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everythingRF

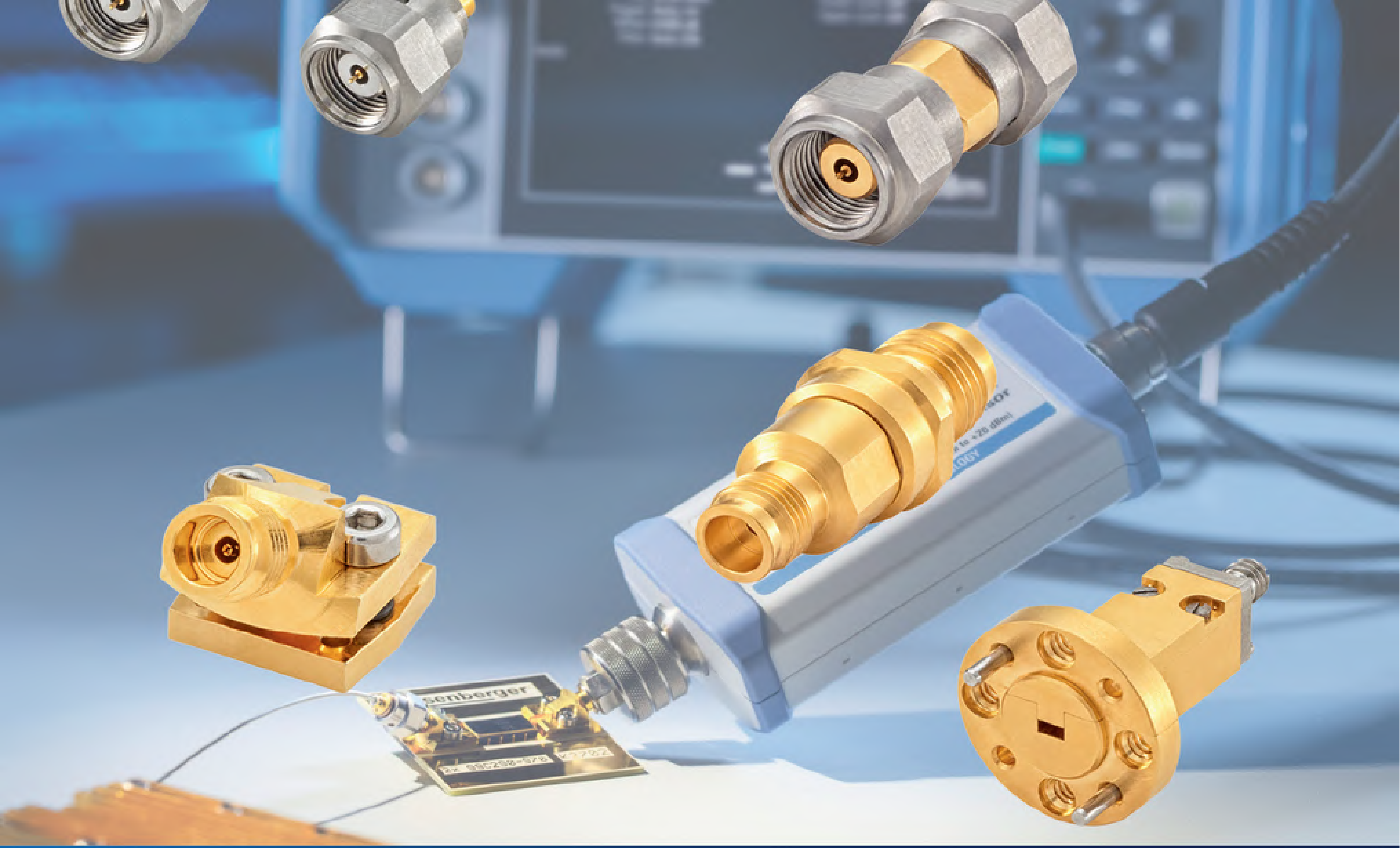
Keeping you up-to-date with the RF & Microwave Industry

ARTICLES ▪ PRODUCTS ▪ INTERVIEWS

SECTORS COVERED

- Aerospace & Defense
- Satellite & Space
- Test & Measurement
- EMC Testing
- Wireless Infrastructure
- Cables & Connectors
- 5G & IoT
- GNSS
- Crystals & Oscillators
- Waveguides

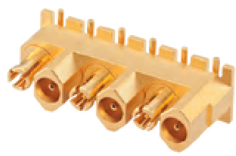
2024
ISSUE 1



Test, Measurement & Calibration

RF and microwave components from Rosenberger play a key role in a variety of test, measurement and calibration applications. RF high precision connectors, adaptors & devices, PCB connections, calibration kits, microwave test cables or VNA test port cables – the precision and quality of Rosenberger test and measurement products have been proven in various applications:

- Microwave measurements and VNA calibrations
- Lab testing, factory testing
- PCB connections
- Semiconductor test applications and high-speed digital testing
- Network testing
- Test and measurement equipment and devices



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FEATURED PRODUCTS

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INTERVIEWS

Aerospace & Defense

Featured Products

Simplify your processing system with direct RF up to 18 GHz

Electronic warfare, radar and SIGINT applications demand direct RF solutions that deliver low-latency, fast data processing for critical real-time decision-making. The DRF3182 3U OpenVPX board offers direct RF wideband data capture with heterogeneous FPGA processing, explosive 51.2 GSPS A/D & D/A speeds, 2-18 GHz Ku band frequencies and six 100 GbE interfaces with an aggregate throughput of 75 GB/sec.
Mercury Systems

Nuvotronics Game-Changing 80W, 4 Way and 2 Way, Power Combiners

Nuvotronics has started sampling 2-Way and 4-Way power combiners based on PolyStrata® Technology. These combiners represent a game-changing performance enhancement over traditional waveguide combiners in terms of size and ease of assembly. The form factor can be up to 100x smaller with PolyStrata® Combiner while maintaining an extremely low insertion loss. They cover the frequency band from 6-18 GHz, 18-40 GHz as well as Ka and Q Band.
Nuvotronics

Digital C-band Radar Transponder Series

The Digital Radar Transponder is a miniature device that enhances the capabilities of tracking radars enabling precision tracking of aircraft, rockets, missiles, and UAS. Delivering high performance at low cost, this solution offers programmable features, such as receive and transmit frequencies, delay, and code spacing. It is available in a range of transmit power outputs, including 50W, 100W, 200W, and 400W.
CAES

Integrated vehicle solutions

V-Track is a fully integrated, multi-mission system with DF, spectrum monitoring, RF recording and signal capture, and geolocation capability. The vehicles support access to real-time RF intelligence, and operators have secure connectivity, allowing rapid, secure, and controlled access to information over wireless transport in the field. V-Track is a quickly deployable system that integrates with drones for ISR, supporting joint land / air missions.
CRFS

ERZIA Wideband Power Amplifier

The ERZ-HPA-0200-2000-44 is a wideband amplifier that operate from 2 to 20 GHz. It provides an output power of 42 dBm with a gain of 51 dB. The amplifier is based on GaN technology and requires a DC supply of 28 V. This compact module is ideal for a wide range of applications including Industrial/Laboratory, Satcom, Telecom, Space, Aerospace, Military.
ERZIA

High-Performance Lightweight Filters

RLC Electronics' "*Weightless Filter*" series is founded on high-Q cavities and engineered to provide premium RF performance. These new miniaturized filters boast a low insertion loss (typically 0.6 dB max) and excellent power-handling capabilities, up to 60 Watts CW. This particular filter measures 0.8"x 0.46"x 0.46" and has GPO connectors to save space and eliminate the need for cables at the system level. It has been used in a family of antennas that is part of a radar system.
RLC Electronics

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Radar systems are growing into multi-function, multi-mission systems that need to be contained in the smallest possible footprint.

Knowles Precision Devices' DLI Brand of RF and Capacitor components are designed to address your SWAP-C challenges by leveraging our decades of Aerospace and Defense expertise in:

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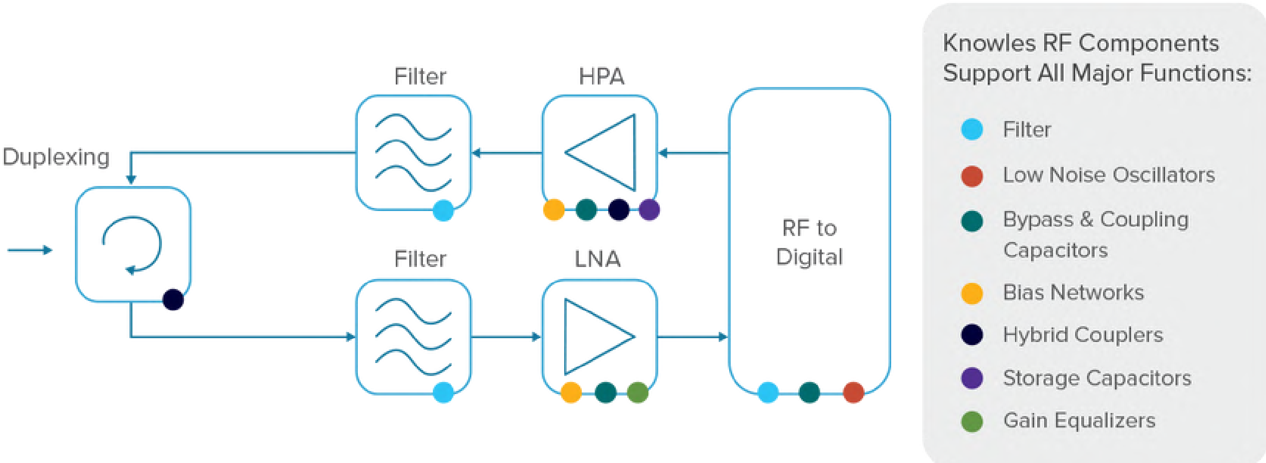
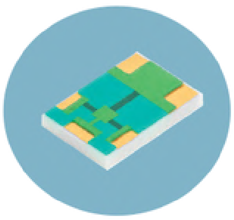
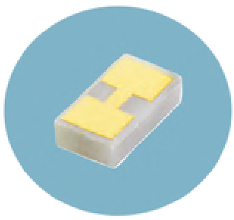


RF and Capacitor components have always played a key role in the success of radar systems as they have evolved over the years. At Knowles Precision Devices, we work closely with you to identify the filter solution you need to meet the challenges you face today.



Solid State GaN Power Amplifier Module

The dB-8015 is a Microwave Power Amplifier module that operates in the 2.0 to 18.0 GHz frequency band, delivering 200 Watts output power in CW operation at midband. This compact form-factor MPM comes in a liquid-cooled package. It's designed for wideband and high-performance MIL-STD apps such as EW, ECM and multi-band coms systems where high reliability is critical to system performance. Prime input voltage required is 28 VDC,270 VDC or 3-phase 400 Hz.

dB Control, Inc.

20 watts / 2 GHz - 18 GHz Wideband RF Amplifier

Elite RF's MB2.0018G434822 is a wideband Class AB RF Power Amplifier, fabricated with GaN on SiC process. The amplifier operates from 2 GHz to 18 GHz, providing 20 W of saturated power with 48 dB small signal gain with a 22 VDC supply input. It is ideally suited for wideband communications systems, electronic warfare, test instrumentation and radar applications across both military and commercial markets.

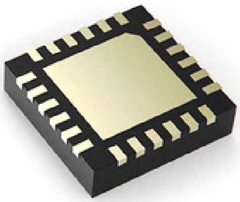
Elite RF

COTS RF High-Pass Filter

The HPF-3000-18000-SS11 is an 11-pole suspended substrate high performance broadband high-pass filter. It has an cut-off frequency of 3000 MHz with a pass-band from 3000 to 18000 MHz and an insertion loss of 1.5 dB. The filter provides over 30 dB of rejection from 100-2600 MHz and has a VSWR of 2:1. It is available in a module that measures 0.50"x 1.150"x 1.625" and has SMA connectors.

COTS RF, LLC

MMIC Low-Phase Noise Amplifier Covers 0.01 to 26.5 GHz



Mini-Circuits' LVA-273PN+ is a GaAs HBT distributed MMIC amplifier specially designed and characterized for applications with low additive phase noise requirements. This model covers the entire 0.01 to 26.5 GHz frequency range with -172 dBc/Hz additive phase noise at 10 kHz offset, +18 dBm P1dB and +28 dBm OIP3. It ideal for use with low-noise signal sources and highly sensitive transceiver signal chains in radars, EW and ECM defense systems.

Mini-Circuits

SOSA-Aligned Microwave Transceiver for EW Applications

This 1-18 GHz Channelized Receiver from Quantic PMI has a broadband input with 20 output channels for surveillance applications with copious transmission signals present in various frequency bands at any given time. The receiver limits the noise to help identify low-power signals without compressing output power for the higher power signals. The 20 output channels allow simultaneous signals of 80 MHz in a 1 to 4.4 GHz IF Band to be output for digitization.

Quantic PMI (Planar Monolithics)

Space Qualified Beamformers

Crane designs & manufactures high performance space qualified beamformers for defense & commercial satellites. They have a vast library of heritage passive designs that can support frequencies from DC thru Ka-Band. Their Multi-Mix® fusion bonding process reduces the size and weight of complex designs by vertically integrating multiple functions into one multilayer package.

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Per Vices Corporation

Challenges and Solutions in Implementing Software-Defined Radios (SDRs) for Radar

Brandon Malatest - Per Vices

Introduction to Software-Defined Radios (SDRs) for Radar

Software-defined radios (SDRs) have revolutionized the field of radar systems by offering unmatched flexibility and adaptability. Unlike traditional radar systems that rely on dedicated hardware components for signal processing, SDRs utilize software algorithms to perform signal processing tasks. This software-centric approach provides numerous advantages in radar applications. SDRs offer enhanced reconfigurability, allowing for rapid changes to waveform parameters and adaptability to different operational scenarios. They also enable improved spectrum utilization by implementing dynamic spectrum access techniques, which optimize the use of available frequency bands. Furthermore, SDRs facilitate simplified system upgrades, as software updates can be applied to improve performance or introduce new functionalities without the need for hardware modifications. Overall, SDRs provide a flexible and efficient platform for radar systems, enabling advancements in performance, adaptability, and operational capabilities. Per Vices SDRs, in particular, have emerged as a leading solution for radar applications due to their exceptional performance and advanced features. These SDRs leverage cutting-edge technology to provide significant advantages in terms of signal processing, hardware capabilities, interoperability, and system integration.

Signal Processing

Signal processing in SDR-based radar systems presents specific challenges that need to be addressed to ensure optimal radar performance. One significant challenge is signal distortion caused by multipath propagation, frequency-selective fading, and clutter echoes. These distortions can lead to errors in target detection, range estimation, and angle measurement. To mitigate these effects, advanced signal processing techniques can be employed. Adaptive filtering algorithms, such as least mean squares (LMS) and recursive least squares (RLS), adaptively adjust the filter coefficients to suppress interference and mitigate the impact of multipath propagation. Digital beamforming techniques help improve spatial resolution and target localization by optimizing the array antenna's radiation pattern. Moreover, interference cancellation algorithms, such as blind source separation and adaptive interference rejection, can mitigate the effects of strong interfering signals. To combat noise, efficient error correction coding schemes and robust modulation techniques, such as orthogonal frequency division multiplexing (OFDM), can be employed to maintain a high signal-to-noise ratio (SNR) and improve detection performance. Per Vices SDRs excel in signal processing, addressing the specific challenges faced by SDR-based radar systems. Leveraging state-of-the-art digital signal processing algorithms, Per Vices SDRs effectively mitigate signal distortion, interference, noise, and dynamic range limitations. These advanced signal processing capabilities ensure accurate and reliable radar performance, enhancing target detection, range estimation, and angle measurement.

Hardware Advancements

While SDRs offer significant advantages in flexibility and adaptability, they also come with certain hardware limitations that can impact their implementation in radar systems. Processing power is a crucial factor, as complex signal processing algorithms and real-time data processing require substantial computational capabilities. The limited processing power of some SDR platforms can introduce delays in data processing, impacting radar


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system performance. Memory constraints also pose challenges, as large amounts of data need to be stored and processed in real-time. To address these limitations, advancements in hardware technology are vital. High-performance processors, such as field-programmable gate arrays (FPGAs) and digital signal processors (DSPs), can be utilized to enhance processing capabilities. Increased memory capacity and bandwidth, along with efficient data storage and retrieval mechanisms, are essential to handle the large volumes of data in radar systems. Low-latency interfaces and high-speed data buses ensure efficient data transfer between hardware components, minimizing delays and improving system performance. Per Vices, SDRs boast cutting-edge hardware capabilities that address the limitations typically associated with SDR platforms in radar applications. Equipped with powerful field-programmable gate arrays (FPGAs), Per Vices SDRs provide exceptional processing power necessary for real-time signal processing and data handling in radar systems. The high bandwidth offered by Per Vices SDRs facilitates the storage and processing of large volumes of radar data, ensuring efficient operation. Low-latency interfaces and high-speed data buses, such as the 10G/40G/100G interfaces offered across Per Vices SDRs, enable seamless data transfer between hardware components, minimizing processing delays and maximizing system performance. These hardware advancements enhance the overall capability and responsiveness of SDR-based radar systems.

Interoperability and Standardization

The integration of SDRs into radar systems presents challenges related to interoperability and standardization. The wide variety of SDR devices and components available in the market can lead to compatibility issues when integrating different devices from different manufacturers. To overcome these challenges, a combination of industry standards/protocols and the ability to modify the SDR to easily integrate into existing radar systems play a crucial role. Standardization efforts provide a common framework for SDR interoperability while the flexibility associated with the FPGA on-board SDRs provides the ability to make modifications to adhere to interface control requirements. Per Vices SDRs prioritize interoperability and ease of integration, making them an ideal choice for radar systems to reduce the overall complexity, costs, and time to market. This facilitates collaboration, simplifies technology upgrades, and promotes system expansions.

Additionally, Per Vices actively participates in industry discussions and standardization efforts, contributing to the development of common frameworks that promote interoperability and ensure the seamless integration of SDR-based radar systems.

System Integration and Complexity

As mentioned above, integrating SDRs into existing radar systems can be a complex task, especially when dealing with legacy infrastructure. Legacy systems often operate on different hardware architectures, use proprietary interfaces, and employ legacy protocols. Achieving seamless integration requires careful consideration of hardware-software compatibility, legacy system upgrades, and migration strategies. Modularity and flexibility in the design of SDR platforms are essential to facilitate integration. Compatibility layers, interface converters, and adapter modules can be utilized to bridge the gap between legacy systems and SDR-based radar solutions for service life extension programs (SLEPs). Close collaboration between radar system designers and SDR manufacturers is vital to address integration challenges and ensure successful system upgrades. Additionally, system architects must consider the impact of integrating SDRs on the overall system performance, taking into account factors such as power consumption, size, form factor, and data synchronization. Per Vices SDRs excel in system integration, simplifying the process of integrating SDRs into existing radar systems. Their modular design and compatibility layers enable seamless integration with legacy infrastructure. These integration support features minimize the complexity involved in SLEPs, ensuring hardware-software compatibility and promoting a smooth transition.

The collaboration between Per Vices and radar system designers further facilitates successful integration, ensuring compatibility with existing infrastructure while unlocking the full potential of SDR technology.

Testing and Validation

The testing and validation of SDR-based radar systems are critical to ensure reliable and accurate performance. Comprehensive testing methodologies are required to verify the correct implementation of signal processing algorithms, assess system behavior under different operating conditions, and evaluate the overall system performance.

It is highly beneficial to have SDR platforms that include both the hardware and software features to enable testing of the system. Per Vices, SDRs prioritize comprehensive testing and validation to ensure the reliable and accurate performance of SDR-based radar systems. They provide a range of testing modes of operation and interfaces. These characteristics help optimize signal processing algorithms, assess system behavior under different operating conditions, and ensure robust performance.

Field testing with Per Vices SDRs validates system performance in real-world scenarios, considering factors such as environmental conditions, interference sources, and target characteristics. Thorough testing and validation ensure accurate signal generation, transmission, reception, and processing, leading to reliable radar operation and trustworthy detection and tracking capabilities.

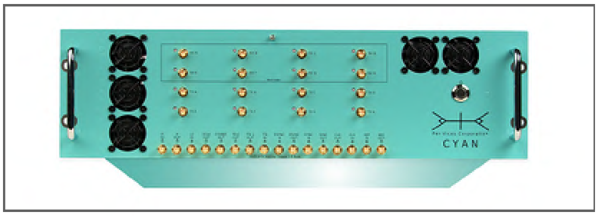


Figure 1. Top of the Line Per Vices Cyan SDR

Future Directions and Solutions

Per Vices remains committed to advancing SDR technology for radar systems, offering future-oriented solutions to overcome challenges in implementation.

These solutions encompass ongoing hardware advancements, software algorithm enhancements, and active participation in regulatory frameworks. Per Vices continues to improve hardware capabilities by leveraging advancements in FPGA and DSP technology, providing even more processing power and memory capacity. Software algorithm enhancements further unlock new capabilities in adaptive waveform selection, cognitive radar, and multi-function radar systems.

