# SATCOM MARKET OVERVIEW

## Cost Effective Solutions Needed to Address the Exponential SATCOM Market Growth

Anokiwave Is Now qorvo

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In 2024, Anokiwave was acquired by Qorvo. The combination of the two company's unique capabilities enables Qorvo to supply highly integrated complete solutions and SiPs for defense, aerospace and network infrastructure applications.

Anokiwave's innovative portfolio of active antenna ICs, combined with Qorvo's complementary products, global scale and significant market reach, provide new options for high integration and high-performance that will democratize phased array active antennas.

The following whitepaper was written to provide a complete overview of the SATCOM market drivers, how the market is defining the user terminals for the systems, how Anokiwave, now Qorvo, enables SATCOM terminals and a look into the future of coexistence and new generations of solutions. References to Anokiwave have been updated throughout the paper to reflect this acquisition.

# Executive Summary

The world with Satellite Communications (SATCOM) is growing and evolving fast.

The need for global connectivity has never been more pressing. As terrestrial networks evolve to 5G to meet this need, many operators are realizing that mobile networks cannot by themselves achieve global coverage without assistance from satellite constellations over the oceans and remote land areas. Such ubiquity is becoming essential in how industries compete and generate value, how people communicate and interact and how militaries pursue security for their citizens.

Anokiwave, now Qorvo, has prepared this series to provide a complete overview of the SATCOM market drivers, how the market is defining the user terminals for the systems, how Qorvo enables SATCOM terminals and a look into the future of coexistence and new generations of solutions.

Part 1 of this series provides an overview of:

- The market drivers and key market segments in the SATCOM market.
- New investments and major satellite constellations that are driving the market.
- Qorvo's role in enabling the new flat panel antennas for this emerging SATCOM market.

Part 2 provides an overview of ways in which the ecosystem of SATCOM user terminals is evolving and the factors that drive this evolution including:

- Scalability requirements based on constellations, markets and platforms.
- Antenna terminal performance considerations including thermal, architecture and cost.
- Qorvo's architecture specifically designed for the ICs to easily integrate into SATCOM antennas with optimal performance.

In Part 3, we discuss:

- The Qorvo Ku and Ka-band silicon ICs, tools and support options to help SATCOM OEMs develop high-performance, cost-effective solutions for active antenna based user terminals.
- Success stories of customers developing and delivering high performance SATCOM terminals using Qorvo technology.

In the final installment, part 4, we discuss:

- The future needs of the market as it converges to an integrated 5G network of networks that include terrestrial and non-terrestrial systems.
- New use cases evolving that demonstrate 5G and SATCOM convergence and coexistence, and how Qorvo enables both markets with high-performance, highly integrated IC platforms in commercial volumes that are compact, cost effective and deliver faster time-to-market for OEMs.

# Contents

*The space economy is projected to grow from $416 million in 2020 to more than $1 trillion by 2040. Of that total, the largest portion will be operations and services — the solutions that companies on the ground (user terminals) can provide with satellites — which will nearly triple, going from $241 billion in 2020 to $687 billion in 2040.*[1]

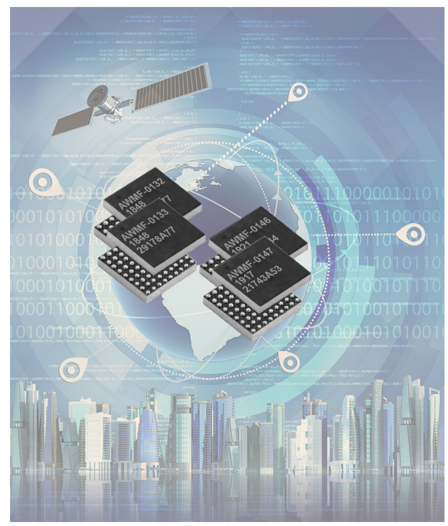
## Part 1 - Market Drivers[2]

Large investments in new communications satellite constellations are driving the demand for new technologies at lower price points and more capabilities. This technology is largely focused on flat panel antennas and more specifically active electronically scanned antennas (AESAs).

Currently, these constellations are focused on Ku- (10.7-12.75 GHz Rx/13.75-14.5 GHz Tx) and Ka- (17.7-21.2 GHz Rx/27.5-31.0 GHz Tx) bands for the user terminal operations. As these new constellations become operational, unprecedented numbers of user terminals will be needed, and most of them will incorporate active phased array flat panel antennas to communicate when the satellite is in motion. The SATCOM AESA market is about to experience exponential growth.

There are a wide range of SATCOM user terminal applications across a variety of market segments. Often these terminals have varying requirements depending on the constellation(s) on which they operate and the markets in which they address.

The four major markets include consumer, commercial mobility, enterprise and government. Many requirements overlap in these markets, including performance requirements, size, weight, power draw, throughput performance, cost and ruggedness. Generally, the consumer market has the least overlap as their requirements are the most unique, with very limited viability outside their intended market.



The future has never looked brighter for satellite operators, given the record-setting number of satellite launches in recent years, the growing number of satellite-based applications, and the huge capital investments being made in a host of planned space ventures.

The other three markets have more significant overlap in requirements with ruggedness being a key differentiator from consumer terminals. With this typically comes higher prices, ability to sustain higher power draw and often the demand for higher throughput performance. Although many requirements overlap, each market has its own unique class of requirements for user terminals, as shown in Figure 1 below.

The constellation(s) with which the terminals operate can also drive required performance capabilities and requirements. Orbits can be divided into two categories: traditional geostationary earth orbit (GEO) and non-geostationary orbit (NGSO). NGSO includes low earth orbit (LEO), medium earth orbit (MEO) and highly elliptical orbit (HEO), all of which bring unique terminal performance requirements.

