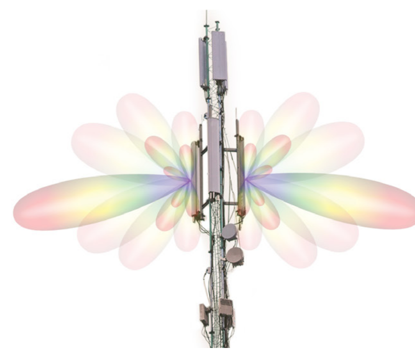
As the industry continues its rapid commercialization of active antennas, there is an intense focus on cost reduction by navigating the traditional volume manufacturing curve, leveraging economies of scale, and eliminating unnecessary, non-value-added activities. Anokiwave's goal is to help customers build the most cost-effective arrays that also improve the total cost of ownership for the service provider. An important illustration of this principle in practice is the elimination of array calibration using Anokiwave's ZERO-CAL™ technology; removing array alignment and costly unnecessary factory testing while at the same time improving predictability of performance. Figures 3A and 3B show an example of ZERO-CAL™ improvements to sidelobe levels. The improvement is drastic.



ZERO-CAL™ ICs

Imagine a new world where array calibration is not needed... It's here.

Active Antenna Solutions for 5G Fast Beam Steering™



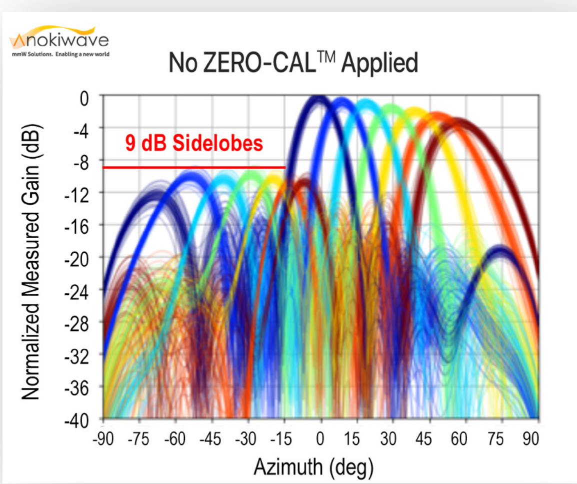


Figure 3A: Antenna Gain without ZERO-CAL™

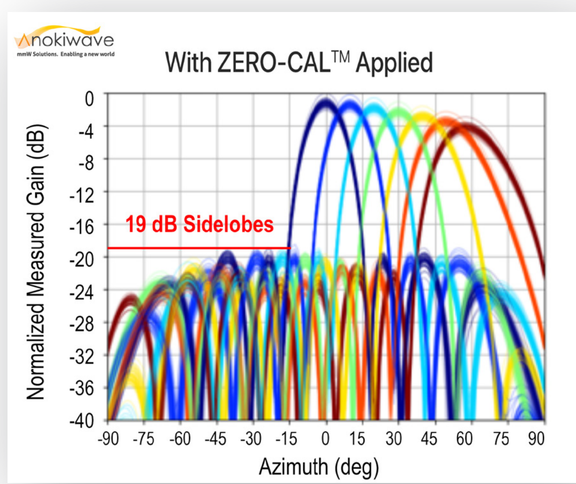


Figure 3B: Antenna Gain with ZERO-CAL™

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A key metric and goal for service operators is $/data-bit, and the need to continually reduce the network operating expenses (OPEX). Unsurprisingly, this is fundamental to the roll-out of 5G-NR. Anokiwave is working intensely to address the energy requirements of the system. For example, a hypothetical mmW 5G-NR network consisting of 500,000 large gNodeB base stations, and 5 million small cells, is projected to consume over 2.65 TWh of power in its active antennas. The superior integration capability of silicon enables Anokiwave to embed power-saving green functionality into its mmWave ICs, resulting in a substantial reduction in operating energy consumption. We believe by using the Anokiwave KINETIC-GREEN functionality, the total energy savings could be up to 33%.

As mmWave active antennas are being industrialized in rapidly increasing volumes, Anokiwave's silicon ICs are providing significant cost and technical advantages to the system, as well as enabling network OPEX improvements. With low-cost materials, embedded ZERO-CAL™ and KINETIC-GREEN functions, field health monitors for remote monitoring, as well as the continued drive to higher power efficiency, Anokiwave is leading the way for the economic and technical improvements that ensure the success of 5G.