In conclusion, the implementation of Software-Defined Radios (SDRs) in radar systems offers significant advantages in terms of flexibility, reconfigurability, and spectrum utilization. While challenges exist in signal processing, hardware limitations, interoperability, system integration, and testing, continuous advancements in technology and collaborative efforts within the industry are driving solutions to address these challenges. Per Vices, SDRs offer exceptional signal processing capabilities, advanced hardware features, interoperability, and system integration support to ensure the delivery of unmatched advantages for radar system implementations. By leveraging Per Vices SDRs, radar systems can achieve superior performance, enhanced flexibility, and future-proof solutions. These SDRs empower radar systems to maximize their efficiency, adaptability, and capability, revolutionizing the field of radar technology.

Interview with Dean Handrinos from Triad RF Systems

everything RF recently interviewed Dean Handrinos who is a co-founder and current co-Managing Director at Triad RF Systems. Dean is responsible for setting the strategic direction and management of the Sales, Engineering, and Product Development groups within the organization.

Q. Triad RF Systems is well-known for its work in the defense and aerospace markets. How did Triad enter the CubeSat market?

Triad has been in business since 2013 when the company was initially founded to bring new thinking around the design of high-power RF systems for Software Defined Radios (SDRs). Triad High Power Radio Systems (THPRs) are commonly integrated into products for military use. The bulk of our experience resides with amplifying MIMO radio systems that have recently become mainstream in the defense space. Designing amplifiers for these systems presents unique challenges and tradeoffs that our engineering team felt they could really take on, and there was clearly a market need for these types of products based on our success so far.

Even though our initial focus and market push was with applications and customers in defense, our products are radio agnostic and can be used for many applications where long-range RF links are necessary for communication or data and sensor information transmission.

This eventually led to companies within the growing commercial space industry ecosystem, including launch service providers, satellite design teams, government research agencies, and others in need of Triad's product solutions for long-range RF links. All of these customers consider Triad a trusted resource and partner in solving difficult radio communication issues including weight restrictions, large bandwidth needs, and energy efficiency.

Q. So, Triad's entry into the CubeSat market wasn't planned from the start?

I would say it was a lucky accident that we had off-the-shelf products that fit into the use case needs of customers within this market. Once we started meeting with these companies and teams, we became very intentional with how we approached the market.

Our first customer in the CubeSat market was actually a launch provider looking to build out and expand their worldwide network of ground tracking stations, enabling better telemetry links with the hundreds of satellites that they manage. That first experience really opened Triad RF up to the possibilities available in this market, as we began to notice that radio links in the CubeSat / SmallSat market faced similar technical challenges that we had spent years solving for our unmanned systems customer base.

Our next opportunity in the CubeSat market came when another company approached us to help design compact, efficient bi-directional amplifiers for

their future satellite constellations, after hearing about what we had accomplished with our extremely long-distance ground station bi-directional amplifier capabilities.

I don't want to oversimplify what was actually a pretty intense engineering partnership, but this is where we had the realization that the software-defined radios used in the CubeSat market are very similar to the software-defined radios (SDRs) we already had extensive experience integrating within the military market. That's when we realized there was something here for us and we could help a lot of design teams bridge these tricky communication challenges where failure isn't an option.

Since then, we've shipped thousands of BDAs, power amplifiers, frequency-translating amplifiers, and other RF subsystems for the CubeSat market which have now accumulated a collective 18 years of use in LEO.

Figure 1. Triad RF Systems bi-directional integrated microwave assembly (IMA) that includes an integrated amplifier and custom radio front end to integrate with Software Defined Radio Systems

Q. What type of products do you specialize in for the CubeSat market? Is the product mix different from the rest of your offerings?

We consider Traid's core specialty as focusing on radio range extension for defense and aerospace applications, in this case, satellites.

Even though it looks like a simple straight shot from orbit to a ground receiver, the signal has to travel for hundreds of miles, pass through several distinct layers of the atmosphere, weather phenomena, and a blanket of other RF transmissions that will raise the noise floor for any incoming signals. Our goal is to mitigate these challenges and help CubeSat companies design the best spacecraft they can to complete their mission obligations.

We have built a substantial amount of goodwill with these customers; they let us worry about the difficulties of long-range, amplified RF communication. We then design the specific components and subsystems to close the links.

For RF range extension, Triad RF products include power amplifiers and bi-directional amplifiers to help enhance the satellite's RF link budget. Allowing the radio to transmit at a higher power improves signal-to-noise ratios, and helps overcome difficult atmospheric conditions. All of these factors combine to yield comfortable radio link margins, which translate to radio links that simply work, and have high availability.

This is a major simplification of the entire process, but there are tradeoffs that can be made by increasing transmit power, receive sensitivity, using a larger antenna, or utilizing different data modulation techniques. We help our customers understand all of the levers that they can pull to get the best performance out of their system without using excessive power.

Triad RF Mixers and frequency conversion products have been popular as well, allowing satellite systems and radios designed for a specific frequency range to be utilized on a different band. This can be desirable if the radio operates at one frequency but the satellite's radio license is for another band, allowing for one platform to be utilized for different applications as just one cost-saving example. It takes an enormous effort for a satellite vehicle manufacturer to design, qualify, and field a radio system in this market. Our customers avoid starting from scratch when they need to operate in a different band, instead we can design an add-on frequency-translating amplifier module to enhance that existing radio's capability.

We also combine these into complete microwave assembly kits for customers, giving them a single drop-in solution to help manage several related RF subsystems together.

Q. How is designing products for the Cubesat market different from the types of applications you're known for in the defense industry?

There are a few factors that converge together to make things a little more complicated when you're designing for space-based applications.

These include handling the extreme hot and cold cycles the satellite and components will go through as they complete each orbit, and designing systems that can effectively deal with waste heat, radiation hardening, and component life issues. Hardening components against damage from radiation is also a factor for satellites that will be in orbit for decades, as is managing power use and solar generating capacity.

Let's start with waste heat dissipation, as it's one of the unique complicating factors in space. It's much harder to dump excess heat in space than it is within the Earth's atmosphere. Cooling electronics within the atmosphere is achieved through three primary means:

1. Conduction, using a physically connected surface like a heat sink to remove waste heat.
2. Convection, using airflow or liquid coolers to assist in the removal of waste heat.
3. Radiation, where excess heat is converted to infrared energy that is radiated off of the spacecraft.

For ground-based or in-atmosphere airborne applications, simply having a heatsink on the amplifier is often enough to bleed off any excess heat into the air. For applications that generate more heat, the air moving across an exposed heatsink or forced air cooling via fan is enough to keep products at their desired operational temperature range.

Due to the lack of atmosphere in space, conduction and convection are unavailable as there is no air to absorb and transfer away waste heat.

Radiation is the least efficient of these methods, but is the only one available, so system designers need to think through this when planning the heat load caused by various components of the satellite. Additional complications also arise from the satellite moving through a complete orbital period around the Earth approximately every 50 minutes, exposing the craft to temperature extremes from -60 to 125 degrees C which must also be managed with other environmental inputs and outputs.

Another significant challenge is dealing with the physical size constraints of CubeSats. Size, weight, and power, or as we call it "SWaP", are the primary considerations. Launching anything into space is costly, and therefore minimizing weight is crucial. CubeSats can range in size from a 4x4 inch cube to something the size of a 20-gallon fish tank. There's a limit to how many solar panels can be added for power and how much battery capacity is available for storage, so power management is another really big focus for us.

When the radio and amplifier turn on to transmit, they'll be the most energy-intensive part of the craft. That has to be carefully managed to not only preserve system power for other needs but also to protect other electronics in the system from interference when these are turned on.

Q. Can you expand upon radiation more? Ground robots were sent to explore nuclear accidents such as Fukushima and Chernobyl, only to be disabled by radiation. How is this handled in space?

Thankfully radiation in space isn't nearly as intense as it is inside a nuclear reactor, so it's a much easier problem to deal with.

For larger, long-life satellites such as you'd see with DirectTV or GOES weather systems, they are expected to stay in orbit for many years or even decades in some cases. Those systems will generally have component-level hardening against radiation to ensure long-term survivability.

For CubeSat applications, the mission lifetime and thus the expected product lifetime is much lower, often in the range of just a few months or years. These products are not designed for the same level of radiation as longer-mission length, non-LEO satellites. Radiation mitigation for these products has been very straightforward for our team, and we've developed product testing and screening methods as part of our typical QA process to make sure our parts and subsystems meet our customer's expectations. Parts used in a CubeSat subsystem don't necessarily have to all carry space-grade certifications. However, there is still a fairly involved process in parts selection, via prior LEO flight heritage, or via other means of proving reliability where MIL-STD-883 or MIL-PRF-38534 screening may not be necessary (or doesn't exist) for certain parts.

Q. What are the biggest issues you typically see among CubeSat customers who are trying to think through their RF communication system?

One of the biggest challenges I see customers facing is just how new, relatively speaking, the actual "Cubesat industry" is. The vendor landscape is not fully mature, platform standardization is still underway, and new government organizations and commercial companies are entering the market all the time.

It’s really not that dissimilar to the growth we saw in the unmanned systems market over the past decade, when a lot of different companies entered with their own ideas on how to best serve the market. It takes a bit of time for the market to sort out which ideas will gain traction.

So we wind up doing a lot of education with customers and working with them to discover what their actual challenges are, because often the company itself is pretty young and the design team doesn’t yet know what they need specific to RF communication.

Another issue is that because the industry is so nascent, sometimes a product solution literally doesn’t exist and has to be engineered for a specific use case, so we help walk customers through those issues as well.

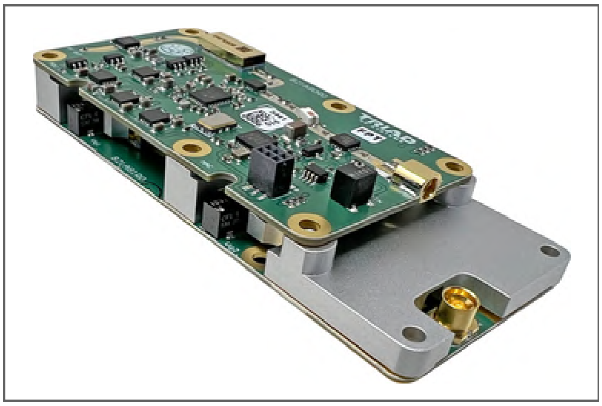


Figure 2. Triad RF Systems Frequency-Translating Amplifier module which converts incoming or outgoing signals from one frequency band to another frequency band used by the Software Defined Radio.

Q. Where do you foresee the future of the CubeSat industry?

Well, the pattern I've noticed started about a decade ago. It reminds me of the early computer age when everyone was trying to find the perfect application for all of this new processing power. We're at a similar stage where we're figuring out what specific functions these devices can best serve.

Companies are finding unique niches for these systems. For example, they're developing ways for oil companies to relay telemetry data from their wells using small pucks and CubeSats. This could present an alternative to more costly, incumbent services like Iridium and Inmarsat.

Q. So, do you think the industry is evolving to shake out and let successful companies emerge?

Absolutely, but while financial aspects can affect the number of players, the industry is also constantly finding new applications. For instance, one of our customers built a network to pick up transponders from ocean-going ships, providing more granular, near-real-time tracking. Another agency was using satellites to enhance weather models by analyzing radio signals passed through cloud formations. Such applications were unknown just a few years ago, or were too expensive to carry out by smaller companies. I think we’ll see much more creative thinking as the market continues to mature.

Q. Is there anything else you’d like to share with our readers?

We’re thrilled to be part of this growing market and to help our customers turn their systems into reality! If you’d like to discuss your CubeSat needs and challenges with us in more detail please contact our engineering experts.

About Triad RF Systems

Triad RF Systems is a leading designer and manufacturer of high-power radios, RF/Microwave bi-directional amplifiers, custom multi-functional amplifier systems, and power amplifiers with decades of accumulated expert knowledge of what is required to design, manufacture, and service RF/Microwave amplifiers and integrated radio systems challenging environments.

Test & Measurement

Featured Products

R&S MXO 5 oscilloscope with 8 channels

R&S MXO 5 oscilloscopes show more of a signal's activity in both time and frequency domains than any other device. They are the world's first 8-channel oscilloscopes with 4.5 million acquisitions/s and 18 million waveforms/s across multiple channels. Digital triggering on all 8 channels and 45,000 FFTs per second allow engineers to tackle ever more demanding design challenges.

Rohde & Schwarz

Real-time Spectrum Analyzer for 5G Networks

SPECTRAN® V6 5G is a real-time spectrum analyzer specifically for monitoring 5G networks (FR1 + FR2). It detects even the shortest signal interference or performance degradation. It has a scanning speed of up to 3 THz/s, making it the fastest USB spectrum analyzer in the world. The modular RTSA-Suite PRO software allows to exactly choose the needed software extensions. SPECTRAN® V6 5G - Made in Germany.

Aaronia AG

Multi-probe Near-field Antenna Test System for Spherical Measurements

The SG Evo is a multi-probe near-field antenna test system to provide high-precision measurements for a wide range of antenna applications such as on satellites, aircraft, or vehicles. Its unique design introduces sampling in elevation via rotation of the arch, allowing the DUT to turn only in azimuth and avoid gravitational deflections of the DUT. The SG Evo operates in an anechoic chamber with instrumentation and dedicated software.

Microwave Vision Group

14.5 GHz, Compact Real-time Spectrum Analyzer

Meet Signal Hound's latest analyzer, the USB-C powered SP145. A high-performance, 14.5 GHz real-time spectrum analyzer and monitoring receiver, the SP145 features sweep speeds up to 200 GHz/sec, 40 MHz streaming bandwidth, -160 dBm displayed noise average, and an internal GPS for enhanced field measurements. The SP145 is your ideal RF analysis companion in the field and at the lab.

Signal Hound

Boonton Real-Time USB Peak Power Sensors

Providing the highest video bandwidth and fastest rise times, RTP5000 Real-Time USB Peak Power Sensors with Boonton's Real-Time Power Processing™ deliver 100,000 measurements per second, virtually no gaps in signal acquisition and zero measurement latency. These sensors are the ideal instrument for fast, accurate and reliable RF power measurements.

Boonton

2-Port 8.5 GHz Vector Network Analyzer with Advanced Features

The S5085 VNA delivers lab-grade performance in a portable package. Advanced analytical features are included in the software, which can be downloaded for free anytime. It can be battery powered and used in the field, laboratory, or production testing. CMT's software can be installed on multiple computers using Windows or Linux OS, making it easy to share the use of the analyzer measurement module.

Copper Mountain Tech

Vaunix USB Programmable Lab Brick Signal Generator 500 MHz - 40 GHz

The Vaunix BLX-403 Lab Brick is a portable signal generator operating from 0.5 to 40 GHz with 100 Hz resolution, 5 ms switching time, and 10 dBm output power. With advanced features like frequency sweeping, 10 MHz reference, and pulse modulation, it offers excellent phase noise. Programmable via USB or Ethernet, it suits handheld, benchtop, or rack-mounted use. In a durable 6.5" x 3.64" x 1.0" aluminum case, weighing 1.5 pounds, it's ideal for L, S, C, X, Ku, K, and Ka-band applications.

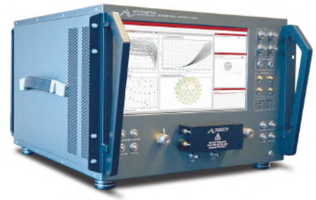
Vaunix

8x8 Butler Matrix from 2.4 to 8 GHz

The RI 3101 Butler Matrix is a 8x8 beamforming network that controls the directions of a beam, or beams, of a radio transmission. The beam direction is controlled by switching power to the desired beam port. In transmit mode it delivers the full power of the transmitter to the beam, and in receive mode it collects the signal from each of the beam directions with the full gain of the antenna array.

Ranatec AB

5G FR1, 5G FR2 and Wi-Fi Wideband Active Load Pull



The MT2000 active load pull system is designed for 5G FR1, FR2 and Wi-Fi device characterization up to 67 GHz. Advanced features include: fundamental and harmonic active load pull of 1-port (i.e. integrated transmitters) and 2-port (i.e. transistors) devices up to 67 GHz; wideband impedance control over 1000 MHz of bandwidth; accurately measure ACPR and EVM with low noise floor; simplest configuration and ease-of-use based on a fully integrated design; proven solution with over 10 years of customer use.

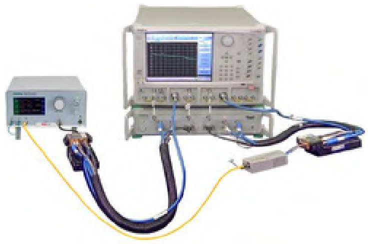
Maury Microwave

Advanced 9 kHz - 7.5 GHz Handheld Spectrum Analyzer

The SH-75S-AOA is an advanced handheld spectrum analyzer for field professionals, operating from 9 kHz to 7.5 GHz. It stands out with its Angle of Arrival (AOA) technology for precise signal source triangulation. The newly added Gate Scanning feature enhances its complex signal capabilities & supports a suite of predefined measurements like ACPR & FM Demodulation. Compatible with Bird Field sensors for diverse RF power measurement functionality for various applications

Bird

VectorStar™ 110 GHz Opto-Electronic Network Analyzer



Silicon Photonics and Photonic integrated chips, and TOSA/ROSA/BOSA devices and Coherent Optical subassemblies are a vital part of the opto-electronic system. The Anritsu 110 GHz ME7848A ONA is the best solution for accurately characterizing all Opto-electronic devices. The ME7848A ONA solution makes the most stable, accurate, and precise measurements of these devices to 110 GHz.

Anritsu Company

SHF's Synthesized Signal Generation up to 64 GHz

SHF Synthesized Signal Generators operate over several decades of frequency (e.g. from 1 up to 64 GHz). In contrast to other high-speed signal generators these synthesizers focus on the generation of CW signals only which enables SHF to offer the most cost-effective solutions in this frequency range. The high purity and fidelity could be achieved by waiving potentially unrequired components and capabilities (like e.g., signal modulation or complex signal sweeps).

SHF

Interview with Dr. Christos Tsironis from Focus Microwaves

everything RF recently interviewed Dr. Christos Tsironis who is the Owner at Focus Microwaves. Focus Microwaves is an innovative engineering company, founded on the groundbreaking work of Dr. Christos Tsironis, who introduced his first manual tuner back in 1973 and is credited with inventing most existing electro-mechanical tuner families. The cornerstone of Focus's success lies in the exceptional engineering and manufacturing capabilities of its dedicated and experienced team of engineers and technicians. These professionals have been nurtured and empowered to spearhead the development of cutting-edge technologies.

Q. Can you give us a brief history of Focus Microwaves?

Focus Microwaves is a pioneering engineering company, built around the innovations of its founder Dr. Christos Tsironis who developed his first manual tuner in 1973 and is the inventor of most existing electro-mechanical tuner families. The success of Focus is based on the engineering and manufacturing skills of its highly motivated and experienced team of engineers and technicians, who have been trained and encouraged to develop new technologies. In addition, listening to our customers needs and insights helps us discover and develop new and measurement methods on an ongoing basis, relentlessly pushing the limits of what is possible.

From humble beginnings in 1988, Focus has become the main supplier of advanced Load Pull and Noise Tuner Systems. Our mission is to provide effective, reliable and innovative solutions for non-50 Ohm testing (Noise and Load Pull) of RF microwave transistors, thus enabling our customers to compete in the marketplace with better designs and to advance the understanding and knowledge of the field.

The Focus Microwaves Group comprises Focus Microwaves Inc., Mesuro Ltd. and Auriga PIV Tech Inc. They are All Engineering and Manufacturing Corporations based in Montreal (Canada), Cardiff (UK) and Merrimack (USA) respectively, as well as a dedicated Sales and Support office in Beijing.

Q. What are some of the key products and solutions offered by Focus Microwaves?

Together, the three companies under the Focus Microwaves Group umbrella cover a wide range of non-50 Ohm measurement products and systems, from active and passive load pull solutions, noise characterization systems, behavioral and compact modelling solutions to pulsed IV measurements and bias tees. With our in-house engineering and manufacturing capabilities, we are able to develop our innovative products quickly and effectively, continuously bringing to market new solutions for the ever-changing demands of the RF landscape.

Q. Focus Microwaves has developed a wide range of Impedance Tuners. Can you tell us more about these products and where they can be used?

To do load pull, one has to control the impedance (or reflection factor) presented to the device. In terms of reflection factor Γ, this is the ratio of reflected to injected power wave into the load at each frequency; assuming a two-port, Γload = <a>/<b>. <b> is created by the two-port (device under test, DUT). By controlling <a> we can control Γ.