The LEO mega-constellations are projected to provide 100x increase in bandwidth from the legacy GEO satellites with reduced latency by 10x, while serving significantly more users.

## Four major markets of SATCOM user terminals:

- Consumer: Home internet users, vehicle, and private maritime users
- Enterprise: Data centers, mid-to-large businesses, and satellite-to-ground teleports
- Government: Aviation, ground mobile, maritime, and ground transportable
- Commercial Mobility: Agriculture, construction, mining, maritime, aviation, and ground transport

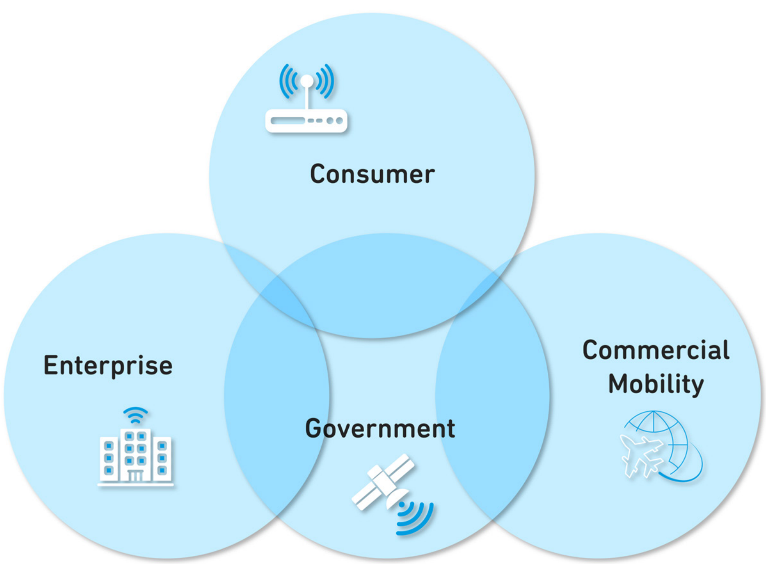



Figure 1: Primary markets have overlapping requirements for terminals dominated by enterprise, government and commercial mobility with consumer terminals nearly standing on their own.

MEO satellites also provide lower latency, higher throughputs and service more users than GEO, but with less global footprint than LEO. HEO satellites are being used to fill the “gaps” in GEO and MEO systems, providing higher latitude and polar coverage.

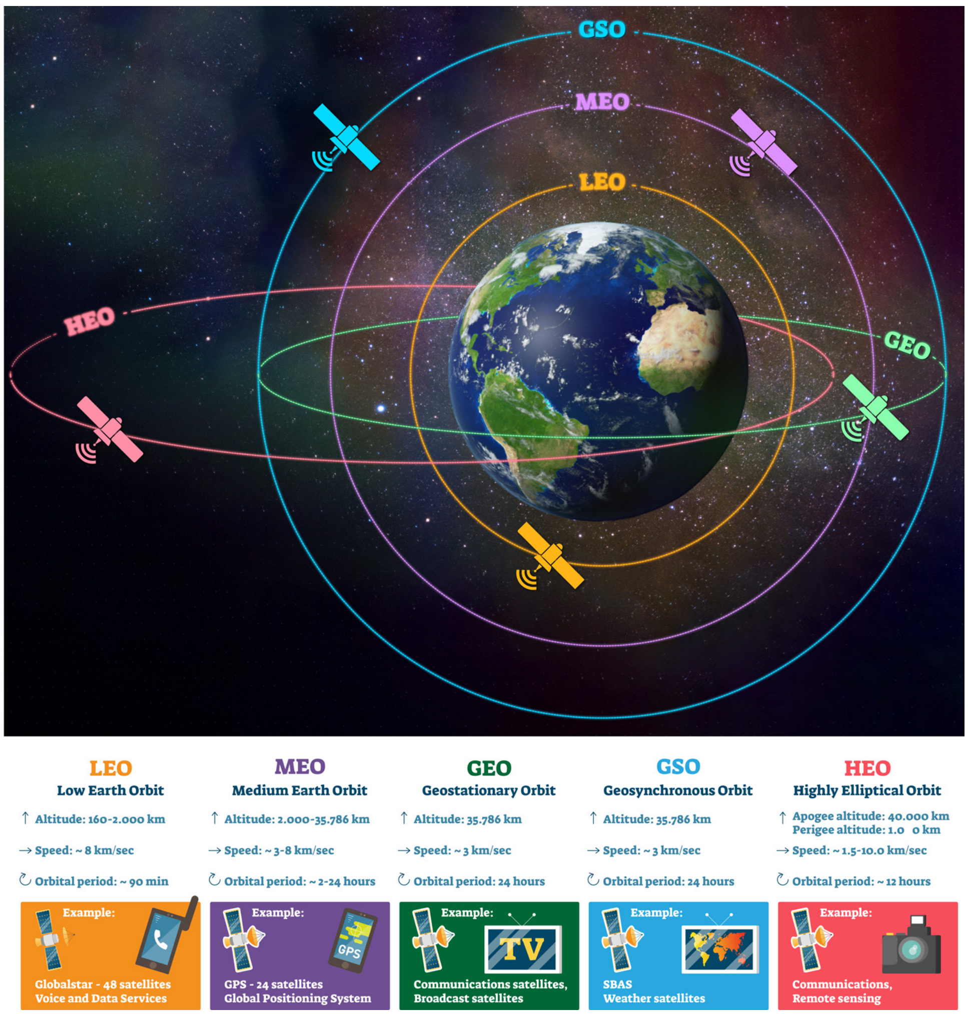



Figure 2: Orbits in which the satellites operate have significant impact on user terminal requirements.