Anokiwave's new Gen-3 5G silicon IC family adds new and enhanced features to make 3GPP compliant cutting-edge performance even easier, and active antennas so powerful that they fit into the palm of your hand. And by harnessing the capabilities of 300mm diameter silicon processes, we’ve reduced cost structures by over 90% in two years making base-stations resemble Wi-Fi access points.

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All Silicon Array Architecture for Commercial Deployment

Silicon is the best technology that can simultaneously achieve the high integration levels, low cost, and reliable performance to enable the volume phased array markets. Proof of concepts exists, what is left is continued work to commercialize the technology.

Anokiwave offers the industry's broadest portfolio of mmW 5G ICs for all major bands and antenna configurations. Figure 4 shows a block diagram for a commercially available beamforming IC at 28 GHz designed to fit behind 4 antenna elements in a planar phased array.

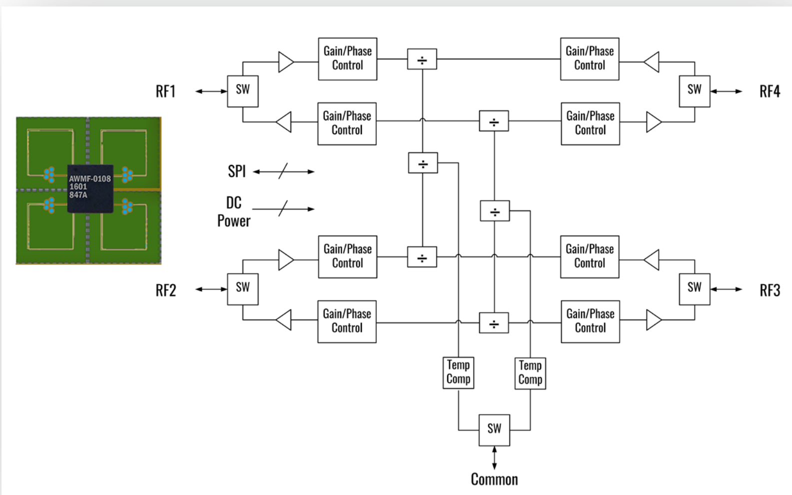

Figure 4: AWMF-0108 - 4 Element, 28 GHz Beamforming IC

An example of a commercially available array using the above beamforming IC is shown in Figure 5 below. This is a 64-element array with 16 ICs in a quad configuration with one common port feeding 4 antennas. It offers an EIRP of greater than 50 dBmi, and a G/T of -6 dB/K. It uses a 12V supply and consumes less than 20W DC power. This array is scalable to create larger arrays while adding in flexibility.

Figure 6 shows an array that scales the 64-element array into 4 sub-arrays. This can be configured to operate as 4 independent 64 element arrays or as a 1x 256-element array. This array offers an EIRP of greater than 60 dBmi (1KW) and a G/T of -2 dB/K in the single 256-element beam state.

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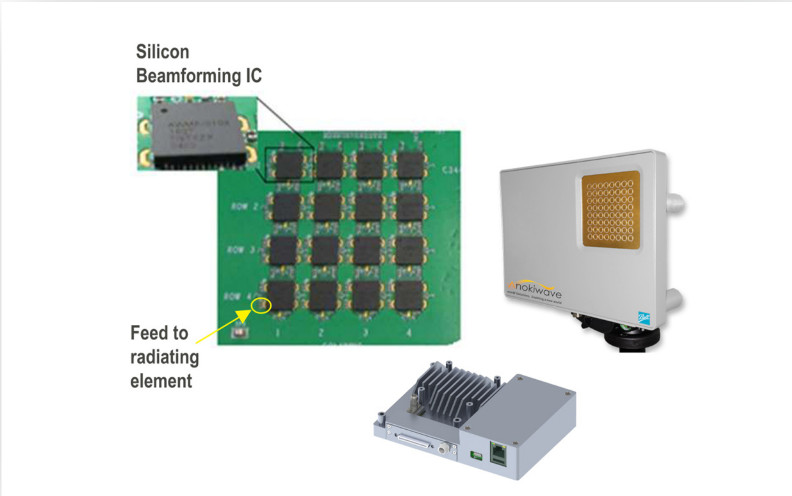