A variable passive load is an impedance tuner. The established technology for such devices is the "slide screw tuners"; these are made of a slotted, low loss airline, mostly in form of a parallel plate airline (airline), inside which reflective probes are moved. The probes are made of metal or metallized plastic, are capacitively coupled with the central conductor and create a variable capacitive load and strong field deformation. The tuners are automated using remotely controlled stepper motors and gear. All tuner operations are described logically using motor steps (X, horizontal, Y vertical).

The maximum limit of |Γ| that can be presented to the DUT is called "tuning range". Tuning range is important, because most microwave power transistors have low internal output impedance Ri, in the range of 1 to 3 Ohms. This corresponds to reflection factors |Γ| of 0.96 to 0.89; (VSWR between 50:1 and 17:1; VSWR = 50/Ri, |Γ| = (VSWR-1)/(VSWR+1).

In 2004 the new concept of multi-purpose tuner (MPT) was introduced. This tuner uses three independent wideband probes (slugs). A new tuner type, the "DELTA" wideband and harmonic tuners solve this problem: in these tuners, designed mainly for 5G applications (10-67GHz), the airline is short, in line and in direct contact with the wafer probe and the tuning probe is immediately adjacent to the tuner test port. This allows VSWR at DUT reference plane higher than 10:1 at 30GHz, which is enough for many 5G applications.

Q. Why are load pull measurements important? Can you tell us about the load-pull measurement solutions that you offer?

Modern active devices in RF/micro- wave power amplifiers can deliver high output-power levels, at times over broad frequency ranges. But this requires establishing optimum

Focus offers following load pull solutions:

- Scalar load pull from 0.1 GHz to 330 GHz using passive tuners
- Vector load pull from 0.1 to 220GHz using passive tuners
- Hybrid Active load pull from 0.1 to 120GHz
- Active load pull solution from 0.5 to 40GHz
- Modulated load pull solution from 0.5 to 6GHz.

Q. Focus Microwaves is also known for its software tools for electromagnetic simulation and analysis. Could you tell us more about these tools and their capabilities? How do they assist engineers in the design and optimization of microwave circuits and components?

FDCS includes several software products aimed at characterizing transistor devices. These comprise of Load pull, Noise parameters extraction, data plotting and API functionalities. Advanced utilities are available for tuner control/calibration, driver-based instrument communication, and reference plane de-embedding. FDCS incorporates advanced software routines for Scalar Load Pull, Time-domain based Vector Load Pull and Hybrid active injection Load Pull allowing the combination of active injection and passive tuning.

Q. Apart from the Impedance tuners and test systems focus microwaves also has other test and measurement ancillaries like calibration kits, test fixtures, etc. Is this also an important segment for you, what made you enter this segment?

In an effort to provide complete measurement solutions to our customers, Focus Microwaves has developed, over time, customized accessories, which will make sure a load pull or noise test system will operate as expected. The accessories offered by Focus Microwaves include TRL Calibration Kits, Low loss bi-directional couplers, test fixtures, high-performance bias tees for Pulsed signal, and noise parameter characterization. Similarly, Focus also offers complete integration solutions for on-wafer applications.

Q. Focus Microwave sells several complete test & measurement solutions. How do you sell these solutions to customers? Is this something that they buy and install at their premise or do you customize the solution for the customers and set it up for them? Can you tell us more about the installation process and support?

Every solution that Focus sells is customized to customers requirements. Every project involves an in-depth discussion between the customer and Focus sales and application team. All customer requirements are thoroughly evaluated and the customer is provided with a quote that best suits his requirements. Upon delivery a Focus applications engineer goes to customer site and helps in complete installation and commissioning process. The system performance is verified both in terms of mechanical integration and RF Parameters. The user is fully trained to independently perform system calibration and verification and run the final measurements.

Q. How does Focus Microwaves ensure good customer support across the globe for their sales and post-sales process?

For all sales-related questions, Focus has sales partners around the world. All initial requests are handled locally via our sales representatives. To educate our customers with all our latest products and solutions we regularly schedule on site customer visits. Also Focus Microwaves is a solution partners with all leading test & measurements companies like Keysight, R&S, NI, Formfactor and MPI. Together with our solution partners we frequently schedule different seminars and webinars.

In terms of post-sales support Focus Microwaves website offer a comprehensive online support in the form of FAQ's. Also, our application engineers are always available for by phone and if required onsite support is also provided.

Q. What are some recent / upcoming product releases?

D-band vector and Noise parameter extraction solutions and its easy scalability to G band; DLP, our newest active harmonic load pull solution; Advanced features in Pulsed IV and Tri-State Pulsed IV measurements and high voltage application (up to 2000V); Ultra-wide band 3F0 harmonic coaxial tuners from 5-67 GHz.

About Focus Microwave

From its modest origins in 1988, Focus has evolved into the leading provider of advanced Load Pull and Noise Tuner Systems. Our overarching mission revolves around delivering efficient, dependable, and ingenious solutions for non-50 Ohm testing (Noise and Load Pull) of RF microwave transistors. In doing so, we equip our clients with the tools they need to excel in the competitive marketplace by facilitating superior designs and enhancing knowledge in the field.

EMC Testing

Featured Products

R&S ESW EMI Test Receiver for Compliance Testing

To help EMC engineers meet the increasing demand for higher measurement speeds, Rohde & Schwarz has developed a unique wideband solution which is able to measure up to 970 MHz in real time, while keeping a high dynamic range and measurement accuracy. With this new extension, the R&S ESW EMI test receiver features the largest bandwidth in the industry and becomes the fastest EMI test receiver on the market.

Rohde & Schwarz

For Rent: Advanced Amplifiers' AA-118G-50 Dual-Band Amplifier

The Advanced Amplifiers AA-118G-50 is a versatile, dual-band solid-state amplifier, ideal for EMI, RFI, lab, CW, Pulse, and communication applications. Offering frequency ranges of 1.0-6.0 GHz and 6.0-18.0 GHz, it features a Class A/AB linear design, high power output, and ultra-wide bandwidth. It's user-friendly with built-in protection circuits, extensive monitoring, and rugged design.

ATEC Rentals

Solid State Broadband High Power RF Amplifier

The 4151 is a 250 Watt Solid State broadband amplifier that covers the 6.0-18 GHz frequency range. This amplifier utilizes Class AB linear power devices to provide low harmonics, high gain, and excellent stability. With robust engineering and employment of the most advanced devices and components, this amplifier achieves high efficiency operation with proven reliability.

Ophir RF

Wideband Double-ridge Horn from 300 MHz - 4.5 GHz

The DRH300 antenna operates in a frequency band starting from 300 MHz and going up to 4.5 GHz and beyond. High gain, low VSWR, input handling capability of more than 800 watts CW, and rugged design make this horn antenna excellent for both immunity and emissions testing. Each antenna is individually calibrated and data can be downloaded in electronic form.

RF SPIN

Portable EMI Antenna Kit from 20 Hz to 40 GHz

Travel made easy with A.H. Systems AK-40G Portable Antenna kit with a frequency range of 20 Hz – 40 GHz provides all the reliable antennas, current probes, and cables needed to satisfy a wide array of customer requirements. Each kit contains a tripod with azimuth and elevation head for antenna positioning and a tripod carrying case. Optional preamplifiers and cables available.

A.H. Systems Inc.

EMC Directory - The Largest Directory of EMC Testing Labs

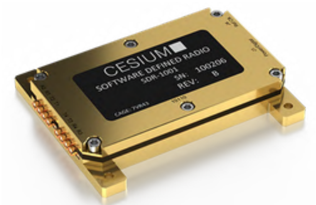
EMC-directory.com is the leading website for the EMC Testing Industry. Find EMC Testing labs based on their location and testing capabilities in the directory. Get quotes for your EMC Testing requirement from multiple companies by filling out a single form.

EMC Directory

Satellite & Space

Featured Products

Software-Defined Radio from 300 to 6000 MHz



SDR-1001 is a high-performance software-defined radio designed to operate in space and airborne environments. It features four receive channels, four transmit channels, and an FPGA in a compact footprint. SDR-1001 is suitable for demanding RF, digital signal processing, and communications applications supporting custom waveform development or standard BPSK, DVB-S2(X), and CCSDS modems.

CesiumAstro

Smiths Interconnect Wilkinson and Resistive Power Dividers

Smiths Interconnect offers an array of surface mount dividers optimized in various frequency ranges design to reduce size and achieve easy for use solutions to support various applications. The configurable design approach provides optimized solutions for Aerospace, Space and Defense markets.

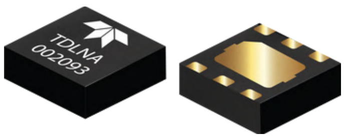
Smiths Interconnect

Wideband Satellite Link Emulator

The RLS-2100 revolutionizes satellite link testing. With a comprehensive set of impairments that can be applied to any wideband scenario, the RLS-2100 is an all-in-one system that gives you total confidence. It delivers everything today's space innovators need: 1.2 GHz instantaneous bandwidth, Multi-orbit support ,Comprehensive modeling ,Seamless test bed integration and much more.

Square Peg Communications

L and S-band Low Noise Amplifier for Space Applications



The TDLNA002093SEP delivers 21 dB of gain across 1 – 6 GHz bandwidth while maintaining a noise figure of less than 0.37 dB and an output power (P1dB) of 19 dBm. It can be positively biased over a 2.7 – 5.0 volt VDD range and has a total dose rating of 100 krad (Si) making it an excellent choice for satellite communication and phased array radar systems.

Teledyne e2v HiRel Electronics

Advanced Channel Emulator

The dBm ACE9600 Advanced Channel Emulator (ACE) is one of the most advanced non-terrestrial RF channel emulation solution to date. The emulated impairments include delay, signal Doppler, attenuation, phase offset, AWGN, frequency hopping, payload and multipath fading. The instrument can house up to four 600 MHz instantaneous bandwidth channels. Impairment emulation can be set to fixed values in Static mode, or continuously changed in real time in Dynamic mode without any phase discontinuities.

dBm Corp

High Performance Small Form Factor Filters for Space Applications

Small form factor, low loss Ka band bandpass filters such as the Knowles DLI brand B291MBOS enable high performance satellite-based phased arrays. Designed from 800MHz to 67GHz, Knowles DLI brand microstrip bandpass filters offer classical filter topologies yielding excellent performance in a small footprint when fabricated on ceramic substrate materials.

Knowles Precision Devices

E-band Antenna + Polarizer assembly qualified for Spaceflight

Flann has developed an antenna + polarizer assembly which is now qualified for spaceflight. Their engineering expertise and in-house processes have aided in achieving high performance 30 dBi mid-band gain over 71 – 86 GHz, in a compact form factor and using a ‘New Space’ approach. The assembly passed a tough shock, vibe and TVAC test schedule at the first attempt and is ready to launch in 2024.
Flann Microwave Ltd.

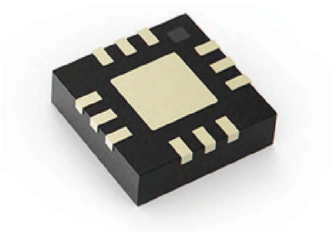
Ku and K/Ka Band SATCOM Beamformer ICs

Anokiwave's SATCOM beamformer ICs, shipping in production volumes, enable low-cost antennas with fast steerable beams, stable temperature performance, and flexible polarization schemes. The Rx ICs feature a very low noise figure, eliminating the need for external LNAs while the high efficiency Tx ICs feature low power dissipation. The ICs, deployed in multiple demonstration and production terminals, have been proven on multiple satellite constellations and in multiple orbits. All parts are available with lead times to meet project needs.
Anokiwave

Cortex – Satellite Command & Control Modems, High Data Rate Receivers

Cortex Series are the risk-free Safran solution for enabling governmental and commercial satellite Command & Control for housekeeping (LEO/MEO/GEO) and data downlink up to 10 Gbps. 7,000+ units worldwide, Cortex are part of all phases of satellite projects from manufacturing to in-orbit operations. Safran now also offers Space-based companions to the Cortex series under the Syrlinks brand.
Safran Data Systems

Wideband MMIC LNA for Ka-Band Satellite Applications



Mini-Circuits’ PMA3-24323LN+ is a pHEMT-based MMIC low noise amplifier, operating over the 24 to 32 GHz range. Ideal for for Ka-band satellite communications, it provides 2.8 dB noise figure, +25 dBm OIP3 and +17 dBm P1dB. Operating on a single 5V positive supply, its compact 3 x 3 x 0.89mm design accommodates dense circuit board layouts.
Mini-Circuits

Falcon K-Band Agile Downconverter

Falcon K-band Agile Downconverter, converts K-band (20.1 - 21.2GHz) to L-band. The Falcon holds up to five converter modules in a compact 1U chassis, which are hot-swap. Each conversion module is 3 slots wide. FLEXIBLE module configurations are available. Choose a mixture of up and down, agile, and block converters with different operating frequencies, in the same chassis. RESILIENCE is also provided by hot-swap dual redundant power supplies and a field serviceable CPU. 10MHz reference source for external/internal (field replaceable). Hot-swap and field-replaceable 2+1 redundant configuration (with standby input/output) or 1+1 redundant configuration (with standby input/output) available.
ETL Systems

Hi-Rel Power-Dense Capacitors Pre-Screened to NASA-EEE-INST-002

Quantic Evans space-level, hi-rel hybrid tantalum capacitors are the most power-dense in the industry, providing significant SWaP savings compared to other capacitor technologies. Pre-screened to NASA EEE-INST-002, they are ready for take-off. Ideal for a wide range of space missions, from Low Earth Orbit (LEO) to deep space. Additional NASA level qualification testing is available.
Quantic Evans

Interview with Chris Dugan from Knowles Precision Devices

everything RF recently interviewed Chris Dugan who is the President at Knowles Precision Devices. In this role, he holds the responsibility for both the Knowles Timing and Capacitor businesses. Chris most recently served as president, Americas for Bridon Corporation. Prior to Bridon, Chris held general management, commercial management, and M&A roles with Cooper Industries and Carrier Corporation.

Q. Can you give us a brief history of Knowles Precision Devices?

Knowles Precision Devices is a division of the nearly 80-year-old Knowles Corporation. The Precision Devices division officially formed in 2014 by bringing together the resources and technology from four strategic acquisitions made across the prior three decades – Dielectric Laboratories (DLI), Novacap, Syfer, and Voltronics. Since then, Knowles Precision Devices has grown to also include the technology and expertise of Johanson Manufacturing, Compex, and Integrated Microwave Corporation (IMC).

Q. Please tell us more about your product portfolio.

We are a specialty components manufacturer, which means we choose to take on the complex challenges that come with developing solutions that must meet requirements for high-reliability, high-temperatures, high-performance, and high-frequencies. We use our materials science knowledge to engineer a wide variety of specialty components including multilayer ceramic, single-layer, high-reliability, and precision variable capacitors; EMI Filters; and microwave devices such as RF filters, splitters, and couplers.

Q. What are the main market segments you cater to?

Our components are essential parts used in a variety of applications throughout the aerospace and defense, medical, power electronics, and electric vehicle (EV) markets as well as in new and emerging applications in the industrial space such as those required for renewable energy.

Q. Knowles Precision Devices makes a wide variety of capacitors. Can you tell us more about this product line, particularly the MLCCs and their applications?

While there are many ways to look at the wide variety of capacitors we produce, something unique about Knowles Precision Devices is that one of our core competencies is in materials science, particularly ceramics. Therefore, we make a range of multilayer ceramic capacitors (MLCCs) using both X7R and C0G dielectric formulations. Our X7R MLCCs are a great fit for lower frequency ranges in circuits that require high capacitance but can allow for a certain amount of derating such as energy storage, smoothing, and EMI filtering. Our C0G MLCCs are an excellent option for lower capacitance, high-frequency RF devices, and other applications that require precision circuitry and high reliability.

Beyond these two dielectrics, we've also developed our own custom ceramic known as Hiteca™. MLCCs designed using Hiteca deliver low losses while offering high, stable capacitance up to maximum voltage and temperature. This combination is generally a perfect fit for the MLCCs required for power electronics used in high-temperature environments such as EVs and industrial applications.

Q. How does Knowles Precision Devices approach testing and screening for mission-critical RF solutions in areas such as SATCOM and military? What are some of the challenges that typically occur in this process?

When launching expensive mission-critical equipment and people into space, there is absolutely no room for failure. However, one big change we've recently seen is that not everything going into space these days is mission-critical. This means the level of testing and screening performed on components must be symmetrical with the mission of the end device. For example, the level of reliability required for a multi-million-dollar system being sent to Mars is quite different than what is necessary for a low-cost new space satellite being put into low-Earth orbit.

Understanding this nuance is one of the biggest challenges we see customers in this industry facing as historically, every component used in a space application was tested and screened with rigor. Since not every space application requires this same level of testing and screening now, there are infinite possibilities for qualifying a part for a space application. These possibilities need to be carefully considered because you can waste a lot of time and money over-testing parts now. While we can perform testing and screening for any MIL-SPEC our customers require, the real value we bring is in developing an understanding of the customer's base mission and then working with the customer to determine the appropriate level of testing and screening needed without overdoing it.

Q. Can you tell us about the different types of RF filters that Knowles manufactures? What technologies do you use? Are there any specific applications for which you develop filters?

We make a wide range of filters, from 300 MHz to 75 GHz in bandpass, lowpass, highpass, and bandstop configurations. Whether a customer needs a catalog part, a build-to-print solution, or a custom build, we are prepared to take on the complex challenges of implementing high-performance filters across the widest range of specifications.

Today, a variety of land, sea, air and space navigation, communication, and detection systems rely on the superior technology and performance of our filters.

Q. Can you tell us more about your EMI and 5G Filter Product Line? Which bands do you design your 5G filter for?

We address the challenges of implementing high-performance filters at mmWave frequencies with off-the-shelf catalog designs in the FR2 band and our custom design services. For example, our 26GHz, 28GHz, and 39GHz catalog filters provide 3GHz of bandwidth, greater than 50dB rejection, are 20x smaller than current alternatives while implemented in surface mount packages for standard tune-free assembly, and temperature stable operation from -55°C to +125°C.

Our EMI filters are designed for the opposite end of the frequency spectrum. We offer a variety of EMI filters depending on the job that needs to be done – from noise filtering in an EV application to a planar array that needs to go into a sophisticated filter connector to support a complex assembly in a jet engine. This range includes relatively simple chip capacitor EMI filters, sophisticated panel mount EMI filters, and complex planar arrays for filter connectors.

Q. Apart from capacitors and filter solutions, Knowles Precision Devices also has its own line of Microwave couplers. Is this an important segment for you? Can you tell us more about it?

At the core of everything we do, lies our ceramics expertise. This technical core allows us to make a complete microwave toolkit, which includes microwave couplers. We've developed numerous custom couplers for customers over the years, which became the basis for our catalog parts. Our couplers are unique as these components tend to cover wider bandwidths and higher frequencies compared to alternatives. Plus, our custom ceramics allow us to make these components quite small.

Q. Do you develop both standard and custom products?

Yes, we offer numerous catalog parts along with build-to-print and custom component design services. Since we are not trying to be your typical commodity component manufacturer, we are ready to help our customers solve even their most difficult engineering challenges by working with them in the exact way they need.

Q. What does Knowles's geographic distribution of customers look like?

We are a global company, and as such, we have customers located all over the world. We serve top-tier companies as well as small organizations and start-ups across many different verticals such as aerospace and defense, medical, power electronics, EV, and new and emerging applications in the industrial space. What's perhaps more impressive than the geographic distribution of our customers though is where you will find our components operating – from 8,000 feet below the Earth's surface to 34 million+ miles away on Mars and beyond.

Q. Can you give your view on the upcoming market trends for RF components and capacitors?

Let's start with trends impacting RF components. Since bandwidth is tied directly to data throughput rates, and we constantly need to move more data faster, there is a perennial need for components that can support increased bandwidth. This means the development of high-throughput satellites for a variety of consumer and defense communication applications is increasing and these devices need the type of high-frequency and high-bandwidth RF components we excel at developing.

Additionally, the United States and many NATO countries are now expanding their investment in radar and electronic warfare technologies and we are seeing increased design activity, especially from European customers, this year. We are well prepared to meet these demands with our custom design capabilities for both the microwave devices and capacitors needed for these applications.

More specifically for capacitors, we are very interested right now in the role of power electronics in renewable energy and EV applications. One key to unlocking the potential of renewables is unfolding now – developing very efficient semiconductors with wide-bandgap (WBG) materials such as silicon carbide (SiC) and gallium nitride (GaN). As the shift to using these WBG material-based semiconductors continues, other board-level components, such as capacitors, must change as well. For example, as systems operate at higher frequencies, the capacitance needed decreases, leading to many instances where film capacitors can be replaced by ceramic capacitors – our specialty.

For EVs, we are seeing increased demand for high-performance capacitors for in-vehicle applications beyond the drivetrain, such as heating and cooling systems, as well as outside the vehicle as the need for more charging infrastructure rapidly grows. This includes innovations in wireless charging and bi-directional charging systems as well. With our advancements in materials and manufacturing R&D and our continued investment in MLCC design innovation, we are ready to meet the needs of this rapidly evolving industry as well.