### SATCOM Orbits Defined

- Traditional geostationary earth orbit (GEO) or geosynchronous (GSO) - a circular orbit 35,786 km above earth and follows direction of the earth rotation.
- Low earth orbit (LEO) - an orbit at 500 km to 1,500 km above earth. These systems offer **100x bandwidth** over GEO and **10x improved latency.**
- Medium earth orbit (MEO) - an earth centered orbit with an altitude between 2,000 - 35,786 km above earth.
- Highly elliptical orbit (HEO) - an elliptical orbit with perigee altitude under 1,000 km and apogee of over 35,756 km.

Looking at the top 4 LEO constellations in consideration today, Amazon, OneWeb, SpaceX and Telesat, they plan for a combined total of 3,176 satellites in the initial deployment and full constellations of 15,687 satellites. The aggregate data capacity of these constellations is staggering, especially compared to the current capabilities of the GEO satellites. As of March 2022, 3,135 communications satellites were in orbit, an increase of over 70% since December 2020, dominated by the LEO launches of OneWeb and SpaceX.

A comparison of the constellation sizes is shown in Table 1. This massive growth in capacity combined with a growing demand in the government and commercial mobility markets is leading to a 6-12% CAGR of growth through 2030. In 2021, the market was $3,877 million and is projected to be over $6,000 million by 2028. This demand and growth mean great opportunities for terminal manufacturers who can develop, manufacture and certify terminals at a reasonable price.

| System | GEO | Amazon | OneWeb | SpaceX | Telesat |
|---|---|---|---|---|---|
| Frequency | Ku & Ka | Ka | Ku | Ku | Ka |
| Number of Initial Satellites | ~1,000 | 578 | 716 | 1,584 | 298 |
| Number of Final Satellites | ~400 | 3,236 | 6,372 | 4,408 | 1,671 |
| Altitude (km) | 35,786 | 590-630 | 1,200 | 540-570 | 1,015-1,320 |
| Latency (ms) | 560 | ~30 | ~40 | ~30 | ~40-50 |
| Satellite Life (years) | | 7 | ~5 | 5-7 | 10-12 |
| Capacity | 3 Tbs | ~30-32 Tbs | ~5 Tbs (~7.5 Gbps/Sat) | ~75 Tbs (~17 Gbps/Sat) | ~12 Tbs (~20-50 Gbps/Sat) |
| Target Markets | Consumer, Enterprise, Mobility, Gov | Consumer, Enterprise, Mobility, Gov | Enterprise, Mobility, Gov | Consumer, Enterprise, Mobility, Gov | Consumer, Enterprise, Mobility, Gov |

Table 1: Top 4 LEO Satellite Constellation Initial Operational Deployment and Full Deployment Sizes

## Qorvo's role in SATCOM Markets

Across all of the emerging SATCOM market segments, silicon based flat panel phased array active antennas are becoming the architecture of choice.

Qrovo provides silicon-based SATCOM ICs to enable phased array antenna user terminals with high performance, small form factor and low cost. Qorvo's ICs are designed to support FDD (Frequency Division Duplex), however they can also support TDD (Time Division Duplex), operation covering global SATCOM Ku, and Ka bands. Each IC in the family supports four (4) dual polarization radiating elements with full polarization flexibility. Each channel has its own individual control of phase and gain for maximum flexibility.

The ICs utilize a commercial CMOS silicon process designed for volume RF production, ensuring the perfect combination of performance and low cost that make commercialization of Flat Panel Active Electronically Steered Antennas for SATCOM a reality.

Over the years Anokiwave, now Qorvo, has become an industry benchmark and a trusted choice for silicon ICs that enable high performance, small form factor and low cost mmWave flat panel active antennas for LEO, MEO and GEO SATCOM terminals.

*Satellite communication terminal technology is constantly evolving to meet the ever-changing needs of users. The key trends in this field include the development of low cost and small form factor devices that can be scaled to meet a multitude of use cases ranging from portable consumer terminals to airborne terminals for in-flight connectivity.*

## Part 2 - User Terminal Drivers

The development of a SATCOM terminal is complicated compared to that of the commercial world of telecom. Industry standards exist for the implementation of a 5G system, creating consistent hardware across the market segments that adhere to a standard specification.

This unfortunately is not the case with SATCOM user terminals, where constellations don't have consistent performance requirements, physical hardware interfaces, waveforms, modems, or IF frequencies. This makes the job of a terminal developer challenging.

Fleets, militaries, and enterprises are increasingly demanding "always-on, everywhere" connectivity, raising the pressure for multi-band, multi-orbit capable terminals, for the right price. However, flexibility to support all possible constellations comes with increased cost. The job of the terminal developer is to find the optimal balance between cost, performance, and features.

Active electronically scanned antennas (AESAs) utilizing silicon mmWave ICs have emerged as the technology that can achieve the delicate balance of cost and performance. Silicon ICs used in Flat Panel AESA designs offer high performance, application flexibility and ease of integration, high energy efficiency and compelling economics.

Portable consumer terminals operating on LEO networks now allow connectivity in the most remote parts of the world.

(Image source: Adobe Stock #551556433; Starlink Terminal)

AESA systems follow a typical volume curve of cost decreasing with increased volume, very similar to other consumer electronics, where the best value comes from a flexible solution that can meet the needs across the constellations and market segments.

Several factors lead to the optimal AESA solution: scalability, antenna performance and cost flexibility, thermal performance and beamforming implementations.

