How Will 5G Influence the RF Compound Semiconductor Industry?

Eric Higham

Strategy Analytics, 199 Wells Ave., Newton, MA 02459, ehigham@strategyanalytics.com, 1-617-614-0721

Abstract

Revenue in the RF compound semiconductor market has experienced steady growth for more than a decade. Wireless applications have been the primary driver for revenue growth but that growth engine is slowing dramatically. This paper examines RF compound semiconductor revenue and how 5G architectures may influence the growth profile and future forecasts.

INTRODUCTION

For more than two decades, GaAs has accounted for the vast majority of revenue in the RF compound semiconductor market. GaAs devices have become integral elements in a wide variety of commercial and defense applications. The success and maturation of the GaAs ecosystem paved the way for the growth and maturation of compound semiconductor technologies like GaN, SiGe and InP. However, the application and technology mix of the compound semiconductor market is changing in response to the evolution of consumer, enterprise and defense needs. The rest of this paper examines the drivers that pushed RF compound semiconductor revenue to roughly $10 billion and how emerging 5G developments will shape the future of the RF compound semiconductor industry.

HISTORY

In the early days of the compound semiconductor market, GaAs devices in defense applications generated all the RF compound semiconductor revenue. As the GaAs supply chain evolved and matured, the breadth of applications expanded and GaAs devices found their way into commercial applications. Since the mid-2000s, data-centric mobile wireless applications have been the growth engine for GaAs and the entire compound semiconductor market. As RF GaAs device volume and revenues increased, the compound semiconductor industry developed other technologies to complement and compete with GaAs in emerging system and component opportunities. Figure 1 shows our last forecast for the market share of total revenue derived from compound semiconductor technologies in RF applications.

STORM CLOUDS FORMING?

Figure 1 shows how important GaAs has been to the entire RF compound semiconductor market and it illustrates the challenge facing GaAs device manufacturers. While GaAs RF revenue will continue to grow, it will lose market share as all the other compound semiconductor technologies listed will grow faster. Figure 2 helps illuminate the challenge with an estimate of the application share of total RF compound semiconductor revenue in 2018.

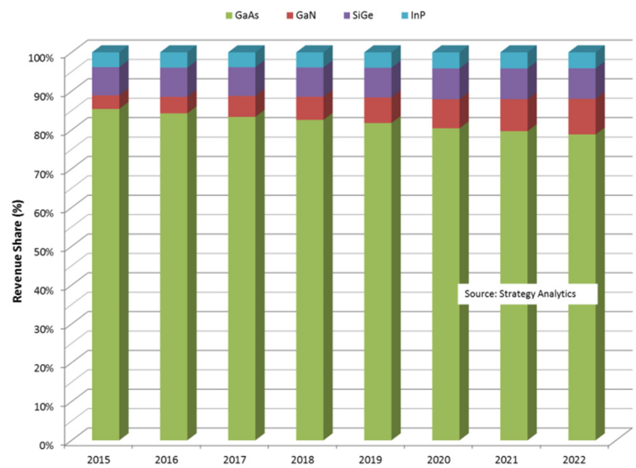


Fig. 1. RF Compound Semiconductor Revenue Share Forecast

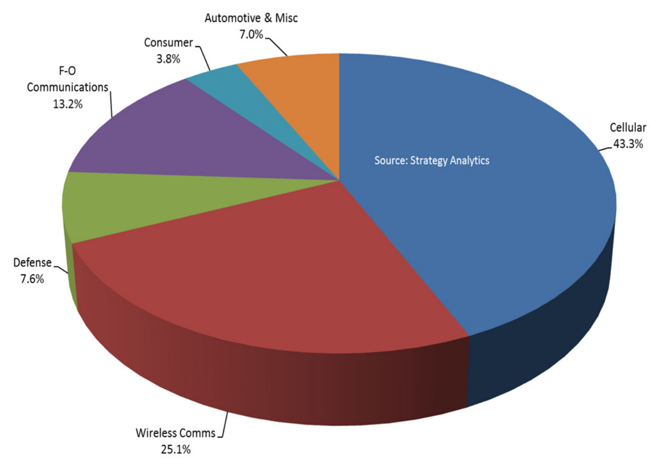


Fig. 2. 2018 RF Compound Semiconductor Revenue Share by Application

As indicated in Figure 1, GaAs device revenue accounts for the lion's share of RF Compound semiconductor revenue. Figure 2 shows how important wireless applications are for the compound semiconductor market. The pie chart specifically breaks out "Cellular"; which includes mobile applications from "Wireless Comms", which includes other wireless applications like Wi-Fi, base stations, wireless backhaul, VSAT, etc. to show the relative importance of the two segments. The wireless applications ("Cellular" + "Wireless Comms") account for nearly 70% of all RF compound semiconductor revenue.