Q. Knowles acquired Integrated Microwave Corporation (IMC). What made you acquire them and where does this fit into your product portfolio? Are there any synergies?

In 2021, we acquired Integrated Microwave Corporation (IMC) because we saw this company as a leader in the design and manufacture of custom precision RF microwave filters and multiplexers for the aerospace, defense, and communications industries. This acquisition was a strategic decision that allows us to now offer a complete range of RF and microwave filtering solutions that support applications from the VHF to the Ka-band. In addition to the small, temperature-stable filters our customers have come to know us for, we can now deliver ceramic and cavity filters for lower frequency and/or higher power applications.

About Knowles Precision Devices

Knowles Precision Devices is a leading manufacturer of Multilayer, Single Layer, High Reliability and Precision Variable Capacitors, EMI Filters and Microwave Devices including RF Filters, Splitters and Couplers.

Your Preferred Microwave and mmWave modules Supplier, DC-400GHz

Broadband Waveguide Low Noise Amplifier
26.5-170GHz, WR-19 to WR06

- ✓ Full Waveguide Band
- ✓ Low NF to 2.5dB
- ✓ Low/High Gain Option
- ✓ In stock for same day shipment

Band	Frequency /GHz	Gain /dB	NF /dB	Waveguide
Ka	26.5-40	23/35/45	2.5	WR-28
Q	33-50	23/38	2.8	WR-22
U	40-60	18/38	3.0	WR-19
V	50-75	18/38	2.5	WR-15
E	60-90	18/38	5	WR-12
W	75-110	18/42	4	WR-10
F	90-140	16/33	5	WR-08
D	110-170	18/33	6	WR-06

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MMIC Filters: Revolutionizing RF Systems with Compact Design and High Performance

Cameron Sheth - Marki Microwave

As next-generation technologies push towards higher frequencies, technologies are capitalizing on wider available bandwidths and higher channel densities, enabling increased data throughput. Consequently, RF market trends for filters are starting to prioritize higher frequency capabilities and size, weight and power (SWaP) and scalability. In contrast to competing filter technologies, Monolithic Microwave Integrated Circuit, or MMIC, planar filters are uniquely suited to meet the demands of next-generation systems.

RF/microwave filters are electronic circuits that selectively permit specific frequencies to pass through a system while rejecting undesired signals outside of a filter's passband. In system designs, filters are crucial for band selection and for cleaning up unexpected spurious tones. Filters are present at multiple points throughout the RF signal chain, commonly placed at the output of multiplier and amplifier blocks to knock down unwanted harmonics or following the frequency conversion block to reject spurious tones, improving system dynamic range.

Filters are often custom designs due to applications having unique frequency bands in which they can operate. For this reason, filters are often designed in-house. While filter designs are ideally planned for during the initial design phase, the need for filters often arise towards the end of a project when issues such as unexpected spurious tones arise. For this reason, it is important that modern filter development is quick and accurate as to not cause project delays and to ensure functionality of an RF system.

Many different filter technologies are in use today, each with their own trade-offs:

- Acoustic Wave Filters provide excellent out-of-band rejection in a small form factor but feature low power handling and are frequency limited to below 8 GHz.
- Cavity Filters utilize higher filter orders relative to other filters and are best suited for frequencies from 1 to 20 GHz. They feature excellent out-of-band rejection, high power handling and low loss but require manual tuning and are physically large.
- Lumped Element Filters are low cost per design, have high yield and feature high Q, but have limited performance and are suited for frequencies below 6 GHz.
- Planar Filters (e.g., MMIC, Thin Film, Laminate) offer a balance between size, performance, cost, and development time, making them suitable for modern applications.

When considering a filter for a particular application, designers will generally look for a filter that has a high Q factor, indicating a narrowband and highly selective filter due to a sharp resonant peak at the center frequency, low center frequency insertion loss, high out of band rejection with steep transitions between the passband and stopband, and sufficient return losses. Additionally, a balance between filter order and size is considered as higher order filters will have steeper rejection slopes at the expense of a larger filter design.

Filters currently consume a large portion of a system's overall footprint, however, as next-generation systems have started to prioritize smaller form factors, filter specifications have been impacted as there is a natural trade-off in Q factor and the max filter order employable as size of the filter decreases. In Marki Microwave's experience over the past year, designers have proven to be willing to trade Q factor as long as they can achieve substantial size reduction while still meeting their passband insertion loss and out of band rejection requirements. This, in addition to reasons that will be discussed further, has allowed MMIC filters to emerge as the ideal filter solution for new systems.


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Performance Metrics and Design Considerations for MMIC Filters

Size Reduction

As mentioned, each filter technology in use today has its own trade-off space and the same is true for MMIC filters. The increasing channel count and bandwidth demands of next-generation systems are met by MMIC technology as MMIC filters are unmatched in terms of the size reduction achievable and the high frequency capability. MMIC's precision lithography and small lumped element capacitors and inductors enable innovative circuit designs that allow smaller filter circuits to be realized. High frequency MMIC filters can be as small as 1.5 x 1.5 mm and integrate with other MMIC blocks or packaging methods to reduce system footprint. One of the differences between GaAs MMIC and thin film technologies is the higher dielectric constant, Dk, of GaAs (12.9) compared to thin film (9.8), which allows for smaller designs that can be realized in QFN packages that are 10 times smaller than equivalent thin film filters. MMIC is the only technology that can get to die-level size.

High Frequency Capability

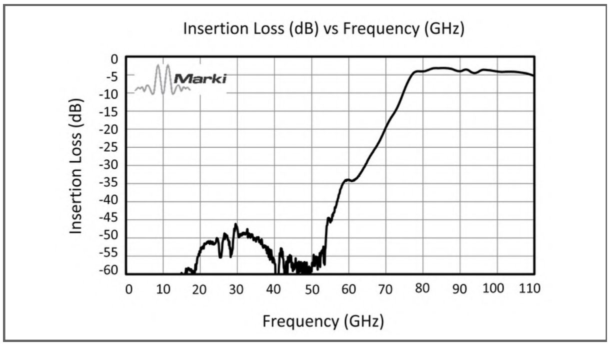

Figure 1. 78 GHz – 110 GHz MMIC Bandpass Filter Response

Utilizing the fine line widths available through MMIC lithography in addition to the use of thin substrates enable high frequency filter designs that were previously unattainable with competing technologies. Standard frequency capability for MMICs has been demonstrated up to 110 GHz thus far. This is crucial as next-generation systems move into E band, W band and beyond to enable higher data rates. Competing planar technologies are capable up to 40 GHz but are typically best suited to 20 GHz or below.

Q Factor

MMIC technology does not offer the same high Q factor achievable through competing technologies, however, the use of unique architectures and topologies provides more levers to pull than just Q factor and filter order to achieve high-performance designs. While the Q factor might not be as high as for laminate, thin film or other filter technologies, Marki Microwave has found that the selectivity and loss of MMIC filters has been more than agreeable from the standpoint of system designers.

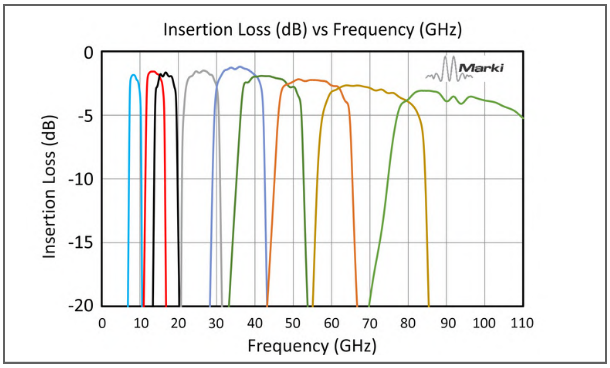

Figure 2. Passband Insertion Loss Vs Frequency for 9 Selected Filters

Q factor is directly related to the filter insertion loss, specifically the center frequency loss. As Q increases, the loss improves. Loss also improves with increasing percent bandwidths but decreases with increasing filter order as higher order filters trade-off size for improved rejection steepness. Typical passband losses for MMIC designs range from 1 to 5 dB, with lower frequency designs exhibiting superior losses. These insertion losses may be higher in comparison to competing planar technologies at lower frequencies; however, these insertion losses have been demonstrated as capable of meeting most system specifications. As previously noted, the move to higher frequencies and smaller filter sizes does impact Q and insertion loss, but MMIC filters outperform laminate and thin film technologies in insertion loss above 40 GHz.

Filter Order and Rejection

In terms of filter order, whereas thin film and laminate filters can use up to 11th and 15th order designs respectively, MMIC can typically employ 9th order circuits and below while keeping sizes small. However, a system designer will be more concerned with the resulting out of band rejection rather than the filter order employed to achieve it. Marki Microwave has found that filter orders between 4 and 8 have been sufficient to develop MMIC filters with acceptable rejections, rejection slopes and passband insertion losses. So far, MMIC filters have been demonstrated to achieve a 40 dBc minimum stopband rejection at 10% from the band edge for designs below 40 GHz, with typical values being much higher.

Return Loss

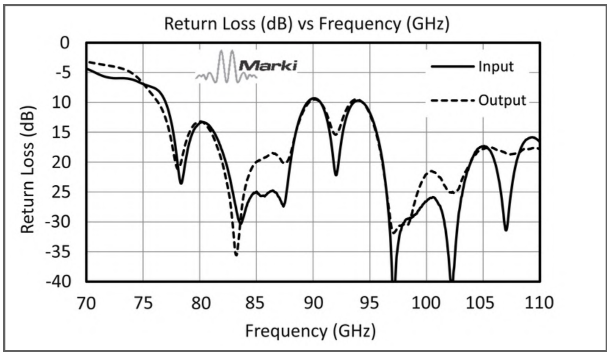

Figure 3. 78 GHz – 110 GHz MMIC Bandpass Filter Return Loss

For reflective filters, MMICs have demonstrated typical passband return losses better than 15 dB for designs below 40 GHz, while at mmWave frequencies, return losses have been measured around 10 dB. A high (negative) return loss indicates efficient signal transfer with minimal reflections. In addition to reflective designs, reflectionless designs have also been developed with excellent return losses both in the passband and stopband, making these designs excellent for eliminating unwanted spurs present in the system.

Integration

MMIC technology offers versatile integration capabilities. MMIC components can be seamlessly integrated with other MMIC blocks or co-packaged into surface mount packages or multi-chip modules. This flexibility allows for the consolidation of various RF and microwave functions into a single, compact package, reducing system footprint and complexity. MMIC integration capabilities are highly valuable in applications where SWaP constraints are critical.

Filter Response Types

The choice of filter response type depends on the specific needs of the RF system, including the desired frequency range, bandwidth, insertion loss, and out-of-band rejection requirements. MMIC technology offers flexibility in designing and implementing these various filter response types:

- **Lowpass Filters:** These filters allow frequencies below a certain cutoff frequency to pass through while attenuating higher frequencies. Lowpass filters are useful for applications where filtering out unwanted harmonics or noise is necessary.
- **Highpass Filters:** Highpass filters permit frequencies above a specified cutoff frequency to pass while attenuating lower frequencies. They are employed to remove DC offset or filter out undesired low-frequency signals.
- **Bandpass Filters:** Bandpass filters allow a specific range of frequencies to pass through, while attenuating frequencies both below and above this range. They are crucial for selecting a particular frequency band of interest. MMIC bandpass filters can be realized with traditional bandpass structures as seen on thin-film and microstrip designs, however in a more compact form factor design. Bandpass filters can also be realized as a cascade of lowpass and highpass filters to provide a broadband response.
- **Bandstop Filters:** Bandstop filters, also known as notch filters, attenuate a specific range of frequencies while allowing all others to pass. Essentially the opposite of a bandpass filter.
- **Diplexers:** Diplexers are specialized filters used to separate or combine multiple frequency bands within a single system. They are commonly employed in RF systems that require signal routing and frequency management.
- **Balanced Reflectionless Filters:** These filters use two identical bandpass filters terminated with quadrature hybrids at both the inputs and outputs. Reflected out-of-band signals are coupled into on-chip 50Ω terminations such that no reflections reach the input or output ports, thus providing excellent return losses both in the passband and stopband.
- **Switched Filters:** As mentioned, due to the integration capability of MMICs, some MMIC filters can incorporate switching mechanisms that allow dynamic selection of different frequency responses. These are valuable in applications requiring reconfigurable filtering or where size is a premium.

Repeatability, Scalability and Simulation

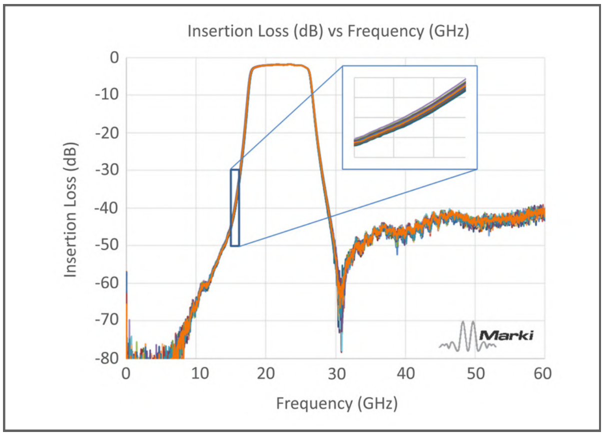

Figure 4. Repeatability of 24 randomly selected MMIC filters from a lot of over 8000 units

GaAs fabrication yields high-volume, repeatable single crystals for MMIC filter production, scalable from thousands to millions of units, meaning that at volume, MMIC filter are cost competitive solutions. Precise lithography optimizes features like transmission zeros, closely matching simulations for quick design success. Tighter tolerances enhance repeatability across units and wafers, outperforming other technologies. MMIC's etching tolerance (0.25 um) surpasses laminate filters (25 um), minimizing detuning issues and improving yield. Thin-film processes, less controlled than ICs, result in lot-to-lot variability. Additionally, the development of an iterative filter design tool is enabling designers to quickly determine whether filter designs are feasible. The tolerances of lithography ensure high accuracy between the initial simulated filter design and the final realized filter, allowing designers to proceed with their projects through accurate simulation files while said filters are being fabricated.

Impedance Matching

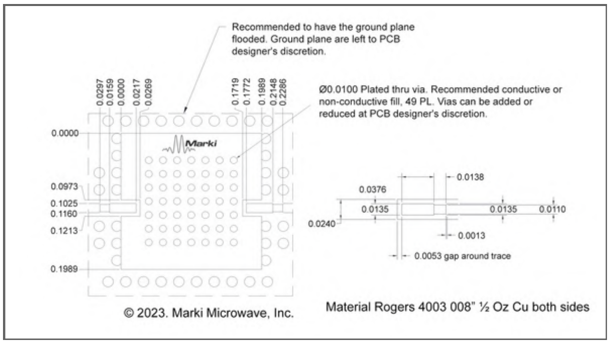

Figure 5. Optimized Landing Pattern for a QFN Filter Featuring an Inductive Taper

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Impedance Matching

Filter performance relies on precise impedance matching to ensure that these components don't detune due to parasitic capacitance and inductance from packaging components such as leads and wirebonds, particularly at frequencies above 40 GHz. This issue is solved by co-designing packages with the die to ensure a well-matched 50Ω transition to optimize the filter return loss. Using optimized landing patterns with inductive tapers is essential to tune the transmission line leading to the filter package.

In conclusion, next-generation technologies are driving the RF market towards higher frequencies, increased bandwidths, and greater scalability. MMIC planar filters are uniquely positioned to meet these evolving demands. RF filters play a crucial role in system design, and MMIC technology offers a compelling solution by combining size reduction, high-frequency capabilities, and versatile integration. These advantages together with a right first-pass design process when shared across multiple designs make MMIC filters a cost-effective and performance-driven choice, revolutionizing their role in custom filter development for modern applications.

IoT & 5G Technology

Featured Products

ADI RadioVerse® SoC Drives 5G Radio Efficiency and Performance

The ADRV904x is a highly integrated, system on chip (SoC) radio frequency (RF) agile transceiver with integrated digital front end (DFE). The SoC contains eight transmitters, two observation receivers for monitoring transmitter channels, eight receivers, integrated LO and clock synthesizers, and digital signal processing functions. Additionally, the SoC is apt for single band and multiband capability.

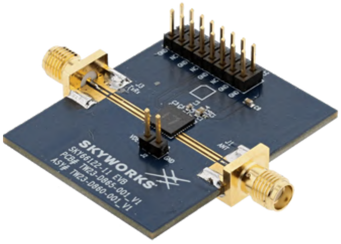
Analog Devices, Inc.

Future-proof One-Box Testing solution for 5G-NR

R&S CMX500 5G one-box signaling tester (OBT) can be used across the whole value chain, from early R&D to type approval conformance testing. The radio communication tester is a future-proof test solution for all 5G mobile devices and chipsets and supports all 5G NR network deployments and frequency ranges (FR1, FR2 and LTE) in a single instrument, fit to cover present and future LTE and 5G 3GPP band combinations.

Rohde & Schwarz

Front-End Module for Wi-SUN® Applications



SKY66122-11 high performance, highly integrated RF front-end modules (FEM) are designed for high-power Industrial, Scientific, Medical (ISM) band, Wi-SUN, and other IoT applications operating in the 863 to 928 MHz frequency range.
SKY66122-11 FEMs are designed for ease of use and maximum flexibility with fully matched, 50 Ω RF input and output, and digital controls compatible with 1.6 to 3.6 V CMOS levels.

Skyworks Solutions, Inc.

Masach™ NextGen RF Shields – 5G Enabled

Masach™ NextGen RF Shields are designed to meet the electronics industries high-frequency – 5G RF applications. They are available in 1 or 2-piece configurations made of Tin-plated Steel or Nickel-Silver materials. The Nickel-Silver series have high corrosion resistance and are used in sensitive-harsh environments in a variety of industries such as medical devices, aerospace, automotive and more.

Masach Tech Ltd.

5G RedCap-enabled IoT modules

Quectel's 5G Redcap module series offer a balance between cost and performance and support the large-scale deployment of 5G into sectors where high bandwidth is not needed, but low cost and power consumption are crucial.
Upgrade your devices effortlessly with our 5G RedCap-enabled RM255C, RG255C or RG255C-Mini PCIe IoT modules. Contact us today and discover how easy it is to boost your device performance.

Quectel

Talaria TWO™ Ultra Low Power WiFi Enables CE-Link Solar Video Camera Design

The Talaria TWO multi-protocol chipset and modules deliver the world's lowest-power Wi-Fi for battery-operated IoT devices. The platform is ideal for IoT remote security cameras, video doorbells, connected sensors, asset tracking, wearables, AI/ML-enabled devices and many others. The end-to-end, market-ready, extreme low power wireless IoT solutions offer a low total cost of ownership, high-performance wireless use cases and rapid time to market.

InnoPhase IoT, Inc.

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Open Python SW controller
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Many sizes & types available

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Below deck instrument bays
Shorter wiring

Integrate with existing instruments
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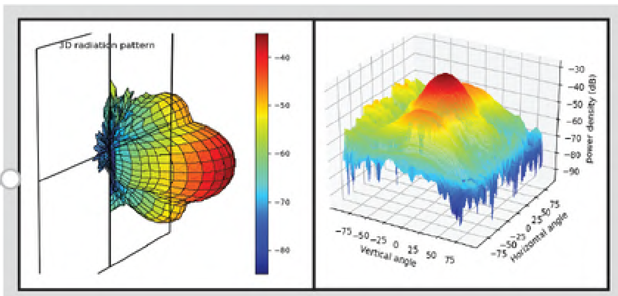
Unlimited automation



More Info

MilliBox
ANTENNA TEST SYSTEMS

millibox@milliwavess.com +1.408.892.9595 millibox.org

IoT & 5G Products

High-Performance 5G Flexible PCB T-bar Adhesive Antenna

The 2JF0783P 5G Flexible Polymer Adhesive T-bar Antenna combines flexibility, conformability, and ease of integration with exceptional global cellular and broadband Internet connectivity, fully compatible with existing LTE networks. This high-performance antenna is an easy peel-and-stick solution with high efficiency and reliability making it ideal for consumer, industrial and commercial device applications.

2J Antennas

Fibocom LTE Cat 1 bis module

Fibocom MC610 is an LTE Cat 1 bis wireless communication module. The product supports LTE, GSM dual-mode communication, and also supports VoLTE, Audio, Recording, SMS , WiFi Scan, BLE and other functions. In addition, the module provides universal interfaces such as USB/UART/SPI/I2C to meet various application demands of the IoT industry. The product positioning covers the low and medium rate IoT market, such as universal payment, sharing, industrial interconnection, tracking, vehicle-mounted rear installation and other application scenarios.

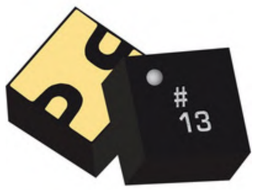
Fibocom

Personal Antenna Array OTA Test System for mmWave and THz Applications

MilliBox offers a range of compact anechoic chambers and 3D positioners designed for antenna radiation pattern and beam steering measurements above 10 GHz. Having a personal bench-top setup increases productivity and scalability by eliminating down time and setup time commonly impacting shared resources. Modularity, flexibility, and affordability are defining principles behind all MilliBox products.