## Scalability

GEO vs. NGSO (LEO, MEO and HEO) systems lead to different EIRP (Effective Isotropic Radiated Power, an indication of transmit power) and G/T (Rx antenna gain/system noise temperature, a measure of the quality of the receiver) requirements. AESAs are naturally a good technical solution as they are inherently scalable in size with the right design implementation. This is achieved through scalable sub-array building blocks to design systems that can be easily sized based on the application requirements.

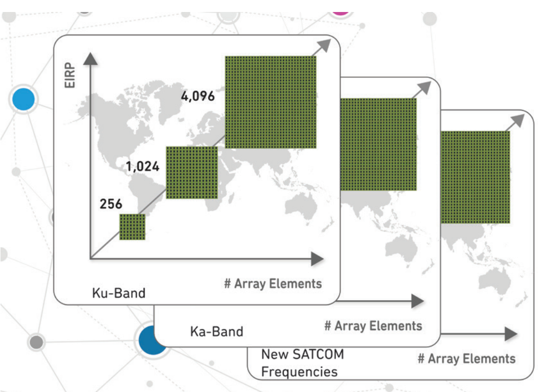



Figure 3: AESAs are inherently scalable in size with the right design implementation.

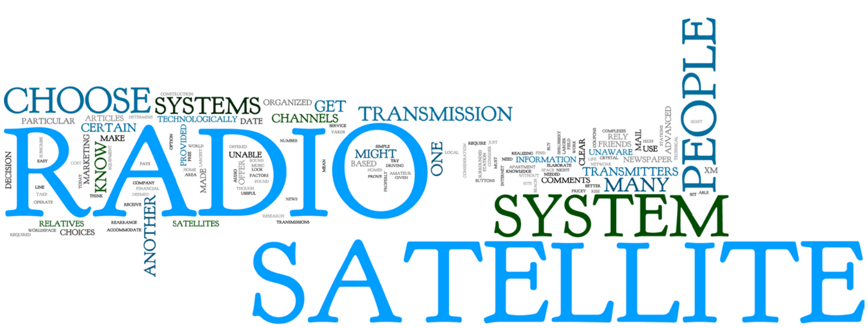



Figure 4: Market pressure exists for multi-band, multi-orbit capable terminals, for the right price. The job of the terminal developer is to find the optimal balance between cost, performance and features.

## Four Key Areas Drive Optimal AESAs:

- Scalability: AESAs are scalable in aperture providing flexible architecture.
- Antenna performance and cost flexibility: Achieved with polarization flexible Silicon beamformer ICs.
- Thermal performance: Stable amplitude and phase over temperature and ease of removing heat from the IC.
- Beamforming implementations: Make-before-break LEO connections are managed with inherent fast beam steering capabilities of AESAs.

## Antenna Performance and Cost Flexibility

**Performance:** System polarization, cross polarization performance, power spectral density (PSD) for transmit and sidelobe performance can be managed with flexible beamformer integrated circuits (BFICs).

The ability to generate and to control any polarization is imperative to support the varied system requirements. Electronically switching from dual linear to right- or left- hand circular polarization at Ku-band allows for interoperability across all constellations and orbits. Similarly switching from right- or left-hand circular polarization at Ka-band meets the same varied requirements of constellations and orbits. Angle based cross polarization management is required to maximize energy in the desired polarization while minimizing the cross-pole radiation for peak performance and to prevent interference when both polarizations are used on the satellite.

Array tapering (the process of assigning different gains to the various elements within the array, where the center elements are assigned the highest gains, and the outer elements are assigned lower gains) is required for PSD control on transmit to manage interference with adjacent satellites.

**Cost:** In multi-thousand element arrays, the cost of GaAs and GaN per $mm^2$ drives unaffordable solutions for high volume SATCOM terminal applications. Highly integrated silicon beamformer ICs provide a compatible size for easy integration within the array lattices at a cost that can be scaled to large volumes. Combined with new printed circuit board (PCB) material/manufacturing capabilities, lower cost is achievable and more importantly mass production is possible. Newer architectures based on commercially viable multi-layer PCBs with radiating elements on one side and surface mounted ICs on the other side have shown cost and performance viability because they are manufactured using existing technologies that are in place to build high volume commercial cell phone and WiFi access point products.[3]


Qorvo delivers Silicon-based SATCOM beamformer ICs in volume, in both Ku- and Ka-bands that meet the various AESA performance requirements with proven performance in commercially deployed SATCOM terminals.

- AWMF-0197: K-Rx SATCOM IC
- AWMF-0198: Ka-Tx SATCOM IC
- AWMF-0146: Ku-Rx SATCOM IC
- AWMF-0147: Ku-Tx SATCOM IC

All of these capabilities can be implemented with Qorvo designed analog silicon BFICs that support transmit and receive bands for Ku- and Ka- band Flat Panel AESA SATCOM terminals. The underlying architecture enables a single IC to support dual polarization feeds of four antenna elements. With features such as a single low voltage supply with integrated logic control, these ICs are easily integrated into large, phased array antenna terminals. Fabricated on a commercial silicon process designed for volume production ensures the perfect combination of performance and low cost.

## Thermal Performance

AESAs must be designed to support a wide range of temperature environments. Airborne user terminals are a great example of the temperature extremes over all terminal types and markets. They must operate on the tarmac where temperatures can reach well over 120°C with solar loading and at -46°C to -62°C when the altitude of the aircraft is over 40K feet.

This temperature range requires good thermal designs with stable electronics performance over temperature. BFIC architectures can be a significant driver depending on their implementation. Phase shifter circuits implemented with vector modulators will require significant amplitude and phase calibration across temperature as their performance varies with temperature. Qorvo avoids this implementation, by using propriety structures that have stable amplitude and phase performance over temperature.