The situation is even worse for RF GaAs revenue and this illustrates both the opportunity and threat for the GaAs device market and the broader compound semiconductor industry. The wireless segment accounts for nearly 85% of the total revenue, while the cellular segment accounts for nearly 58% of the total GaAs revenue. As the cellular market has matured, many mobile devices have cellular radios included, but mobile handsets dominate the cellular market, with roughly 2 billion new mobile handsets sold each year. Figure 3 shows the mix of mobile handset sales over time.

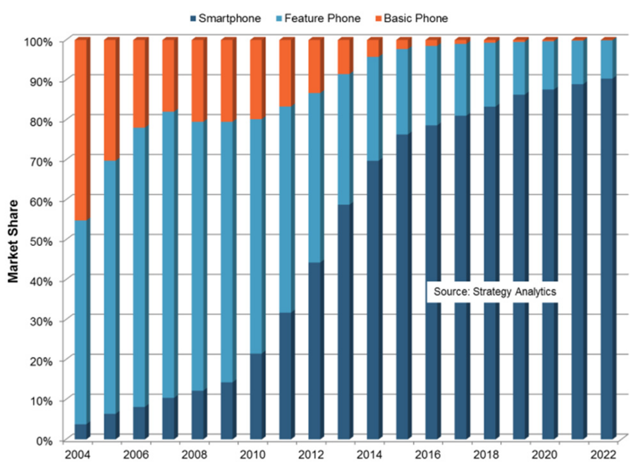


Fig. 3. Mobile Handset Segmentation

Smartphone development in the mid-2000s ushered in the "wireless revolution". The explosive growth in wireless data traffic pushed the evolution of smartphones to much more sophisticated devices that accommodate multiple bands and standards. While the GaAs content of smartphones is limited just about exclusively to power amplifiers, rapid consumer adoption and a steadily increasing number of frequency bands means the GaAs RF content and revenue grows quickly.

Figure 3 shows the challenge facing GaAs and the compound semiconductor industry. This forecast shows a rapid increase in smartphone market share in the decade between 2004 and 2014. Since then, the rate of growth has slowed substantially. The reality is that not everyone will have a smartphone and we are rapidly approaching a point of smartphone saturation. As we get closer to saturation, the rate of growth of smartphones is approaching the growth rate of the entire mobile handset market; mid-single digit compound growth rates. With approximately 2 billion phones sold each year, each containing an increasing amount of RF content, GaAs revenue will remain large, but growth is likely to slow substantially.

What About GaN?

The fastest growing RF compound semiconductor technology the past decade has been GaN. Strategy Analytics estimates RF GaN revenue will surpass \$1.1 billion in 2022. The defense industry nurtured and provided the first applications for GaN technology, but wireless infrastructure applications have become very important for GaN. As Figure 4 shows, driven by rapid 4G deployments in China, infrastructure applications accounted for more than 50% of the total RF GaN revenue in 2016. The infrastructure revenue will continue to grow, but lose share to defense applications in the process.

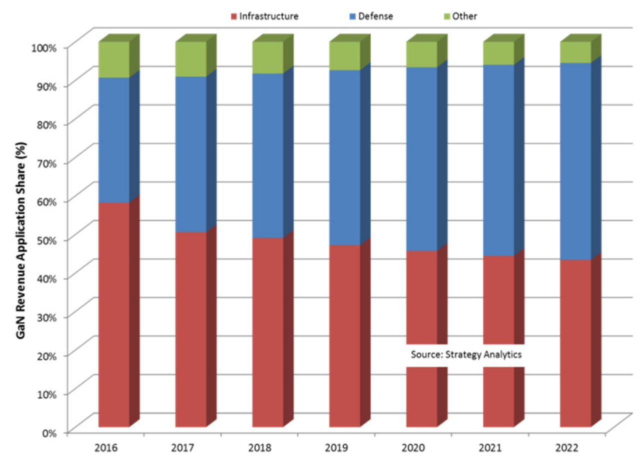


Fig. 4. RF GaN Revenue Applications Share Forecast

This is a very interesting forecast for the compound semiconductor industry, because it illustrates a changing trend for GaN revenue. Commercial RF GaN revenue in surpassed the defense revenue for the first time in 2014. While the defense industry birthed and nurtured the fledgling GaN ecosystem with funding and the first applications, the volume of these applications is limited. The trigger for the rapid increase in commercial RF GaN revenue was the widescale deployment of LTE base stations in China. The enormous scale and quick timing of LTE deployments by the Chinese wireless operators propelled the commercial portion to nearly 68% of the total RF GaN revenue in 2016.

The signs of what appears to be a new trend are just beginning to emerge. Even though we anticipate RF GaN revenue in wireless infrastructure applications grew to nearly \$300 million in 2018, the share of the total will decline. The decline in revenue share will be the result of wireless infrastructure network architectures incorporating more "small cells" that will not require as much RF transmit power and fast growth in the defense sector.