MilliBox

Die-Level Limiter Performance in an Ultra-Compact SMT Package



The HLM-8010CSP1 is a high-power GaAs Schottky diode signal limiter featuring high IP3 over a broad DC-40GHz bandwidth. It offers low insertion loss and excellent return loss from DC through Ka band and low +8 to +14 dBm flat leakage. The limiter's compact 1.5 x 1.5 mm size makes it ideal for protecting sensitive components in space constrained applications, such as 5G mmWave and satellite AESAs.

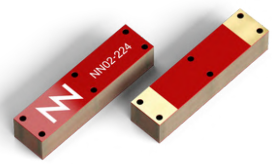
Marki Microwave

5G Ready Millimeter-Wave Couplers from 6 to 40 GHz

MECA has developed a Family of 5G ready millimeter-wave Couplers, covering C to V bands. Available in 10 & 20 dB models covering 6-40 GHz with 2.92 mm connectors. Since 1961 MECA Electronics (Microwave Equipment & Components of America) has served the RF/Microwave industry with equipment and passive components covering up to 40 GHz, featuring products manufactured in the USA with a 36-month warranty!

MECA

Small but powerful antenna component: RUN mXTEND™



Ignion's customers are successful using RUN mXTEND™ for smart metering. It is compact in size and cost effective and easily adapts to almost every wireless device and to any radio technology within a 824-8000 MHz frequency range with reliable connectivity.

Ignion

Solutions That Are Above and Beyond

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Our family of remote spectrum monitors with Vision PC software allow for automated inference detection over wide geographical areas. Protect your spectrum from illegal transmitters and interferers with 24/7 monitoring and long-term trace logging. Monitor multiple nodes, collect spectrum history, identify signal patterns, and conduct coverage mapping using the advanced Vision PC software.

Locate, Analyze, and Identify

VectorStar™
ME7838x

Single Sweep 70 kHz to 220 GHz VNA/SPA with Differential Probes

Building on more than 40 years of design experience, Anritsu has broken the millimeter-wave barrier with the VectorStar ME7838x series VNA/SPA. RF and microwave engineers now have access to a powerful measurement tool for performance analysis of devices ranging from transistors in an on-wafer environment to communication systems.

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Field Master Pro™
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Lab Grade Performance in the Field

Our Field Master Pro handheld spectrum analyzers are built to deliver in the toughest environments and offer leading edge performance up to 54 GHz with 110 MHz analysis bandwith. Providing a large 10 inch touch screen for quick and easy setup and results display, ruggedized case, and battery operation, you can be confident of getting the job done wherever you go.

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Signal purity, output power, and frequency stability are essential distinguishing characteristics of a high-frequency microwave signal generator. The Rubidium MG362x1A signal generator product line is built to deliver outstanding signal purity and frequency stability across a broad frequency range, even at high output power levels.

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Cables & Connectors

Featured Products

Microwave Cable Assemblies for Applications up to 110 GHz

Rosenberger, RF & microwave products supplier, provides a wide range of microwave cable assemblies - with and without armouring and characterized by excellent phase and amplitude stability as well as high electrical and mechanical stability. The standard range covers ultra-low loss and high-phase stable variants for 18 GHz, 26.5 GHz, 40 GHz, 50 GHz and 70 GHz. VNA test cables for applications up to 110 GHz are also available.

Rosenberger

VITA 67.3 Cable Assemblies now with Nano RF!

Introducing the VITA Nano RF connector on Storm Flex 047 cable (3.52 dB/ft at 50 GHz) assemblies added to Teledyne Storm Microwave's product family. With excellent electrical performance over a range of flexing this cable will be welcomed into a market where durability is necessary. For even smaller spaces, contact us about info on Storm Flex 034 cable.

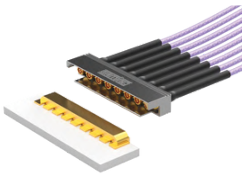
Teledyne Storm Microwave

Multicoax Interconnect redefines High-speed Digital Testing

The MXPM90 connector system provides ultra-precise, highly repeatable S-parameter measurements up to 90 GHz. With its tight phase matching of single assemblies, broadband return and insertion loss characteristics across the entire bandwidth, the MXPM90 ensures superb integrity for data analysis up to 112 Gbps. The compact 2.54 mm pitch design allows for close positioning to the DUT/chip, keeping traces short and losses low. The self-mating connecting mechanism with an integrated magnetic lock prevents improper mating to ensure a correct connection at all times.

HUBER+SUHNER

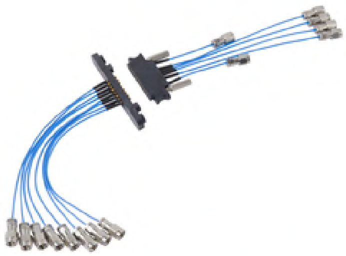
Magnum RF™ Ganged SMPM Solutions



Samtec's newest line of multi-position products delivers an SMPM interface into a tightly packaged solution. Magnum RF™ connectors offer 40-percent greater density, decreased processing time, and better positional alignment versus single channel solutions. Board-to-board and cable-to-board mated sets are available.

Samtec

Humboldt Multiport RF Cable Assembly Builder



SV Microwave's newest web tool, the Humboldt Multiport Builder, is an intuitive drag-and-drop platform that allows you to create any 2-, 4- or 8-port cable assembly harness you can imagine. Instantly see pricing and data sheets and receive your custom RF multiport assembly in 15 days!

SV Microwave

LMR® Complete Coaxial Cable System by Times Microwave Systems

The LMR® cable solution offers a complete line of highly flexible, rugged, low-loss braided cables with the fastest, easiest connector installation available. LMR cables provide superior performance compared to RG cables of similar size. They also provide significantly better attenuation, shielding effectiveness, and UV resistance.

Times Microwave Systems

Cables & Connectors Products

Harwin's Connector Backshells Deliver EMI/RFI Screening and Mechanical Strength

Harwin offers a variety of metal backshells that enhance the company's connectors by combining EMI/RFI screening with improved mechanical strength and electrical longevity. Compatible with both male and female cable connector housings, backshells can be easily fitted during cable assembly construction or as an additional post-manufacture improvement. Lightweight design makes them ideal for aerospace and other applications that demand minimum weight.

Harwin

Pisces range of waterproof interconnect solutions.

The Pisces range of connectors & adaptors are designed for use in harsh environments, where reliable signal transmission is critical.
The Pisces range includes a variety of connector types, including SMA, N, TNC, and BNC, as well as custom designs. Connectors are available in a range of configurations, including straight, right-angle, and bulkhead, as well as in various cable types and lengths.

IntelliConnect

Milli-Flex Cable assemblies

For applications above 30 GHz, IW has an established range of cables designed to provide exceptional attenuation performance at key frequencies for commercial and military applications, with the 180, 150, 157, 140 and 125 series low loss/phase stable cables in addition to the RF085 Re-Flex hand formable.

Insulated Wire, Inc.

StabilityWafer™ cable assemblies empower accurate and repeatable on-wafer measurements

StabilityWafer™ on-wafer probing cable assemblies (SW-series) have been specifically designed to empower accurate and repeatable on-wafer measurements when used with coaxial wafer probes. Its small outer diameter, light weight and superior flexibility allow for the tight spacing typically required for on-wafer measurements and eliminate pressure on the wafer probes that would cause a loss of contact with the device-under-test.
StabilityWafer™ is is available with 3.5mm, 2.92mm, 2.4mm and 1.85mm connectors up to 67 GHz.
StabilityWafer™ employs color-coded connectors to reduce potential for connection mistakes

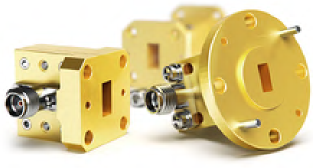
Maury Microwave

Armored Ultra Flexible RF Cable

With increased phase stability and power handling capacity, the HLB055 Little-110 GHz armored ultra flexible RF cable is designed for demanding microwave interconnect requirements. This extremely flexible cable is well suited for dense microwave packaging with a 0.79" minimum bend directly at the connector matting point, eliminating the need for right angle adapters and connectors. The HLB055 Little-110 GHz cable series are constructed with the outer conductor made of silver-plated copper tape and braid.

HASCO

Mini-Circuits Introduces Waveguide to Coax Adapters



Mini-Circuits has introduced a new family of right-angle waveguide to coax adapters to support high-frequency applications including radar, mmWave 5G, OTA testing and more. Model WR22-VFR+ is a 2.4mm-F to WR22 adapter covering the 33 to 50 GHz frequency range. Model WR28-KFR+ is a 2.92mm-F to WR28 adapter covering the 26.5 to 40 GHz range. Both models feature compact, gold-plated construction and provide insertion loss less than 0.2 dB and VSWR less than 1.2:1.

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Ruggedized Test Cable Assemblies are engineered to perform reliably in a variety of test and measurement applications.

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High-Power Double-Ridge Waveguide 4-Port Magic Tee

High-power magic tees are an essential component for the power-combining assemblies and radar system. Magic Tees govern the phase and amplitude of incoming signals, allowing for seamless and interference-free signal merging. SMC is pleased to offer wide range of magic tee operating from 1-40 GHz, with exceptional isolation between E and H-Ports (30 dB min.) and collinear ports (15 dB Typical).

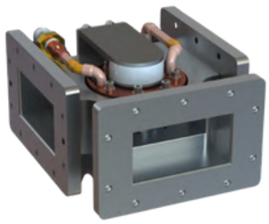
Scientific Microwave Corporation

D-Band Frequency Extender Supports Vector Network Measurements

Compatible with many industry-standard coaxial vector network analyzers (VNAs), model STO-0620300-CM-E1 is a Transmit/Receive frequency extender that measures transmitted and received signals through its WR-06 test port. Dynamic range is 100 dB from 110 to 170 GHz. One TX/RX extender can measure S11 or S22 while two extenders can measure S11, S12, S21 and S22 simultaneously.

Eravant

High-Power Waveguide Circulators



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What are Waveguide Polarizers?

Peter Young - Flann Microwave

Communication links from antenna to antenna often use dual-polarization as it allows a doubling of the information capacity of a wireless channel. Circularly polarized waves can offer better propagation with reduced fading and multipath losses because it is possible to receive all orientations of the signal. Signals propagating in rectangular waveguides have linear E-field as the energy is in the TE10 mode, so to transmit and receive circular polarization, via a conical or lens horn antenna for example, requires a polarizer. Ideal characteristics for such an instrument would be a good axial ratio (low cross-polarization components) over as wide a band as possible, with low VSWR and low residual insertion loss.

There are many ways to convert between linear and circular electromagnetic waves. Flann Microwave, for example, currently offers three different types of polarizers - namely the dielectric vane polarizer, septum polarizer, and corrugated polarizer. These three instruments are described and compared below.

Dielectric Vane Polarizers

In the vane polarizer design, the transition from a rectangular to a circular waveguide features a dielectric vane within the circular section. This vane is called a quarter-wave plate and is sized to provide a 90° phase shift (λ/4 delay). With the angle between the E-field of a linearly polarized wave and the vane set to 45°, the component parallel to the vane will be delayed by 90° relative to the perpendicular component, which suffers no delay. The result is equal orthogonal components 90° apart which is a mathematical description of circular polarization. Whether the vane is at +45° or -45° relative to the E-field arriving at it determines whether the circular polarization is left-hand or right-hand.

In truth, the magnitude of the two orthogonal components will not be equal across the band and will only be so at either end of the range (see Figure 2). The phase shift may also vary with frequency, typically up to 1 or 2 degrees. The combined effect of these variations can be seen in the axial ratio for the instrument (Figure 3)

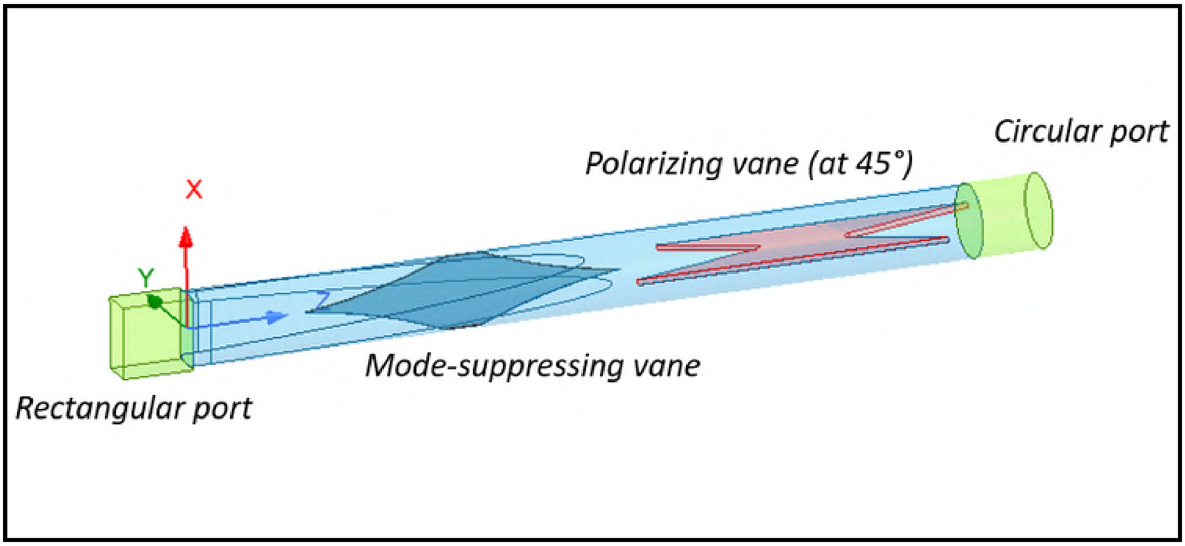

Figure 1. Dielectric Vane Polarizer

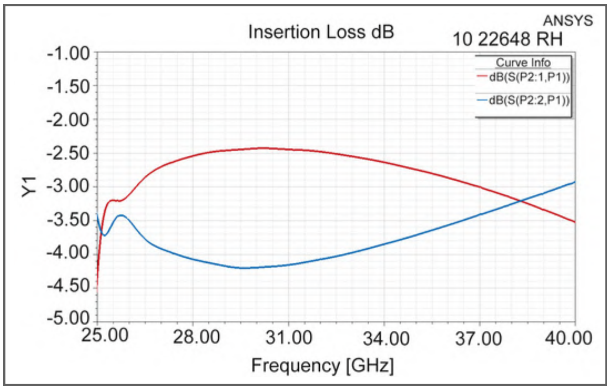

Figure 2. Through Coupling (S12 in dB) to the Two Orthogonal Modes (magnitude only) for a WR-28 (WG22) Dielectric Vane Polarizer (Flann model 22648)

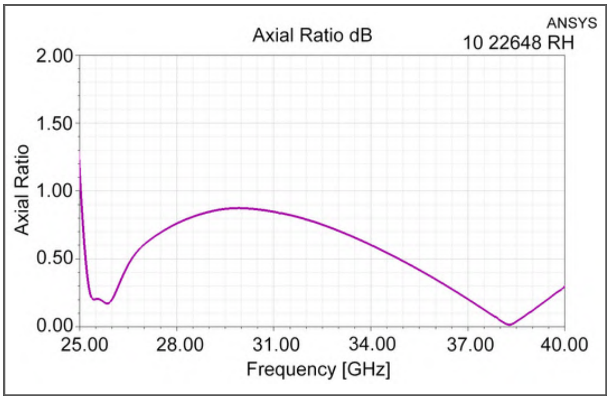

Figure 3. Simulated axial ratio for a WR-28 dielectric vane polarizer

Perfect circular polarization means an axial ratio of 0 dB, which is not achievable in practice and there is always some degree of ellipticity. The simulated axial ratio shown includes the limitations of the basic design, but it does not include the effect of manufacturing tolerance which may introduce additional asymmetry. Examples of this asymmetry include non-perfect roundness of the circular waveguide section and misalignment of the flange.
The vane works in reverse, and circularly polarized waves arriving at the vane will have one component attenuated, resulting in a linearly polarized wave whose orientation will depend on the rotation of the circular wave (left or right hand).

Dielectric vane polarizers can be full waveguide band devices. In the example above full-band is 26.5 to 40 GHz, and the axial ratio is better than 0.9 dB (26 dB cross-polarization) over the whole range. The mode-suppressing vane (shown in Figure 1) has a conductive layer parallel to the E-field of undesired (cross-polar) modes to prevent their reflection back to the rectangular port. Use of the dielectric vane, which does have some loss, limits the power which can be handled by this type of polarizer. The vane is necessarily thin, and its power handling depends on how it is mounted.

Septum Polarizer

The Septum Polarizer uses a stepped septum to convert between linear and circular polarization. The instrument has two rectangular ports that combine at a stepped septum into a square cross-section waveguide (Figure 4). The action of the septum converts approximately half the energy to the opposite polarity with a phase shift of around 90°, so there are both TE10 and TE01 modes, the component parts of a circularly polarized wave. The step lengths and heights are optimized to give the best axial ratio over the target frequency band. A linear sloping taper would work, but steps offer better performance (more equal orthogonal E-field components and correct phase shift). Driving one rectangular port produces right-hand polarization and driving the other produces left-hand polarization, at the common port, which can be either square or circular.

The square size is set by the desired frequency range and therefore the rectangular ports are custom sizes too. The feed to the septum polarizer uses tapered or stepped bends from a standard rectangular waveguide size.

For circular to linear conversion (de-polarization), the component perpendicular to the septum splits either side of the septum, while the phase-shifted parallel component effectively enters single-ridged waveguide and propagates at a lower phase velocity. The resulting fields cancel at one rectangular port and add in the other depending on the sense of the incoming circular polarization.

The figures below show a WR-12 (WG26) septum polarizer designed for E-band operation between 71 and 86 GHz, with the simulated coupling to the orthogonal modes and the theoretical axial ratio in dB. Isolation between rectangular ports is better than 20 dB.

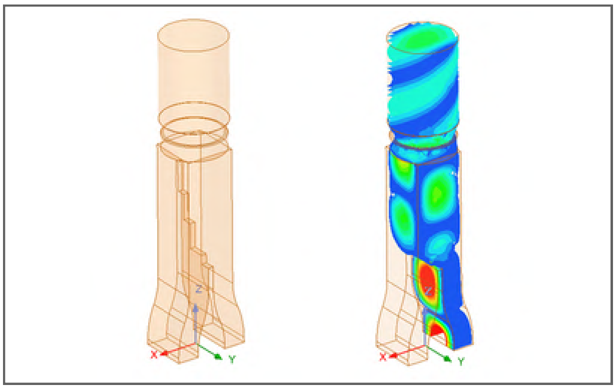

Figure 4. Septum Polarizer in WR-12 (WG26), With and Without the E-field (HFSS simulation)

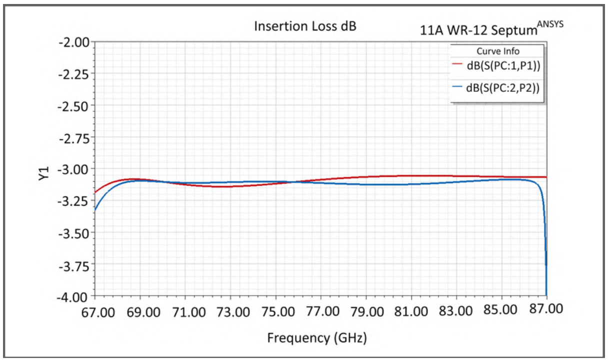

Figure 5. Coupling (S12 in dB) to the two orthogonal modes (magnitude only) for Flann model 26782 septum polarizer

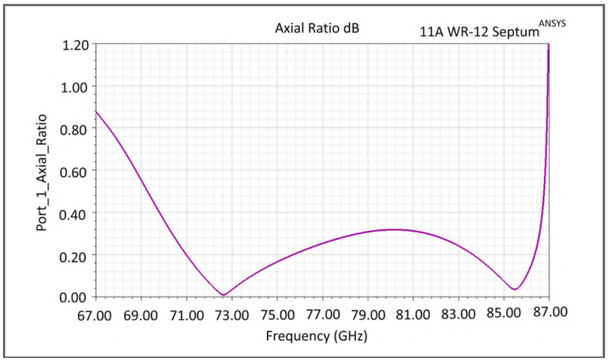

Figure 6. Simulated Axial Ratio, Better than 0.4 dB Over More than Half the Waveguide Band

Corrugated or Iris Polarizer

Corrugated polarizers are able to produce right-hand or left-hand circular polarization from a linearly polarized input and can operate at relatively high power.

Each polarizer is optimised for the frequency band of interest and designs are generally suitable for use over about 40% of a waveguide band.