## Dual Beam Implementations

A misconception in the industry is that SATCOM terminal receive ICs require dual beam implementations to support a make-before-break connection. As the use cases, technology and new orbits evolve, we see that the dual-beam architecture is not needed as the connections are managed within the network where AESAs can provide inherent fast beam steering.[4]

Low profile AESAs with high performance, using commercial manufacturing methods, and scalable in size will enable the satellite industry to mass produce antennas with electronically steerable beams in sufficient volumes to leverage the significant space resources being deployed.

Multiple tests, demonstrations and now operational consumer terminals have validated single beam architectures. Additionally, multi-beam implementations negatively impact satellite capacity, therefore none of the LEO providers currently support multi-beam handoff.

Instances exist of other terminal operators specifying simultaneous dual service for resilience or increased capacity. These applications are unique and sound good on paper but have their limitations. The cost for subscription fees to multiple simultaneous services can quickly become untenable and difficult to manage which service should be in use at any time or location. Some operators are starting to provide packages that combine LEO and GEO service, using a single beam, that automatically provides the best applicable service given location, available capacity, and user demand.

Bonding channels across services, which allows the service provider to deliver higher throughput, also comes with technical challenges given the overall network latencies. GEO and LEO systems are great examples where their propagation delay differences are significant. Additionally, among the different LEO systems, total path delays vary greatly depending on ground station location and possible implementation of inter-satellite links.

Single beam architectures in user terminals offer significant savings by removing the requirement to integrate a second analog beamforming network or to move to more complicated and costly digital beamforming to achieve the dual beam architecture. These savings are not only in the devices, but also in the complexity of the PCB, resulting increased power draw and increased thermal dissipation.

Why dual beam architecture is not needed in today's SATCOM systems

- Make-before-break connections are **managed within the network and enabled by inherent fast beam steering capabilities of AESAs** eliminating the need for dual beam architecture.
- Current LEO satellite systems in operation do not support make-before-break multi-beam handoff.
- Operators have moved to packages that combine LEO and GEO service for best applicable service - providing economic solutions to end users that do not require multi-beam solutions.
- Single beam architectures offer significant savings in complexity, power, and cost.

## The Optimal AESA Solution

After reviewing scalability, antenna performance and cost flexibility, thermal performance, and beamforming implementations of AESAs, it is apparent that commercial, high-volume terminals communicating with multi-orbit SATCOM systems require low-cost antennas with extremely fast steerable beams, designed with IC architectures that enable stable temperature performance and flexible polarization schemes. The Anokiwave CMOS based SATCOM beamformer ICs improve performance, reduce cost, simplify thermal management, and provide a host of unique digital functionality to simplify overall system design that enable the optimal AESA solution.

# Qorvo Enables High-Performance, Cost-Effective SATCOM User Terminals

SATCOM user terminals utilizing silicon technology have emerged as the technology that achieves the delicate balance of performance and cost.

Qorvo is the market leader and most experienced provider of silicon-based Ku and Ka-band beamformer ICs for flat-panel electronically steered antennas for multi-orbit SATCOM systems. Unlike other suppliers which have only recently begun to gravitate to silicon, Qorvo has multiple generations of its technology in volume production, enabling us to offer OEMs unparalleled application expertise, leading to better array designs and faster time-to-market.

Qorvo ICs are used in multiple terminal designs operating live satellite links globally, and their performance, cost-effectiveness and availability in volume enables customers to design, build and deploy SATCOM systems with confidence in their choice of ICs for commercial success.

*For investments in SATCOM infrastructure to realize a return, cost-effective access to the satellite signals is fundamental. Operators and terminal providers are in a race to reduce terminal costs, as the price to the consumer directly relates to the adoption of the service.[5]*

## Part 3 - Solutions that Enable Success

Qorvo is delivering high volume production beamformer ICs (BFICs) for SATCOM user terminals that support transmit and receive functions for Ku- and Ka- bands. The ICs are built on a commercial silicon process designed for volume production and are the key enabling technology making electronic beam steering in flat panel active antennas commercially viable at both volume and cost points.

The ICs are designed to support FDD (Frequency Division Duplex) operation, however they can also support TDD (Time Division Duplex) architectures covering global SATCOM Ku- and Ka- bands. The underlying architecture of the ICs enables a single IC to support four (4) dual polarization radiating elements with full polarization flexibility. Each channel has its own individual control of phase and gain for maximum flexibility.


Qorvo delivers silicon-based SATCOM beamformer ICs in volume, in both Ku- and Ka- bands with proven performance in commercially deployed SATCOM terminals.

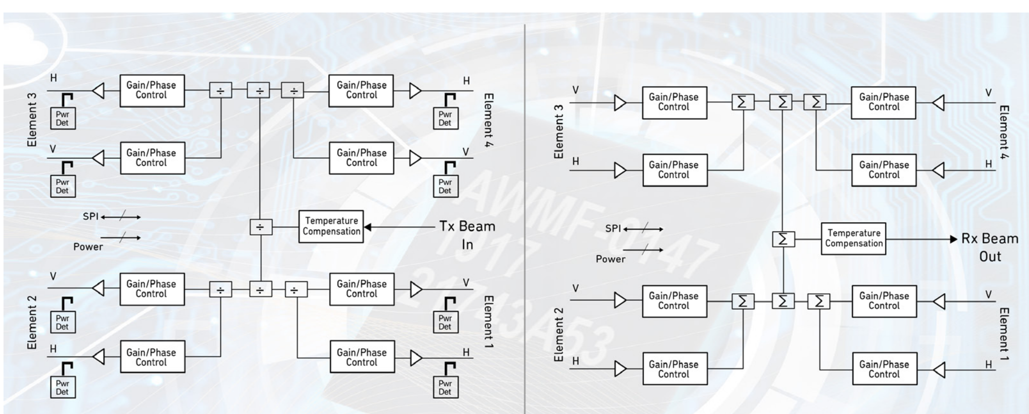



Figure 5: Qorvo's BFIC architecture supports four (4) dual polarization radiating elements with full polarization flexibility.