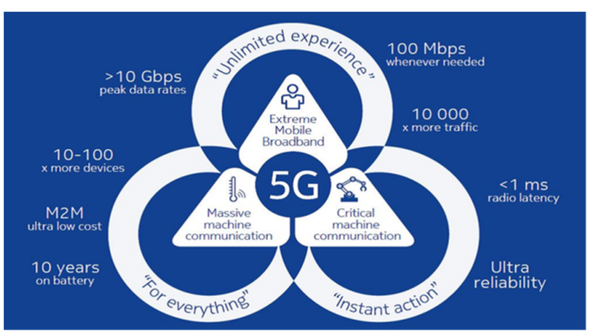
Given the heritage, the defense industry has always embraced the performance advantages of GaN technology.

These GaN devices, primarily power amplifiers, but also low power switches and LNAs, have become mainstays of new designs for electronically scanned phased array radars and wideband tactical radios; the "volume" of defense applications. The procurement cycle is also in alignment, meaning that many new programs and major upgrades that contain substantial RF GaN content are reaching the production phase. This is a significant development because it means RF GaN manufacturers that ignore defense applications do so at their own peril. It also means that the trajectory of RF GaN revenue may get a bit choppier, to reflect the defense procurement cycle. We also expect that the quantity of RF GaN devices manufactured by large defense contractors for internal, captive applications will increase.

WHAT IS THE NEXT GROWTH ENGINE?

A closer look at Figure 1 shows that GaAs and GaN account for nearly 90% of the total RF compound semiconductor revenue. The analysis to this point has indicated some storm clouds. Smartphone growth is slowing, wireless infrastructure is evolving to a "small cell" architecture and defense applications, with long and unsettled procurement cycles are becoming more important. Despite these developments, we are forecasting that GaAs, GaN and total RF compound semiconductor revenue will continue to grow.

One of the biggest reasons for this optimism is the upside potential of 5G. The much-anticipated 5G era is upon us, as operators have started deploying 5G fixed and mobile networks, with more deployments scheduled in 2019. In the face of the headwinds described for GaAs and GaN, the RF compound semiconductor industry is looking to 5G to be the next growth driver.



Source: Nokia

Fig. 4. The 5G Vision

The vision of 5G, shown in Figure 4 is both transformative and ambitious. The goal of this new network is to provide *unlimited* access to information, with capability of sharing this information anywhere and at any time by anyone or anything. There are many graphical representations of this vision but they all include the pillars of the unlimited experience of extreme mobile broadband, the instant action of ultra-reliable, low latency critical machine communication and the all-encompassing, "for everything" aspect of massive machine type communications, more commonly referred to as Internet of Things (IoT) networks. The metrics sprinkled around the three pillars of the 5G vision represent network goals and some of them entail revolutionary, rather than evolution advances from existing networks.

Figure 5 shows a network concept that illustrates some of the features and architectures that will enable the goals of the 5G vision. Implicit in this diagram is pushing more intelligence and processing to the edge of the network, developing devices with more internal network capability, accommodating an increasing number and variety of cells, incorporating the vehicle as a communications platform into the network and understanding that backhaul become a critical component of the 5G network.

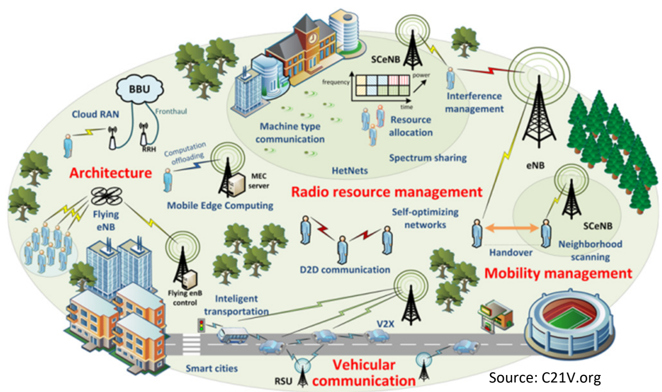


Fig. 5. 5G Network Concept

Compound semiconductor opportunities exist in the implementation of all the features just mentioned, but one of the most exciting and fundamental features of the 5G network is the reliance on massive MIMO (multiple input, multiple output) antenna arrays with beam steering capability. A complete discussion of MIMO and beam steering is beyond the scope of this paper, but this technique is essential to reach the data rates shown in the 5G vision of Figure 4. Channel capacity is related to the SNR of the channel and the channel bandwidth. To increase capacity, the bandwidth and/or the SNR must increase. However, SNR has a logarithmic relationship with capacity, while capacity varies linearly with bandwidth. This explains the trend toward carrier aggregation and the move to millimeter wave frequencies where channels inherently have more bandwidth.