The guide cross-section is square with ridges (corrugations) on two opposite sides (the other sides are flat). This is shown in Figure 7. The ridges are the same in the two faces. A circular waveguide interface is provided at each port with a re.ctangular to circular transition at one end, forming the full corrugated polarizer assembly. The linearly polarized incident wave is launched into the square guide at 45° to the ridges, which results in it being split into TE10 (parallel) and TE01 (perpendicular) components. The ridges (which can also be described as irises, and the instrument as an iris polarizer) appear inductive to the TE10 mode and capacitive to the TE01 mode, meaning phase advancement and delay respectively. When phase offset between components equals 90°, there is perfect circular polarization at the output port.

The guide is somewhat overmoded and relies on mode-matching to achieve the best axial ratio over a wide band. Rigorous mathematical analysis of the corrugations is possible but complex. A suitable corrugation design can be achieved by optimising towards specific performance goals in a 3D-simulation tool such as Ansys HFSS. The aim is to keep the number of corrugations and instrument length to no more than is needed, by careful use of higher-order modes.

The figures below show a WR-90 (WG16) corrugated polarizer designed for wideband operation, with the simulated coupling to the orthogonal mode, the phase offset between them, and the axial ratio in dB. Although this instrument can operate over as much as half the waveguide band, depending on the degree of ellipticity considered acceptable, the instantaneous bandwidth of the signal to be polarized may be limited to a few hundred MHz due to the higher modes excited

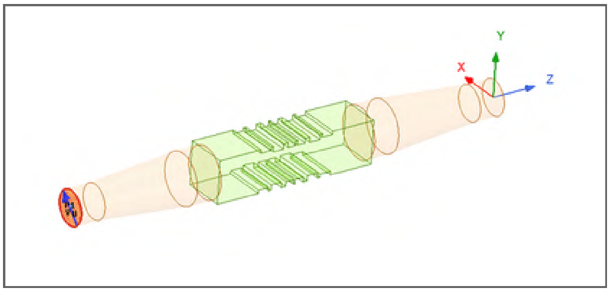

Figure 7a. Corrugated Polarizer in WR-90 (WG16), Showing the Input Polarization at 45°

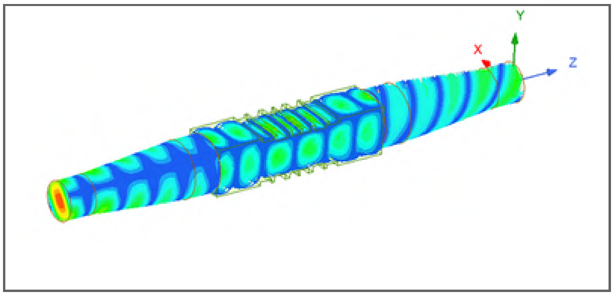

Figure 7b. Corrugated Polarizer with the E-field (HFSS simulation)

In the example shown above, flanges can be arranged to allow the corrugated polarizer to be manually positioned for either right-hand or left-hand circular polarization (i.e., by turning through 90°).

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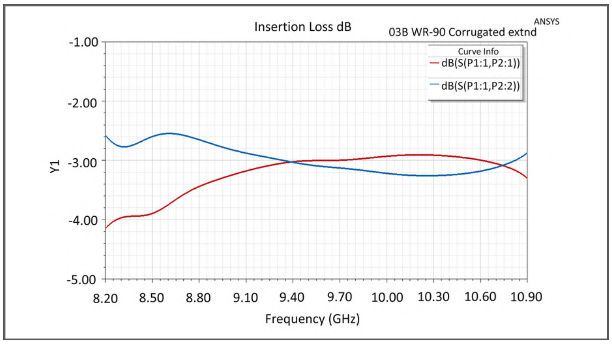

Figure 8. Coupling (S12 in dB) to the Two Orthogonal Modes (magnitude only) for Flann model 16651 Corrugated Polarizer

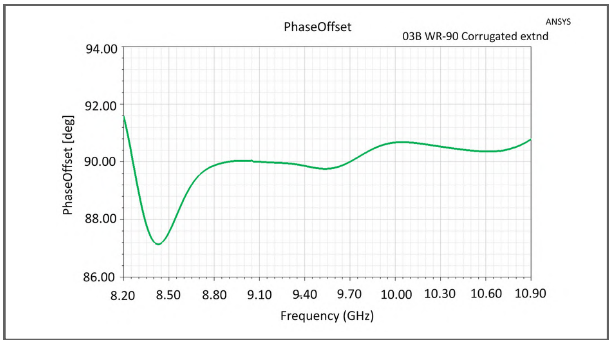

Figure 9. Variation of Phase Offset Between the Two Orthogonal Modes

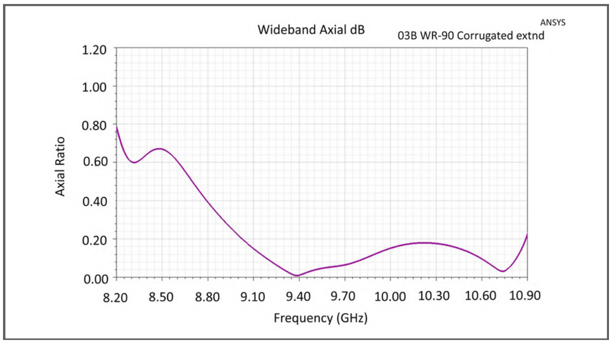

Figure 10. Simulated Axial Ratio, Better than 0.4 dB over 50% of the Waveguide Band, Better than 0.2dB Over 45% of the Band

Improved axial ratio and bandwidth may be obtained using a quad-ridged structure, but this makes both the design and manufacture more difficult. Other possibilities exist for introducing the inductive and capacitive discontinuities needed to make this type of polarizer work, and have been described in the literature, for example central ridges along the length of the waveguide or the use of dielectric posts.

Comparison of Instruments

Of the three waveguide polarizer types described, the dielectric vane polarizer is usually considered to be a full-band instrument which can offer reasonable axial ratio, while the other two types are usable over 40-50% of a waveguide band with superior axial ratio and higher average power rating.

Both septum and corrugated polarizers would typically be machined split-block devices, to allow for accurate manufacture of the internal features. There are possibilities for putting a radius on the sharp edges of the septum or corrugations to reduce the risk of field breakdown when there is a high peak field requirement.

The vaned polarizer can be electroformed as the internal features are the vanes, which can be put in place after making the body of the instrument. Manufacturing costs may determine the most suitable solution for a given application. As wavelengths go down into sub-millimeter territory, vanes become more difficult to make and mount, and the machined features of the other polarizers require expensive and very precise CNC machines. New ways in which polarizers can be made, such as using metamaterials, have been the subject of research in recent years.

Wireless Infrastructure

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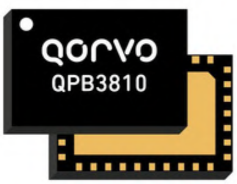

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RF GaN: A World of Potential, But at a Critical Crossword

Aymen Ghorbel & Ezgi Dogmus - Yole Group

Over the last two decades, RF GaN technology has evolved, initially finding its roots in defense applications and now exploring new frontiers in meeting the demands of telecom infrastructure and satellite communications. As GaN-on-SiC technology reaches maturity, it is emerging as a standard for various applications, steadily gaining market share over competing technologies such as Si LDMOS and GaAs. With a focus on power efficiency, reliability, and space optimization, GaN technology is becoming indispensable. The telecom infrastructure market is witnessing a significant shift in power amplifier (PA) requirements, paving the way for GaN-on-Si technology introduced by Infineon on an 8-inch platform in 2023. This strategic move not only intensifies competition with GaN-on-SiC but also could unlock new prospects, especially in the handset market.

Driven by the demands of 5G telecom infrastructure and defense radar applications, the overall value of the GaN RF device market is projected to surge from US $1.4 billion to over US$2.2 billion, according to Yole Group's RF GaN Compound Semiconductor Monitor Q4-23 edition, exhibiting a robust compound annual growth rate (CAGR) of 8.7% during the 2022-2028 period.

While the RF GaN market may not be evolving at quite the same pace over the 2022-28 period as wideband gap (SiC and GaN) markets for power conversion applications, it remains dynamic and is transforming its supply chain. US-based MACOM, a key player in the industry, completed two significant acquisitions in 2023 — French OMMIC SAS for its GaN-on-Si technology and US-based Wolfspeed's RF GaN-on-SiC business, a leader in the RF GaN sector. These strategic moves position MACOM to potentially emerge as one of the leaders in RF GaN.

Concurrently, players such as SEDI, Qorvo, and NXP are maintaining their strong leadership in the RF GaN industry. In China, players like SICC, Sanan IC, Dynax, and CETC continue developing and addressing the local RF GaN market. Earlier in 2023, Infineon introduced the first commercial GaN-on-Si Pa technology on 8-inch wafer to the telecom infrastructure market. Other players like ST Microelectronics, UMC, and GlobalFoundries are likely to follow in the coming years.

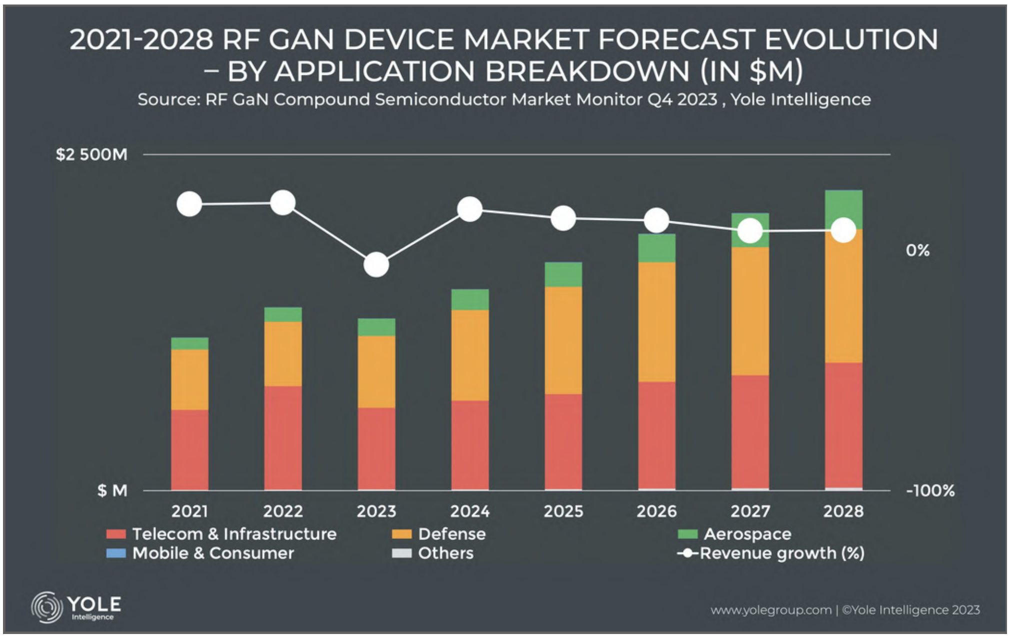

Figure 1. GaN Device Market Forecast

RF GaN Reaching Success for Several Applications

Since the 1990s, the U.S. Department of Defense has recognized the superior output power and efficiency of RF GaN-on-SiC compared to materials such as InP, GaAs HBT, GaAs HEMT, and Si LDMOS. RF GaN not only offers a broader bandwidth but also facilitates a reduction in system size – two attributes highly sought after as telecom infrastructure expands its frequencies and base station models.

The exceptional power and efficiency characteristics of RF GaN have led to its widespread adoption in defense applications, particularly in addressing thermal challenges in higher-power scenarios, such as airborne radar systems. Defense continues to stand out as one of the largest sectors in the RF GaN market.

Airborne systems, characterized by a high device count, are expected to dominate the market, with an increase also foreseen within shipborne systems in the coming years. Beyond the borders of the United States, both Europe and China are actively cultivating their GaN ecosystems, with a specific focus on expanding deployment in military radar applications. Although the electronic warfare market remains largely concealed and shrouded in secrecy, sustained growth is assured from the ongoing demonstrations and GaN projects within this segment. GaN enjoys industry favor over alternative technologies owing to its broadband operation and enhanced reliability. Substantial growth in military satellite communication is anticipated during the period spanning 2022 to 2028. GaN devices emerge as the preferred choice for deploying Ka-band block upconverter systems, showcasing a blend of high-power output and lightweight properties. In the realms of C and X bands, the selection of GaN systems is guided by the crucial criterion of Power-Added Efficiency (PAE).

Simultaneously, RF GaN has begun making inroads into the SatCom market, leveraging its high efficiency compared to other materials to enable smaller device sizes, thereby saving valuable space at the system level. After the telecom infrastructure and defense markets, satellite communication is the third-largest RF GaN market and is expected to reach US$270 million by 2028 with an 18% CAGR2022-2028. RF GaN power amplifiers offer higher data throughput, smaller antennas, wider bandwidth, and better efficiency. Transitioning from L/C/X-bands to Ku/Ka-bands enables higher data rates in mobile satellite communication. While traveling wave tube (TWT) technology was dominant historically, it has limitations, such as bulkiness and reliability issues.

Solid state power amplifiers (SSPA) based on GaAs are gaining interest for low-power and lightweight satellite systems but have efficiency and bandwidth limitations compared to GaN. GaN PAs offer numerous advantages over GaAs SSPAs, making them attractive for various applications like GEO HTS, “New Space,” LEO, and Earth observation at higher frequencies. We are witnessing a growing focus on satellite communications, particularly due to the rising interest in the “New Space” trend. Additionally, the telecom infrastructure industry is showing increased attention to satellite communication, especially with Space X's plans to provide 5G coverage through satellite technology. This approach raises the possibility of a world without areas lacking reliable phone network coverage. RF GaN technology can take this opportunity to increase its presence in the market.

Originally introduced by Huawei in 2015, volume production of GaN-on-SiC for telecom infrastructure began in 2020 for 4G base stations. Since then, RF GaN technology has benefitted from the 5G rollout by meeting the new base station requirements and replacing LDMOS technology. There have also been significant investments from companies around the world, such as SEDI, Wolfspeed (whose RF business is now part of MACOM), NXP, and Qorvo, ensuring GaN-on-SiC dominates in its target applications and replaces its counterpart Si LDMOS.

4G micro and macrosite base stations are predominantly based on remote radio heads (RRH), integrating the base station’s RF chains and analog-to-digital conversion components with up to eight multi-stream PAs at up to 100W output power.

As the 4G era is coming to an end, the reliance on LDMOS-based PAs in 3GHz base stations is expected to recede. Emerging sub-6GHz 5G base stations are moving from a 2x2 MIMO model to a 64x64 Massive MIMO (mMIMO) with active antenna systems (AAS) replacing RRHs.

At the same time as increasing the number of PAs, each PA is expected to operate with a lower output power (from 100W to 5W). PAs are also required to handle increasing data traffic volumes while reducing power consumption.

GaN can address all these requirements. The LDMOS market share is expected to decline as GaN-on-SiC addresses frequencies up to 7GHz for 5G. For 5G mmWave and 6G, as the requirements are more for high frequencies and lower power, RF GaN technology is expected to face tougher competition with other materials such as SiGe and InP technology.

How can RF GaN evolve?

As the sub-6GHz 5G telecom base station demands PAs with lower power, GaN-on-Si stands to carve a niche in 32T32R / 64T64R mMIMO base stations operating below 10W. Over the past two years, key players like STMicroelectronics with MACOM, OMMIC (now part of MACOM), GCS, Infineon Technologies, and foundries such as Global Foundries and UMC have collaborated to introduce RF GaN-on-Si technology.

The shift to mmWave small cells (2- and 4-stream) operating at 28 – 60GHz with reduced output power presents an additional opportunity for GaN-on-Si. As telecom infrastructure increasingly adopts lower output power systems, the adoption of GaN-on-Si is propelled by the requirements of Antenna Array Systems (AAS) and small cells to meet the demands of multi-stream, small cell, and mmWave beamformer performance. Looking ahead to the next generation, 6G, which will feature even higher frequencies, GaN-on-Si is anticipated to coexist with the incumbent technology, GaN-on-SiC.

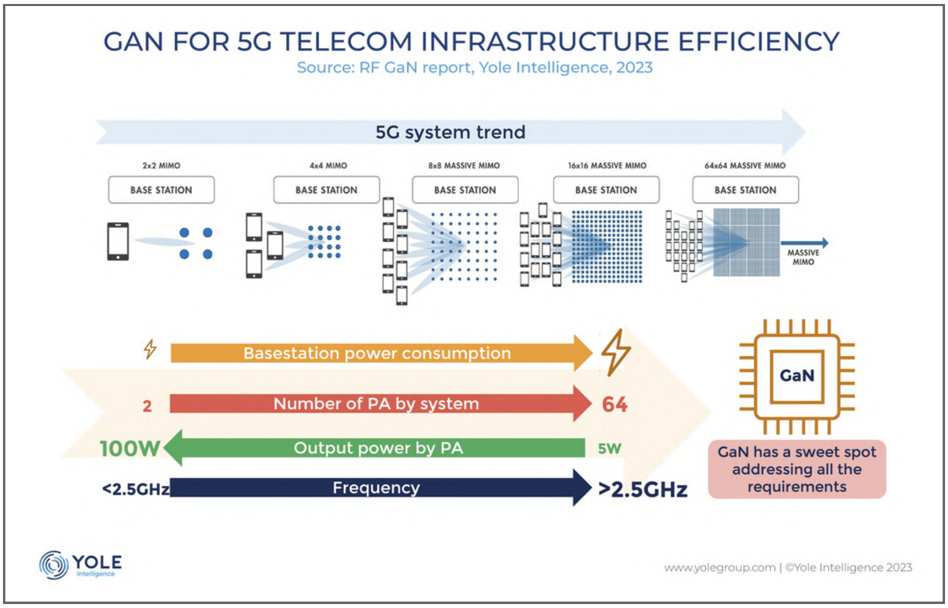

Figure 2. GaN for 5G Telecom Infrastructure Efficiency

In a significant development this year, Infineon Technologies introduced GaN-on-Si PAs on 8" technology to address the telecom infrastructure market. Anticipating a trend, other major players like Global Foundries, UMC, MACOM, and STMicroelectronics are expected to follow suit in the coming years. Notably, many players opt to enter the market directly with GaN-on-Si, bypassing the use of GaN-on-SiC technology.

GaN is projected to constitute over 87% of telecom infrastructure PA device shipments by 2028. Within this, more than 77% will be GaN-on-SiC and 10% GaN-on-Silicon, while LDMOS is expected to lose market share.

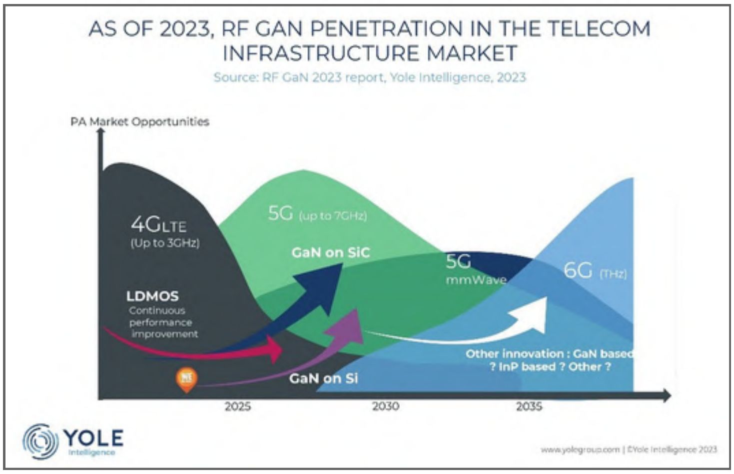

Figure 3. RF GaN Penetration


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The prospects for GaN-on-Si technology extend to 5G handset power amplifiers in the FR3 band. While there is potential for GaN-on-Si in sub-7GHz and 5G mmWave frequencies for handset PAs, it's essential to acknowledge the existing dominance of well-established GaAs solutions in sub-7GHz and the traction gained by silicon-based solutions in mmWave applications. These technologies, having matured both in terms of technology and supply chain, present themselves as significant competitors. In the open competition of FR3, GaN-on-Si holds promise but requires complex design changes for integration into handset systems, making its adoption in the FR3 band a longer-term goal.

The decisive influence of the fate of GaN-on-Si technology ultimately lies with smartphone Original Equipment Manufacturers (OEMs) such as Apple, Samsung, and Xiaomi, potentially serving as a turning point for the GaN-on-Si industry.

A Moving Ecosystem for a Dynamic Market. RF GaN Still Raises Attention and Questions.

Today, GaN-on-SiC, as the primary platform, has a well-established supply chain. Device suppliers such as SEDI, Qorvo, Wolfspeed and NXP, as well as defense-related companies Raytheon, BAE Systems, and Northrop Grumman, offer GaN-on-SiC technology. In 2022, SEDI, Qorvo, and Wolfspeed were the leading players in RF GaN. As a newcomer in the GaN space, NXP has experienced significant growth by entering the telecom supply chain with the opening of its 6-inch GaN-on-SiC fab in the US in 2020. In a short time, the company, which also has an LDMOS offering, has become a leading player in the GaN-based telecom infrastructure sector. Furthermore, GaN-on-SiC has welcomed innovative players like Altum RF, mmTron, and Gallium semiconductors over the last few years. Now, this expanding industry makes more room for GaN-on-Si technology, where low-power GaN solutions are promising for 32T32R / 64T64R mMIMO base stations below 10W, with ever more products becoming available this year.