# Qorvo is Enabling Companies to Successfully Deliver AESA based Antennas

Qorvo is dedicated to enabling customer success with key innovations and tools for faster time to market with proven solutions.

A critical issue for many of our customers lies in the need to model and optimize SATCOM systems, requiring unique multidisciplinary skills spanning the RF, digital, thermal, and system requirements. Our advanced systems and antenna teams offer customers industry knowledge and insights for maximizing the performance of the ICs in the overall system.

The SATCOM array calculator, offered on our website, accelerates time-to-market for manufacturers by offering key advice in relation to antenna sizes, transmit power, receive G/T, scan volumes, and more.

Anokiwave's, now Qorvo's, customers have had great success implementing our BFICs into their terminals. The ICs have been demonstrated in multiple live satellite links globally, in multiple applications, across multiple constellations and in multiple orbits. Their performance, cost-effectiveness and availability in volume enables customers to design, build, and deploy SATCOM systems with confidence.

The following sections contain some of our customer success stories.

## Case Study 1: Smartellite™ Terminals[6]

Collaboration with our customer has enabled them to develop a low-cost voice, data and internet-of-things (IoT) family of terminals. They operate in either Ku- or Ka- bands and are compatible on multiple LEO (Low Earth Orbit), MEO (Medium Earth Orbit) and GEO (Geostationary Earth Orbit) constellations. The terminals can be easily used by individuals or by enterprises with a complete Network Management System (NMS). Using a dedicated app on any mobile device, users and organizations can freely communicate anywhere, anytime.

Over the 20+ years of delivering commercially deployed mmWave ICs, Anokiwave, now Qorvo, has the experience and understanding of commercial array development for deployable mmWave phased array antennas, unlike any other company, and is proven by the unique features of the ICs and tools that make our customers successful.

Our customer has successfully integrated the BFICs into their small form factor terminals that have been demonstrated on multiple GEO satellites and have achieved Ku-band compliance with FCC (US Federal Communication Commission) and ETSI (European Telecommunications Standards Institute) standards.

## Case Study 2: Modular, Scalable AESAs[7,8,9]

Our collaboration with our customer, a leader in creating innovative antenna solutions, has led to the development of modular, scalable Flat Panel AESAs to support a variety of applications and markets in the Ku- and Ka-bands. These AESA products are designed to support the rapid growth in demand for SATCOM terminals, including the proliferated LEO SATCOM constellations. Our customer has started high volume manufacturing with a global contract manufacturer already working in the communications products markets. The AESA architecture leverages the contract manufacturer's advanced manufacturing infrastructure and assembly processes, simplifying the production ramp and resulting in cost-effective manufacturing.[10]

Alaska Airlines have recently announced the use of Intelsat's AESA terminals to outfit regional jets with high-speed connectivity. Image Source: Alaska Airlines[11]

The units are fully electronic, have no moving parts or special materials, and are modular, allowing customers to meet their design and cost requirements.

These AESAs are found in many commercial products supporting multi-orbit capabilities, with in-flight connectivity (IFC) leading the commercial demand. The ability to use GEO in airline hub-cities for capacity and across the oceans is a great complement to the capacity of LEO and their polar coverage. This seamless, multi-orbit connectivity has been demonstrated using single beam receive technology.

A relevant example of airborne AESAs is found in Alaska Airlines recent announcement to use an Intelsat airborne user terminal to communicate with both traditional GEO satellites and new LEO satellites to offer streaming-fast satellite Wi-Fi on their aircraft.[11]

## Case Study 3: ESA (Electronically Scanned Antenna) SATCOM Terminals[12]

Our collaboration with a Sweden based customer who delivers fully integrated terminal solutions for LEO, MEO and GEO connectivity, has allowed them to develop a range of products to be used over multiple satellite constellations. The ESA family of products support both manpack deployable and SATCOM-on-the-Move (SOTM) terminals.

The terminals in this family provide full duplex communication and are capable of GEO, LEO and MEO operation with single beam fast switching and scanning. ESA terminals are provided in various levels of integration including up to a fully integrated terminal with embedded modem, Antenna Control Unit (ACU), beacon receiver, GPS, Inertial Measurement Unit (IMU) and up and down conversion. The ESA terminals can also be integrated with Wi-Fi and Cellular communications.[13]


Lightweight electronically scanned antennas at Ku- and Ka- bands, powered by Qorvo's SATCOM ICs, are delivering high performance, low-cost user terminals for manpack and SATCOM-On-The-Move.

# Qorvo is Commercializing AESA Antennas for SATCOM

Anokiwave's, now Qorvo's, success is determined by the successes of our customers. It's a philosophy engrained in our 20+ year history. Anokiwave, now Qorvo, saw the mmWave communications market coming and invested early in mmWave silicon ICs for phased arrays; our mission was to commercialize mmWave active antennas. Today, Anokiwave, now Qorvo, has multiple generations of SATCOM, Defense and Aerospace and 5G products in volume production.

The ability to service multiple market segments enables us to bring innovations from each market and apply them to our products. This allows us to continuously leverage developments in all of our market segments and to bring those developments into newer market segments, repurposing them for newer applications.