Introducing multiple transmit and receive antennas, coupled with spatial multiplexing techniques allows for signals to be simultaneously transmitted and received from different radiating elements. To a first approximation, with everything else held constant, channel capacity increases by the number of data streams generated from the antenna. This combination of millimeter wave frequencies for more bandwidth and more data streams to increase the spectral efficiency and capacity of a channel is what has the compound semiconductor industry excited.

Figure 6 [1] shows a representative architecture for a transceiver in a massive MIMO antenna array. This diagram illustrates a hybrid digital/analog beamforming approach that is representative of current industry practice. This diagram illuminates several important features that will define how 5G will influence the compound semiconductor industry.

Starting on the right side of the diagram, each transceiver feeds a subarray panel of cross-polarized radiating elements in the array. Each RF front end may drive multiple radiators (a "tile) and each digital signal (data stream) may fan out to multiple tiles through the RF beamformer. The number of radiators in a tile and the number of tiles in a subarray panel will influence the characteristics of the resulting beam. The number of subarray panels defines the number of beams from the antenna. The industry appears to be looking at anywhere from 32 to 128 *cross-polarized* radiators. This increases the number of RF chains by a factor of two, when compared to the number of radiators.

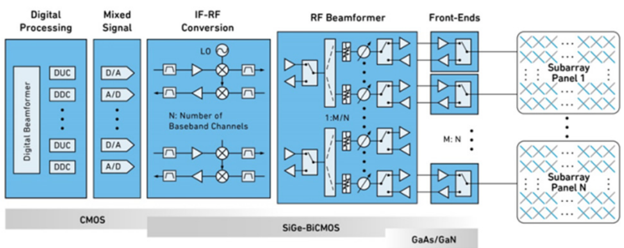


Fig. 6. Massive MIMO Transceiver Architecture

The other very important feature shown in the diagram in Figure 6 is the overlap of technologies for the functions. This is both the opportunity and the challenge that 5G presents for the compound semiconductor industry. Stringent performance requirements and millimeter wave frequencies have historically favored compound semiconductors and that represents the opportunity. The challenge is the improvement in silicon-based technology, along with the frequency profile of 5G.

This paper has mentioned the advantages of millimeter wave frequencies and millimeter wave 5G networks are being deployed in fixed wireless access applications. Mobile networks, with their inherent volume, are currently being deployed in the <6 GHz 5G frequency ranges. These frequency ranges are low enough that silicon dominates the entire transceiver, with the possible exception of the RF front end.

In both frequency ranges, silicon proponents argue that silicon, with its integration capability and cost structure is the only solution that meets the performance and scale requirements of 5G. Since the transmit power of a base station or terminal is regulated, as the number of antennas increase, the transmit power of each element decreases. For this reason, the silicon proponents argue the advantages of more elements in a massive MIMO array.

The GaAs/GaN communities make the argument that fewer antennas are the best choice. This argument acknowledges that DC power consumption (OPEX) is an important consideration to operators. Fewer GaAs and/or GaN power amplifiers, with higher efficiency means lower DC power dissipation, which translates to cost savings. This DC power savings can also be "reinvested" into more digital processing that increases the functionality and flexibility of the massive MIMO array.

CONCLUSIONS

The RF compound semiconductor industry has grown to nearly $10 billion of revenue, with GaAs the foremost beneficiary and contributor. The success of GaAs has provided a blueprint for other compound semiconductor technologies to flourish. GaN is now the fastest growing compound semiconductor technology, but both the GaAs growth engine is sputtering and the revenue drivers for GaN are changing. Against this backdrop, the highly anticipated deployment of 5G networks offers the possibility of being the next big growth driver for the compound semiconductor industry.

The 5G vision is attractive to the compound semiconductor industry because it relies on the development and deployment of a new wireless network. This network will accommodate fixed and mobile wireless broadband and operate in new frequency bands from below 1 GHz into the millimeter wave range. The most likely network architectures rely on many, lower power base stations, each containing a massive MIMO array with many RF transceivers. These conditions all point to increased *semiconductor* revenue, but the question is how much of this revenue goes to compound semiconductors. The answer lies in the details and successes of the architectures being deployed today and those answers will determine the future trajectory of compound semiconductor revenue.

REFERENCES

[1] B. Peterson, *Power Amplifier Requirements for mm-Wave 5G Systems*, IMS2018 Session WSC-3, June 2018.

ACRONYMS

GaAs: Gallium Arsenide
GaN: Gallium Nitride
InP: Indium Phosphide
IoT: Internet of Things
LNA: Low Noise Amplifier
LTE: Long Term Evolution
MIMO: Multiple Input Multiple Output
SiGe: Silicon Germanium
VSAT: Very Small Aperture Terminal