The S.I. SiC wafer market remains shared by the three major suppliers, Wolfspeed, Coherent, and SICC. In the defense segment, Raytheon, Northrop Grumman, and Chinese CETC are leading in the adoption of GaN. DoD-trusted Wolfspeed and Qorvo also serve as GaN foundries. Focusing on the supply to the telecom market, Ericsson and Nokia keep stretching the supply of the volume of RF GaN devices from multiple device suppliers while Samsung cooperates closely with Korean device players. Since the US sanctions, Huawei and ZTE have turned to the Chinese supply chain to develop domestic capability.

To overcome the US sanctions, China continues developing its domestic RF GaN technology and the Chinese supply chain. In the GaN-on-SiC eco-system, the leading players are world-class at the wafer and end-system levels, such as SICC, Sanan IC, CETC, Dynax, Huawei, and ZTE. Since 2020, China has been accelerating the development of epiwafer, front-end, and back-end processes and design. More than one active player at each level has been identified, showing the Chinese ecosystem's progress in the past two years. At the device level, GaN-on-SiC at the 0.25μm node has become available from HiWafer and Sanan IC to serve the existing sub-6GHz market. In our understanding, Sanan IC is also working to develop GaN-on-Si technology.

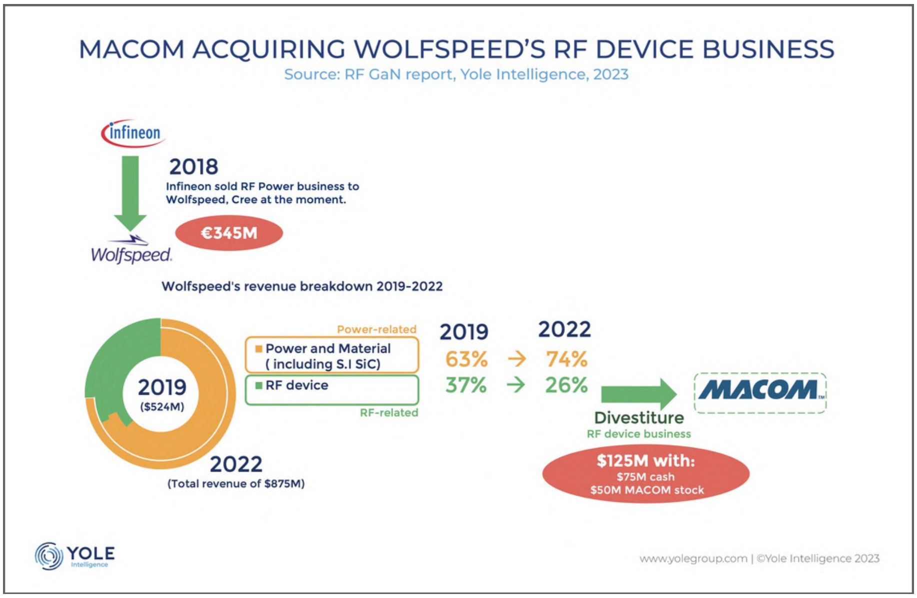


Figure 4. MACOM Acquisition of Wolfspeed's RF Business

Yole Intelligence's RF GaN 2023 report accurately predicted Wolfspeed's decision to divest its RF business, marking a strategic shift toward SiC power technologies. Acquired for US$125 million from Infineon Technologies after an initial purchase of US$345 million in 2018, this move positions Wolfspeed as the primary player in the power SiC industry. The decision to cease supplying competitors after the sale enhances their potential for expansion.

In parallel, MACOM's early exploration of GaN-on-Si and alignment with STMicroelectronics since 2018 has positioned it as a pioneer. The successful production of RF GaN-on-Si prototypes in 2022 reflects their commitment to introducing GaN-on-Si technology, emphasizing applications in the telecom and consumer sectors. MACOM's strategic acquisition of OMMIC SAS in 2023 showcases their dedication to mmWave technology, enhancing their portfolio for the defense and aerospace sectors in the US and Europe.

Responding to defense sector demands, MACOM strategically shifted focus to GaN on SiC technology in the early 2020s, specializing in high-power devices up to 7kW. Collaborating with the US defense sector, their partnership with the Air Force Research Laboratory achieved significant progress in GaN on SiC technology, operating at high frequencies in the K to Ka-band.

MACOM's recent acquisition of Wolfspeed's RF business strengthens its position in the defense, aerospace, and telecom markets. Leveraging Wolfspeed's standing in the RF GaN market, MACOM has solidified its strategic presence, emphasizing its commitment to expanding its share in the RF GaN market with a comprehensive portfolio covering GaN-on-Si and GaN-on-SiC technologies across a wide frequency range.

Regarding the GaN-on-Si ecosystem over the last years, companies such as STMicroelectronics, MACOM, Infineon Technologies, and foundries like Global Foundries and UMC have been actively involved in the development and introduction of RF GaN-on-Si technology. Infineon Technologies introduced GaN-on-Si PA technology on 8” wafer earlier this year to address the telecom infrastructure market. We expect other players to follow.

Companies like GlobalFoundries, STMicroelectronics, and Infineon are already active in the power GaN industry. Despite challenges such as technology node and epitaxy control, these players are exploring synergies between RF and power GaN, leveraging similar GaN-on-Si technologies to address distinct markets.

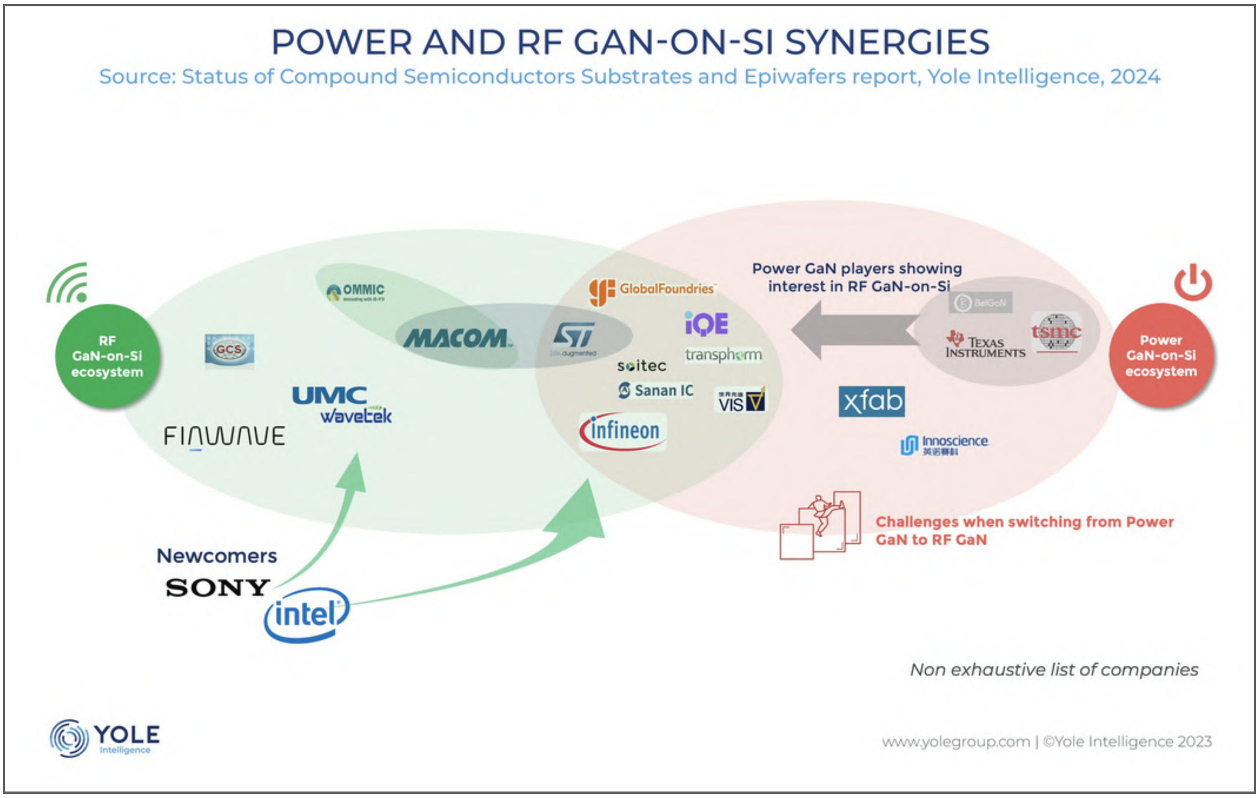


Figure 5. Power and RF GaN-on-Si synergies

Additionally, innovative companies are entering the ecosystem, like Finwave, which is focused on developing 3DGaN FinFET technology on 8-inch GaN-on-Si wafers. They are utilizing standard silicon foundry tools in their development process. Alongside these innovative companies, established companies like GCS, UMC, Sony, and Global Foundries have the potential to adapt and enter the market quickly.

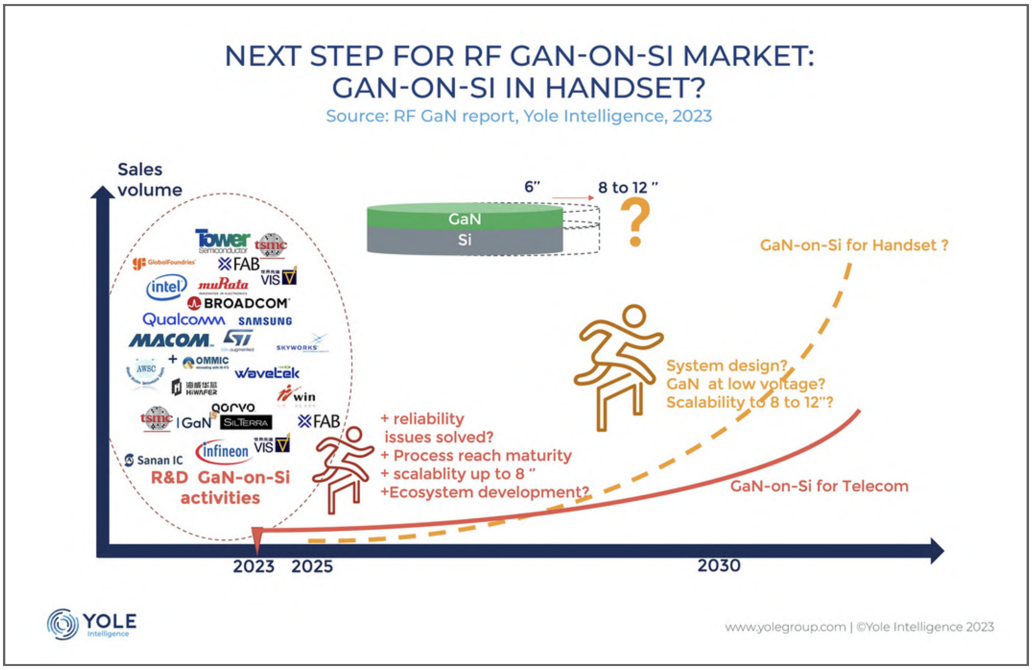


Figure 6. Next step for RF GaN-on-Si Market

The players are preparing for these killer applications to run their technology and open a new era for high-volume GaN-on-Si manufacturing in the RF industry.

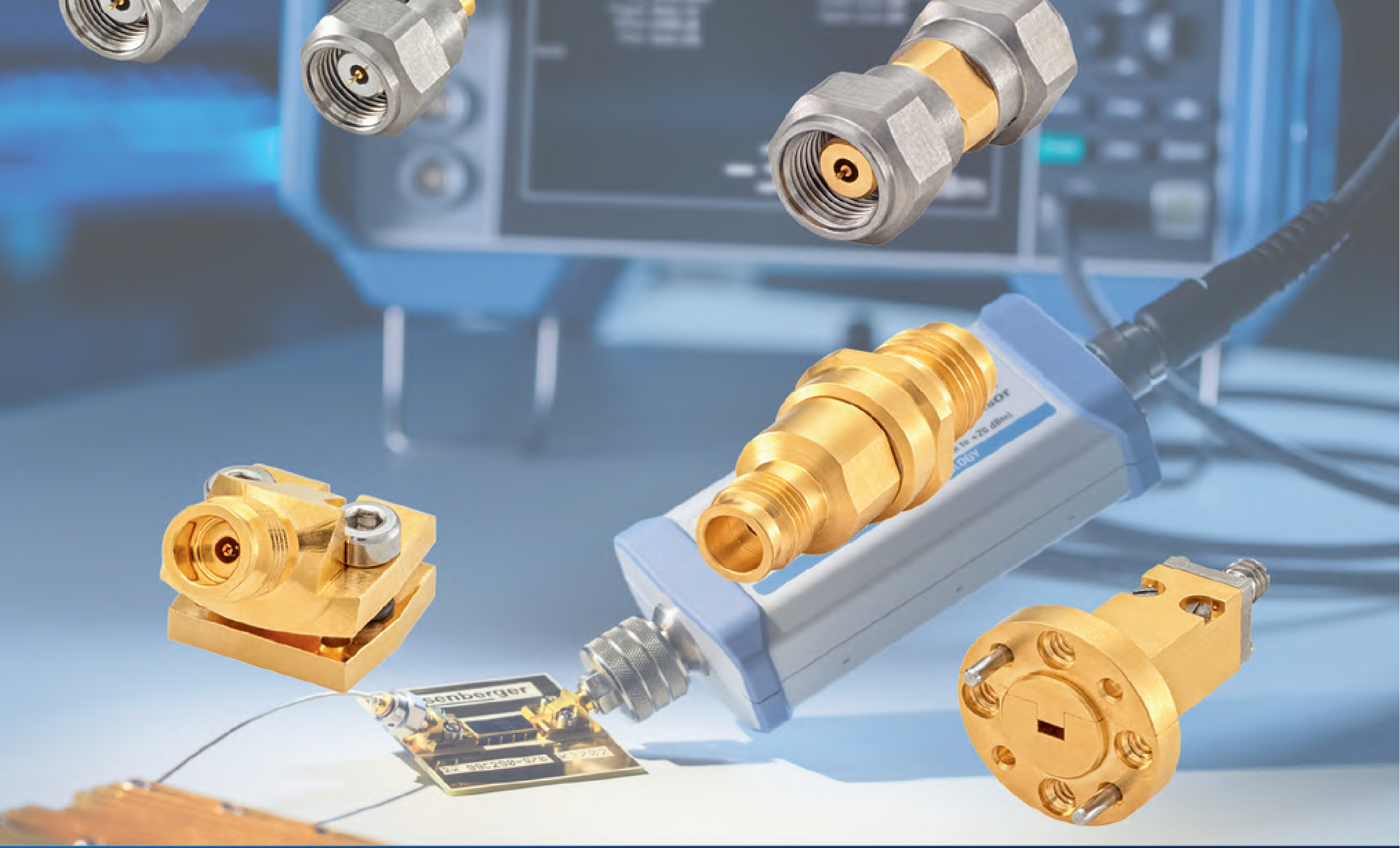
What comes after for the RF GaN industry?

In conclusion, the RF GaN industry has transformed over the last two decades, moving from dominating in defense applications to coexisting in several markets, such as telecom and satellite communications. GaN-on-SiC technology has become a mainstream technology in defense and telecom infrastructure PAs, gaining market share. The introduction of GaN-on-Si in telecom infrastructure hints at growth and opens new opportunities. Yole Group's RF GaN Compound Semiconductor Monitor Q4-23 edition predicts strong growth, driven by 5G and defense applications, and expects the RF GaN device market to exceed US$2.2 billion by 2028.

The year 2023 has been significant so far, with two remarkable strategic acquisitions from MACOM that could help them gain more market share in the current landscape, while Infineon introduced the first GaN-on-Si Pa technology based on their 8-inch platform.

Globally, GaN is gaining importance in defense, particularly in airborne systems. The advent of 5G offers opportunities for GaN in mMIMO base stations, extending into the anticipated 6G era. GaN-on-Si shows promise in handset technology trends but faces stiff competition from established platforms. The RF GaN-on-Si supply chain is diversifying with new players, fostering sustainable market growth in the future.

In the final analysis, the RF GaN industry stands at a pivotal juncture as GaN-on-Si technology matures. This prompts contemplation: Is it the opportune moment to explore new growth prospects in untapped markets? Alternatively, will GaN-on-Si manage to secure a larger market share over GaN-on-SiC?



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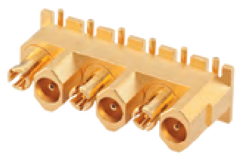

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Solving the Issue of Reflected Waves at D Band

Greg Rankin - Micro Harmonics

Looking to deliver reliable test, measurement and prototyping equipment for D band, led NI to THz-enabled isolators designed for NASA.

The call for "more D band" has gone out. With the ability to transmit 100 Gigabits per second (Gbps), the D band will unlock a number of technologies across a wide range of industries. Wireless communication is often the focal point, but commercial applications include high-precision sensing, radio astronomy, and airport security detectors. For the military, the D band will open the door to the next generation of inter-satellite links, imaging radars, and stand-off detection.

However, as research and development teams attempt to deliver on the much-anticipated move into the frequency range between 110-170 GHz, they are running into a common problem of signal reflections, also known as mismatches. These undesirable waves, or ripples, can attenuate power output, distort the digital information on the carrier and, in extreme cases, damage internal components. To offset the issue of mismatches at lower microwave frequencies, engineers rely on Faraday rotation isolators but at higher frequencies, like those within the D band, traditional isolators often struggle to deliver the same results.

"When you get above 110 GHz it's sort of uncharted territory," explains Ed Loewenstein, Chief Architect at NI. "Your connectivity gets a little strange and cables don't work very well anymore. So, most things are done in waveguides."

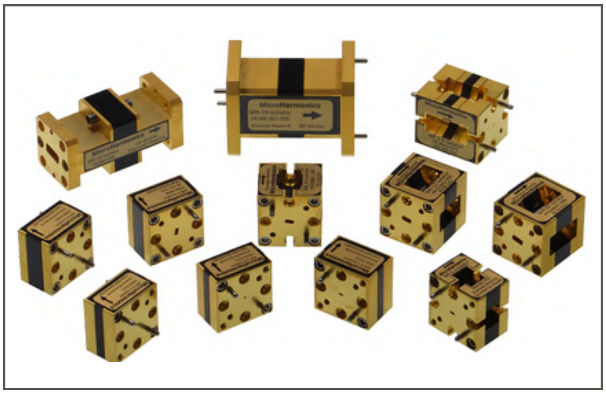

Figure 1. Micro Harmonics Isolator Collection

Suppressing signal reflections

Until recently, there has been limited test and measurement equipment available at D band frequencies, with few standards and little-to-no traceability to NIST (National Institute of Standards and Technology).

"What we often hear is that once someone sets up their equipment to make a test or measurement at these frequencies and something doesn't go quite right, they spend most of their time trying to figure out whether it's their test equipment or the device that they're testing," adds Loewenstein.
Therefore, the development of the D band is dependent on companies like NI, formerly known as National Instruments, which create the equipment that engineers rely upon to efficiently and accurately perform comprehensive research, testing, and validation. However, recently, as the company was looking to create a new 6G sub-THz reference architecture they ran into the issue of reflected waves themselves in the waveguides.

"We were really struggling with bad mismatches in our waveguide system and kept getting these really bad frequency ripples," adds Loewenstein.

In millimeter wave (mmW) systems, the distance between components is often much larger than a wavelength. As you sweep frequencies, the phase changes and there are nulls, dips, and degraded performance. To resolve that in microwave frequencies, engineers simply insert an isolator between components, and the reflected signal gets absorbed.

However, as you move up the electromagnetic spectrum shorter wavelengths require smaller constituent parts. At mmW frequencies, the parts are tiny and even the smallest misalignment can significantly degrade performance. As demand for D band systems increases, so does the number of isolator options available. Unfortunately, their performance still lags behind what engineers have become accustomed to at lower frequencies.

Advances in mmW Isolator Design

“We evaluated the isolators on the market from what data was available and it was pretty easy arithmetic to see that Micro Harmonics was the most appropriate thing for us,” adds Lowenstein.

Micro Harmonics Corporation is a Virginia-based manufacturer specializing in the design of mmW components. Under a NASA contract, Micro Harmonics essentially reinvented the isolator so that it can operate well into THz frequencies.

The traditional method to manufacture an isolator has been to use ferrites that are substantially longer than required, and then tune the magnetic bias field to achieve optimal performance. This delivers good isolation but at a much higher insertion loss.

What Micro Harmonics did to minimize loss was reduce the ferrite length by as much as possible. The design developed for NASA saturates the ferrite with a strong magnetic bias field, which allows for the shortest possible length of ferrite to achieve the ideal 45° of rotation. This lowers the insertion loss to less than 1 dB at 75-110 GHz and only 2 dB at 220-330 GHz.