This ability to scale in volume across different market segments is good news for SATCOM terminal manufacturers. With a significant reduction in launch costs, improvements in satellite manufacturing, broad adoption of cloud computing and a growth in private capital fueling innovation, the SATCOM industry is poised to transform how a modern internet experience can be delivered on a global scale, and terminal providers need cost-effective solutions to make the connections to the satellites.[14] Qorvo's SATCOM ICs enable this exciting market with high-performance, cost-effective solutions for user terminals that are available in high volume today.

*The next generation of communication networks will combine terrestrial and satellite telecommunications, allowing us to be connected to everything, everywhere, at any time, and nearly any speed. Satellites and space technologies are instrumental to build and operate such future networks, offering unique advantages in terms of security, resilience, coverage, and mobility.*[15]

## Part 4 - Looking to the Future

Exponential growth in demand for ubiquitous connectivity and continued explosion of 5G use cases will result in a unified network infrastructure that incorporates terrestrial 5G networks and multi-orbit constellations to increase the scale and scope of access to communications networks.

In a 5G network, satellites are ideal to provide additional backhaul, to incorporate redundancy to critical segments, and to provide remote and rural areas with greater connectivity. The 3GPP standards body considers non-terrestrial networks (including high-altitude platform systems, drones, and NGSO and GEO satellites) as one area of expansion for 5G and has included support for non-terrestrial networks in both Release 17 and 18.

A common intersection of these trends is the need to support both types of systems with mmWave Flat Panel AESAs. Anokiwave, now Qorvo, has been in these markets for over 20 years. We have developed multiple generations of both SATCOM and 5G products, shipping in volume production that enable OEMs unparalleled application expertise. This allows our customers to develop better array designs with faster time to market as well as, and most importantly, the experience to support our customers who are expanding their networks beyond traditional 5G or SATCOM use cases.


Qorvo's mmWave Silicon and antenna technologies are enabling the future coexistence and convergence of terrestrial and non-terrestrial networks to increase the scale and scope of connectivity for all.

## 5G for Non-Terrestrial Applications

Approximately 40% of the world's population does not have access to efficient internet connections.[16] Only a small portion of that demand can be met through direct satellite connections, however there is a growing use case where the satellite connections are used for backhaul to support other communications services.

NGSO satellites will play a key part in extending cellular 5G networks to air, sea, and other remote areas not covered by small cell networks. For the end-user, satellites enable a seamless extension of 5G services from the city to airplanes, cruise liners and other vehicles in remote locations.

### SATCOM Joins the Telecom Market

The integration of non-terrestrial networks into the 3GPP 5G standards marks an opportunity for satellite service providers to rebalance their focus from providing proprietary solutions for a niche market to providing more integrated solutions for a mass market.[17]

A standard architecture for all communications opens opportunities for satellite service providers, ranging from backhaul and traffic unloading to mobile edge computing and connectivity services to mobile users.

Use cases are already beginning to demonstrate ways in which the coexistence and convergence of terrestrial and non-terrestrial networks will evolve. As with all new communications networks, new use cases will develop that are even beyond our imaginations of today.

### In-Flight Connectivity (IFC)

The In-Flight Connectivity (IFC) application is a good example that uses the satellite's large data throughput to service multiple users simultaneously. This use case is leading the commercial demand for SATCOM today.

What is the optimum use case for future communication networks like 5G and SATCOM?

"It's an exercise in futility as it will be clear once the infrastructure has been built out. Then entrepreneurs and innovators will come with new applications on top of the platforms, and that will create multiples of value compared to the infrastructure itself."[18]

A relevant example of the IFC use case is found in Alaska Airlines recent announcement to use an Intelsat airborne user terminal to communicate with both traditional geostationary (GEO) satellites and new low Earth orbit (LEO) satellites to offer streaming-fast satellite Wi-Fi on their aircraft.[19]

## Extending 5G Networks Beyond Densely Networked Areas

Another emerging application of network convergence is for 5G backhaul, for which LEO and MEO services are well suited given the low latency (20x improvement over GEO) and throughput capabilities, enabling better connectivity options in rural areas. This is a great complement, and many believe alternative to ground-based fiber connections.

As demand for connectivity continues to increase exponentially, satellites will need to serve areas outside highly networked cities for purposes such as connections on the move, critical emergency services, edge networking, and connected devices (IoT).

As demand for connectivity increases exponentially, satellites will serve areas outside highly networked cities for purposes such as connections on the move, critical emergency services, edge networking, and connected devices (IoT).

According to the Wilson Center, a US based policy forum group, an evolution of the underpinning technology and the business models of satellite companies make this integration both technically possible and economically feasible[20]

## Future Military Applications

The U.S. military wants to adopt 5G to improve communications from commanders to soldiers and military equipment in austere environments. For 5G networks to accommodate future military operations, however, some believe the infrastructure must include systems based on earth and in space.

"What 5G in space brings for us is the ability for us to disperse our forces as they move out in operations," said Brig. Gen. Jeth Rey, the director of the Network Cross-Functional Team at Army Futures Command, during a panel at the Satellite 2022 conference in Washington, D.C.[21]

To realize this goal, the U.S. Department of Defense (DoD) has announced funding to demonstrate 5G networks at military bases. These experiments serve as an indicator of how the military intends to use commercial technologies for fixed and mobile communications, which could shape future demand for space-based services.[22]

## New Generations of Solutions and Use Cases

As stated earlier, the optimum use case for future convergence and coexistence of terrestrial and non-terrestrial networks will happen once the infrastructure is built out. Many applications can be envisioned from smart cars to global shipping, all of which are driving volume demands that ultimately drive down the cost of user terminals utilizing Flat Panel AESAs. The integrated data roadmap across all these sectors is highly complex where we can envision a convergence of SATCOM with 5G to support the geographically and diverse data needs across the world. The figure below shows many examples of integration of SATCOM to all aspects of communications in our society.