Figure 5: 64-Element Array

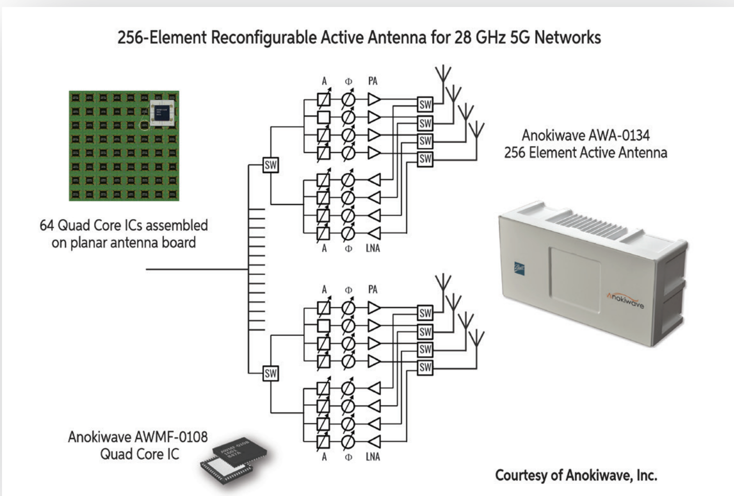

Figure 6: 4 x 64-Element Array for MU-MIMO

It uses a 12V supply and consumes less than 65W DC power. Using this array configuration, multiple data streams, MU-MIMO can be traded off for high power depending on the instantaneous power requirements for the system. This array demonstrates the power level that can be achieved with silicon.

Both the 64-element and the 256-element are based on our Gen-1 5G ICs. Our latest Gen-2 ICs offer up to 6 dBm additional linear power per element as we continue to push the power levels with each generation.

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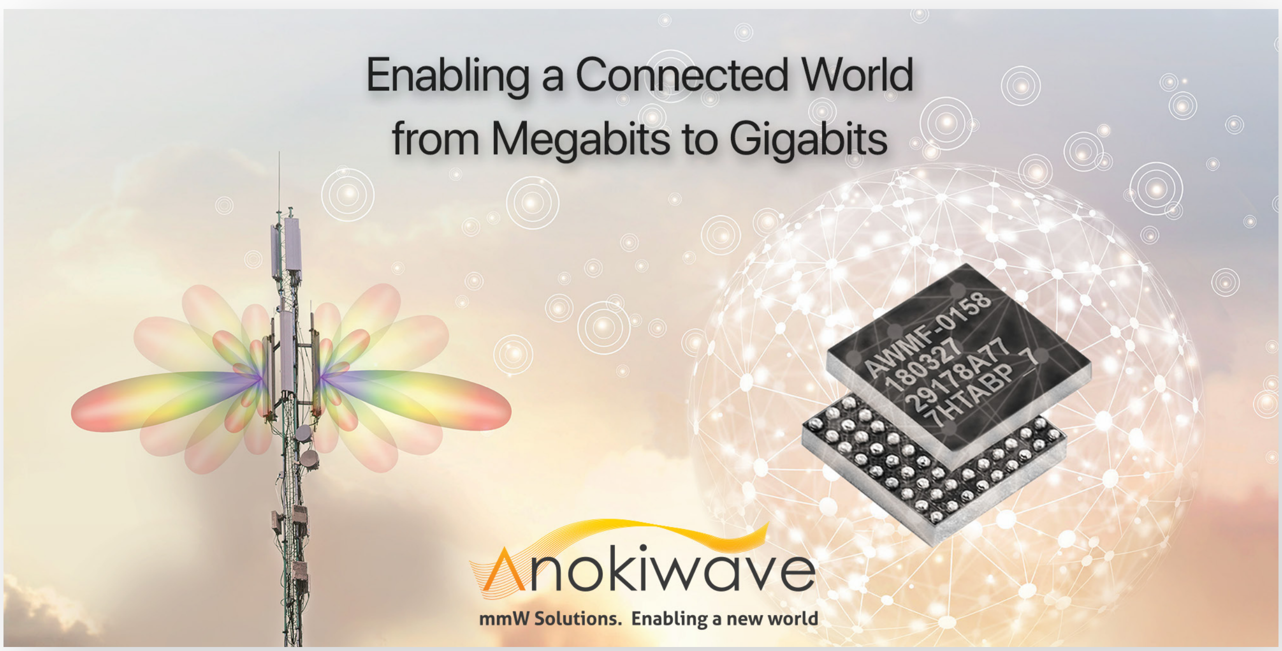
Conclusion

mmWave Silicon ICs are commercially available and in production now. The path is clear for all-silicon, high efficiency, planar arrays to be deployed in a variety of markets. The technology has moved beyond proof of concept and academic research. The years to come will see further productization as they move to high volume manufacturing. We expect mmWave active antenna technology to become ubiquitous and by 2020 every network operator, every OEM, and likely every UE manufacturer will be using active antennas in high volume.

With over five years of focused innovation, three generations of ICs, and significant quantities of 5G ICs delivered, Anokiwave has made millimeter-wave 5G a commercial reality.



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