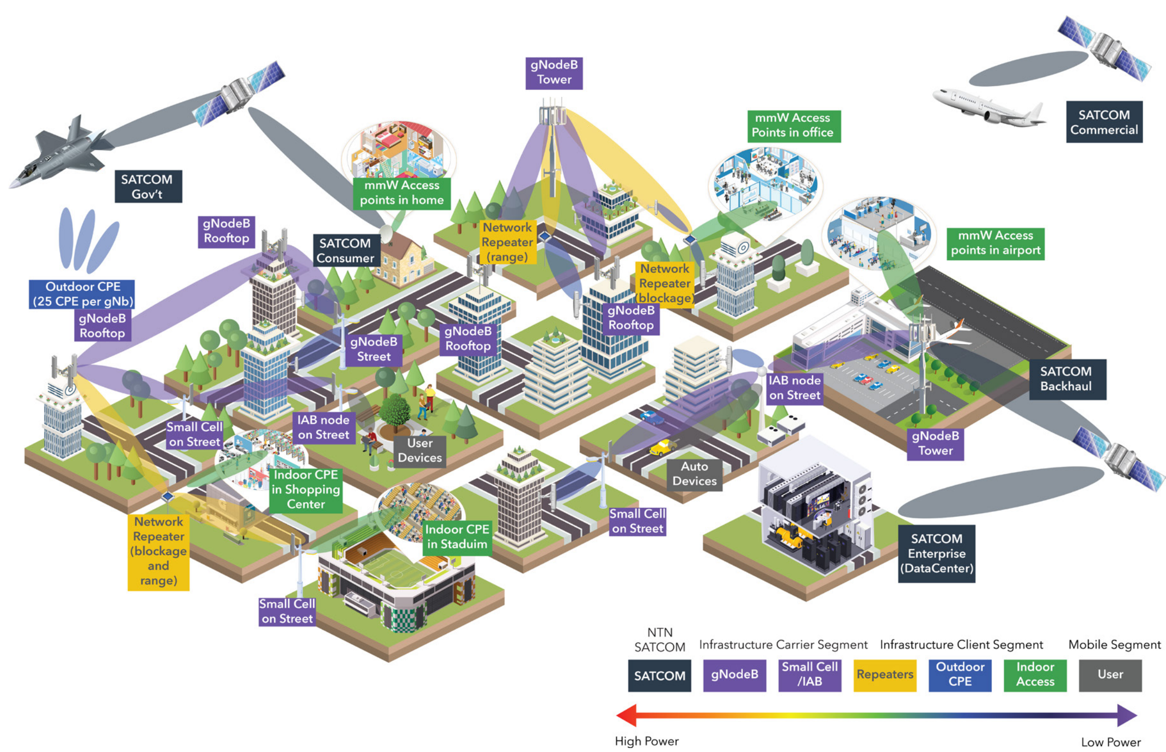



Figure 6: SATCOM integration with 5G and private networks is highly complex with many insertions and applications.

## Qorvo Enables the Commercialization of Coexistence and Convergence

As the market is converging to an integrated 5G network of networks, Qorvo continues to focus on delivering a high-volume manufacturing platform that provides the lowest cost and highest performance to meet market demand.

The Flat Panel AESAs used in the applications described in this paper can be implemented using Qorvo beamformer ICs (BFICs). We continue to innovate and develop new products to make these implementations easier, more cost effective and with improved performance. Our next generation of BFICs are pushing the limits of IC performance and cost curves to a new level, with similar architectures of prior generations to maximize existing designs. These advancements are demonstrated in our 4th generation 5G ICs which have been widely adopted by the major equipment manufacturers.

Through cutting-edge solutions and co-innovation with customers, we continue to make mmWave easy for OEMs as the trusted source of innovative solutions. Qorvo is dedicated to developing high-performance, highly integrated IC platforms in commercial volumes that are compact, cost effective and deliver faster time-to-market for our customers.

## Ubiquitous Connectivity

By looking at a complete overview of the SATCOM market drivers, how the market is defining the user terminals for the systems, how Qorvo enables SATCOM terminals and discussing the future of coexistence and new generations of solutions, we see the role the SATCOM market plays in creating ubiquitous connectivity for all

To achieve true ubiquitous connectivity, commercial, high-volume terminals communicating with multi-orbit SATCOM and 5G systems require low-cost antennas with extremely fast steerable beams, designed with IC architectures that enable a stable temperature performance and flexible polarization scheme. The Qorvo silicon based mmWave beamformer ICs improve performance, reduce cost, simplify thermal management and provide a host of unique digital functionality to simplify overall system design that enable the optimal AESA solution for ubiquitous connectivity with the most economical solution that makes the business case for operators and consumers commercially viable.

Anokiwave, now Qorvo, has been in these markets for over 20 years. We have developed multiple generations of both SATCOM and 5G products shipping in volume production that enable OEMs unparalleled application expertise. This allows our customers to develop better arrays with faster time to market as well as, and most importantly, the experience to support our customers who are expanding their networks beyond traditional use cases.

Anokiwave Is Now Qorvo

**About Anokiwave**

In 2024, Anokiwave was acquired by Qorvo. Anokiwave's innovative portfolio of active antenna ICs, combined with Qorvo's complementary products, global scale, and significant market reach, provide new options for high integration and high-performance that will democratize phased array active antennas.

The two companies' technologies enable a unique combination of innovation + commercial scale + reputation to deliver with proven commercial success across mmWave 5G, SATCOM and D&A markets.

- mmW Silicon ICs
- Intelligent Array IC Solutions®
- mmW Algorithms to Antennas®

# Endnotes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