The only way to confirm such precision is to fully characterize each isolator on a vector network analyzer. This validates total compliance, as opposed to just spot-checking at a couple of frequencies in the band. The test data are then supplied with each isolator.

“They are one of the vendors that we’ve encountered that actually supplies full S-parameter files, which include magnitude and phase,” says Lowenstein. “When dealing with a high-value component, whose performance you are counting on, I would say this type of information is essential.”

Meeting deadlines for D band

NI needed to deliver its new mmW test and measurement equipment as well as its advanced software-defined radios which can greatly accelerate prototyping and next-gen wireless innovation.

Loewenstein says it was important that the isolator could cover the entire D band which the isolators designed for NASA could do.

“It was a nice bonus that it is designed in a small cube, so it fits directly onto a flush surface without a rear accessible flange, explains Loewenstein. “You don't need extra waveguide sections or anything.”

Figure 2. NI 6G Sub-THz Test Setup

NI measured their systems before and then after inserting the isolator and saw a noticeable improvement in the ripple which they said was due to cleaning up the mismatch reflections. This allowed them to announce the 6G Sub-THz reference architecture that provides calibrated measurements with up to four gigahertz of modulation bandwidth.

“We can now receive and transmit at D band. We can also use software-defined radio techniques to prototype and make measurements that are traceable to a power meter,” says Loewenstein.

The insatiable demand for data bandwidth, especially for communications, and the existing spectrum available within the D band has companies charging ahead at lightspeeds. As part of that allure, the FCC recently allowed some experimental licenses in the D band and up to 220 gigahertz so that people can begin to develop new broadband communication methods that use those frequencies.

“Right now, people are looking to do research in sub-terahertz communication. They are designing future chipsets, radio links, or the protocols,” explains Loewenstein. “So, we are looking to allow them to make tests and measurements as well as utilize our software-defined radios to enable future growth within the D band and beyond.”

Crystals & Oscillators

Featured Products

ECS Inc.'s ECX-34Q Automotive Grade Tuning Fork

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ECS Inc. International

RTN5032A - 5 x 3 Ultra Stable TCXO with <50 fs ultra-low jitter

The RTN5032A is one of the first products based on Rakon's newly released Ultra Stable TCXO platform, Niku. In addition to high stability, this Stratum 3 TCXO offers ultra-low jitter of <50 fs and a low g-sensitivity of 0.2 ppb/g. Available frequencies range from 10 to 100 MHz, making this TCXO the right fit for applications such as 5G / 5G Advanced RAN, data centres, satellite terminals and Industry 5.0.

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Ultra-Low Power and High Stability Oven Controlled Crystal Oscillator (OCXO)

The OCXO3321AW02 is an ultra-low power (90mW typ. @25°C) high stability OCXO with a small size and fast warm-up time (60s typ. @25°C). Its excellent frequency stability (Less than ±2PPB from -40°C to +85°C) and performance make it possible to replace TCXO's in hand-held communication equipment to provide reduced communication delay and improved synchronization accuracy.

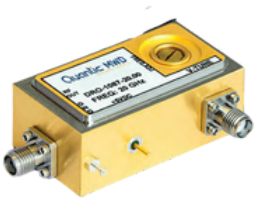
Dynamic Engineers, Inc

DRO based Phase Locked Oscillators

The NEW line of DRO based Phase Locked Oscillators from Z-Communications, Inc. provide high frequency sources with exceptional phase noise, packaged in an all-metal enclosure suitable for lab/field use. The FSG9000LX provides a clean 9GHz signal with -110 dBc/Hz @ 10KHz and +15 dBm output power, drawing only 150mA, while locked to an external 100 MHz reference. The FSG-LX series products are offered in frequencies from 8 - 16 GHz.

Z-Communication, Inc.

Space Qualified Free Running Dielectric Resonator Oscillator



Available from 1 to 36 GHz, the DRO-1080 series is hermetically sealed for mission-critical space applications. Quantic MWD performs assembly, testing, screening and qualification testing for free-running DRO's according to different classes and levels of military and aerospace agencies' specifications. Quantic MWD is certified under the new AS9100 Rev. D quality management system.

Quantic MWD

Golden VHF Bootstrap Oscillator

Available from 80 MHz to 130 MHz, the Golden VHF Bootstrap oscillator provides ultra-low phase noise performance and low-g sensitivity of better than 5e-11/g below 300 Hz offsets, and 5e-12/g sensitivity above 300 Hz when vibration isolation is included. Their proprietary bootstrap oscillator technology consists of two rugged OCXOs of the same frequency phase locked together.

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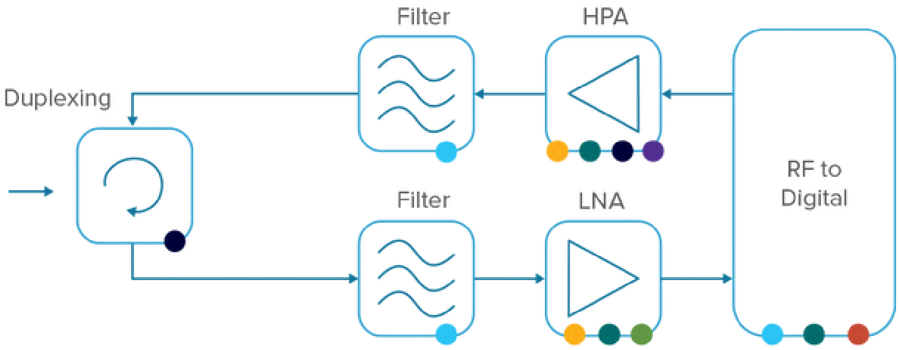

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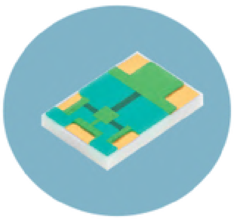

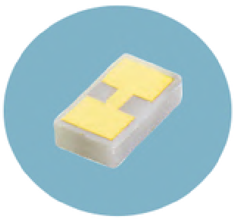

TAOGLAS

GNSS Antenna Selection Guide

Baha Badran - Taoglas

As GNSS technology continues to advance, a new reality is emerging. Our world increasingly relies on location-based services for daily activities, and this trend is set to continue. According to research by Markets and Markets, the global GNSS chip market is projected to grow to $4.9 billion by 2026, representing a remarkable 48% growth over the next five years. The rise of autonomous vehicles, advanced robotic applications, precision agriculture, and many other use cases is spurring this demand. As a result, we are witnessing GNSS technology become a more integral part of our daily lives, cities, and industries.

In recent years, there has been a trend towards combined technologies (sensor fusion, PPP, RTK etc.) in GNSS systems, resulting in productivity gains and devices that are increasingly accurate and versatile. However, this adds further complexities and challenges for antenna design.

Selecting the correct GNSS antenna performance is crucial to deliver a high level of accuracy and to justify the GNSS receiver's cost. GNSS signals are extremely weak; with that, you need a high-performing antenna and receiver, but most importantly, the optimal integration for the antenna, which many underestimate. Poor antenna integration will result in poor system performance, low accuracy, delays in device development, and commercial costs, ultimately leading to unhappy customers. So always consider which antenna best suits your application and the required receiver, and ensure you integrate them properly inside your device.

Choosing the most suitable GNSS antenna for your device can be daunting, especially with many available options. In this article, we will determine the necessary considerations for selecting your device's GNSS antenna.

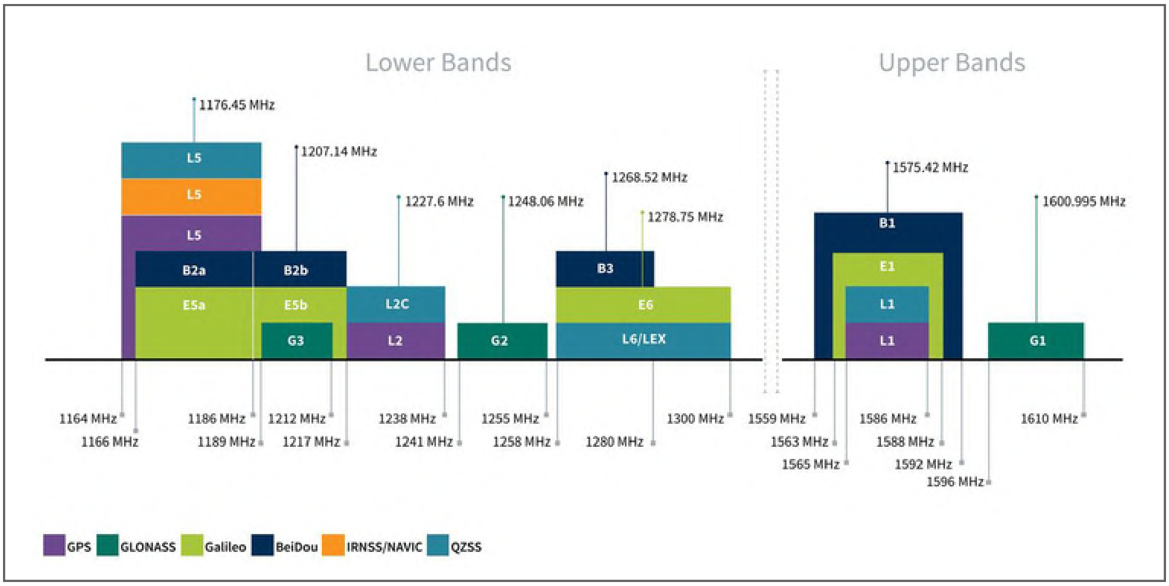

Figure 1. GNSS Constellation Types and Spectrum Bands

Figure 1 shows the bands that each constellation uses. The most common band used for GNSS is the L1 band, as it's been available for several years. But in the last few years, bands L2, L5 and L6 were made available to the public sector, and they are allowing greater access to many more satellites. The introduction of the L2 band, the increasing availability and utilization of L1+L5, and the development of dual-band receivers have all contributed to improved positional accuracy and reduced impact from ionospheric errors and interference in GNSS systems.

Multi-Constellations GNSS Systems

While GPS-based positioning served us well in the past for applications such as navigation and logistics, today's use cases demand higher precision. In particular, mission-critical applications such as emergency services and autonomous driving require cm-level accuracy.

New technologies such as Real-Time Kinematic (RTK), which uses a reference ground station to provide real-time corrections to GNSS signals, can correct errors in GNSS signals and other positioning systems. Additionally, a multi-constellation, multi band approach helps to minimize the influence of obstructions caused by cityscapes or foliage and enables more precise location information. These receivers can improve accuracy and reliability by combining signals from multiple systems, such as GPS, GLONASS, and Galileo. Consumer chipset manufacturers have recognized the benefits of multi-constellation, with more than 30% of all chipsets supporting four constellations.

Multiband GNSS Receivers

When it comes to multiband GNSS receivers, selecting the correct radio module plays a crucial role in boosting the precision and reliability of your device, as it determines the constellations and bands accessible to you. To maximize the capabilities of your GNSS receiver, choose a device that offers access to a wide range of constellations and bands. By doing so, you ensure that your receiver can tap into the signals transmitted by multiple satellite systems, enabling you to benefit from a larger pool of measurements, achieve enhanced accuracy in your positioning calculations and open a world of capabilities for improved performance in positioning.

The accuracy of a GNSS receiver is also heavily dependent on the quality of its antenna. A poor-performing antenna can introduce errors in the positioning data, leading to reduced accuracy and sub-par performance. To simplify selecting the appropriate antenna, Taoglas provides reference guides for leading module providers including u-blox, Nordic, and Sierra Wireless, making it easier to filter and choose the most suitable antenna for the module. By selecting the right radio module and antenna combination, device manufacturers can optimize their products' performance and improve the user experience.

GNSS Antenna Form Factors and Environment

GNSS antennas come in many different sizes and form factors from chip, flexible PCB, and patch to dipole and helical. Figure 2 summarizes the major types and characteristics.

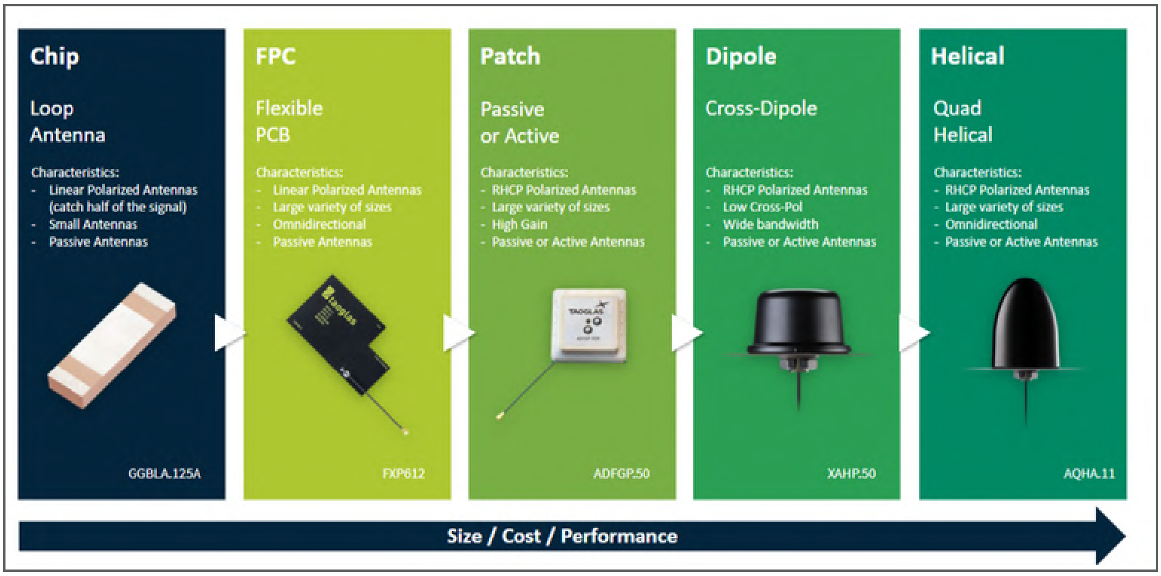

Figure 2. GNSS Antenna Types, Characteristics and Form Factors

The type of antenna you choose for your device will depend on the commercial application of the device. Key considerations include (but aren't limited to) the device's application/use case, the type of enclosure you need, how much space is available, what kind of directionality is required, if the device is static or mobile and how you will connect the antenna.

Motorsport Telemetry solutions can help us understand some of the challenges and considerations when choosing an antenna. In Motorsport, accuracy is everything. The margins are impossibly slim, and the difference between winning and losing can come down to a few thousandths of a second. The harsh environment of racing vehicles also presents unique challenges, such as heat and vibration, so when developing a telemetry solution, you're straddling the boundaries of what is both technically and physically possible. Every gram counts - the antenna needs to be highly compact and lightweight, so it doesn't affect the vehicle's overall weight. In addition, it needs to work across several frequencies seamlessly. Lastly, it is essential that the antenna solution can withstand harsh conditions for long periods without its performance being affected. In this case, choosing a high-performing, multi-band GNSS antenna such as Taoglas' ADFGP.60A is an example of considering these challenges. It is made from Terrablast, a material used instead of traditional ceramic antennas when impact resistance and weight are key considerations for the devices use case. Terrablast antennas are 30% lighter than ceramic antennas and highly durable, making them the perfect solution for a mobile environment. Additionally, it performs well on all worldwide GNSS bands, including the L-bands.

GNSS Antenna Performance

The typical parameters you need to consider for your GNSS antenna's performance are the Antenna Gain, Axial Ratio, Phase Centre Offset (PCO), Phase Centre Variation (PCV) and Group Delay. Figure 3 further demonstrates these characteristics in detail.

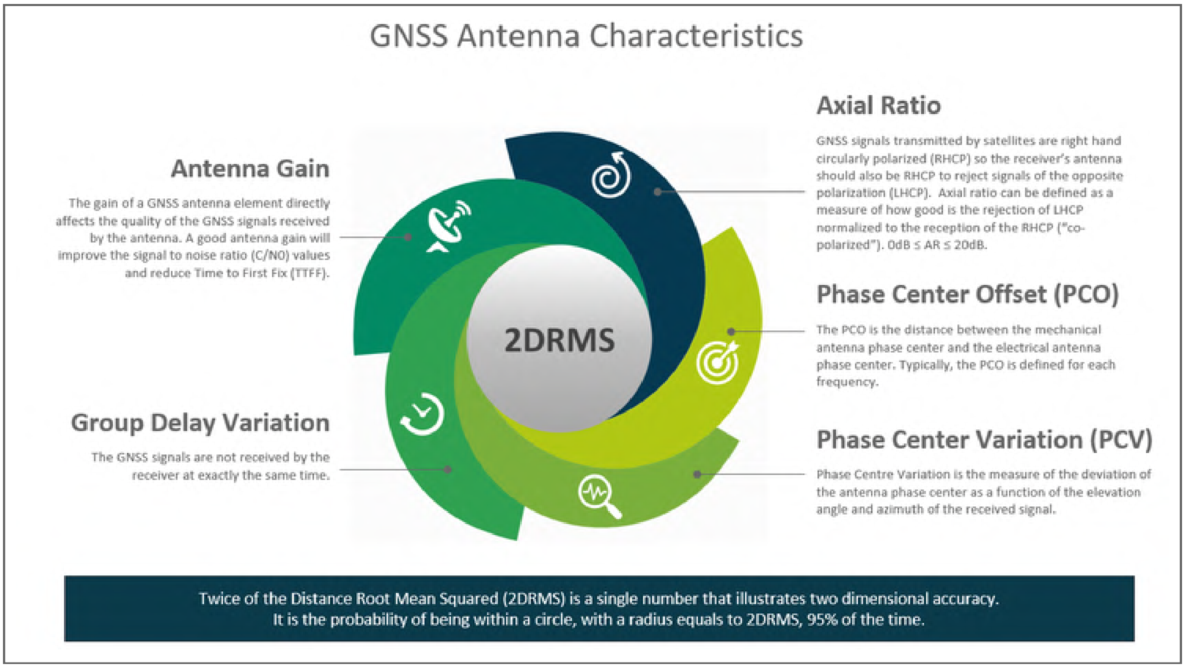

Figure 3. GNSS Antenna Characteristics

GNSS System

From the perspective of RF Engineers, when analyzing the GNSS system or subsystem within a product or device, we perceive it as comprising multiple distinct parts rather than a single subsystem. Additionally, we recognize that the GNSS system cannot be considered in isolation; it is essential to assess the entire product and understand that external factors may impact device performance or introduce issues. Figure 4 illustrates a comprehensive GNSS system encompassing the receiver, RF front end (which integrates the antenna and receiver module within the subsystem), and the antenna.

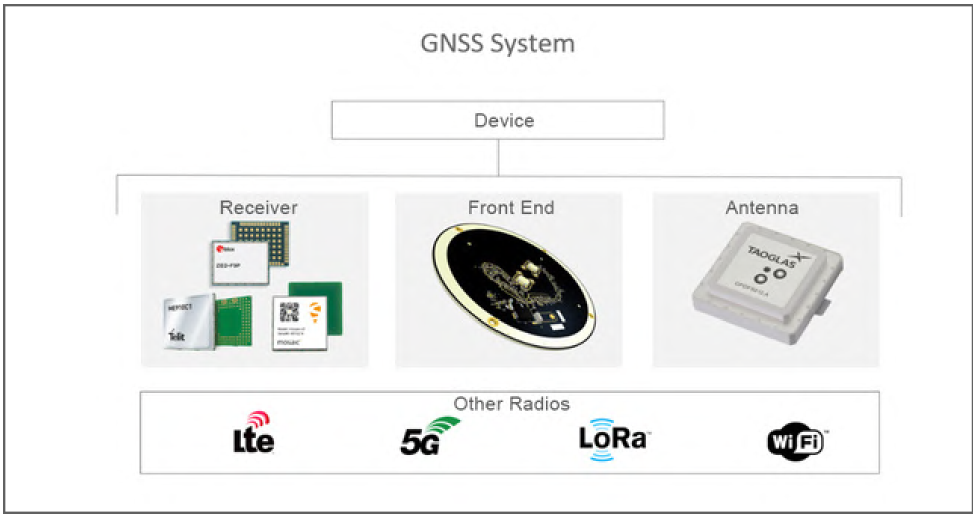

Figure 4. GNSS System

It is crucial to recognize that the GNSS system cannot be evaluated independently, as other factors can potentially cause problems. These include other radios and potential sources of noise and interference, even if they operate outside the GNSS system bands. Failure to account for these factors may result in jamming and interference with the GNSS system. While 3G GPRS radios posed challenges a decade ago, the concern today is typically LTE, and we anticipate 5G to present future issues.

GNSS Antenna Location and PCB Size

Ceramic Patch Antennas

Ceramic patch antennas are typically the primary form factor considered for a standard GNSS antenna.

It is essential to determine the optimal placement of the patch antenna, whether on a PCB or a ground plane. We recommend using a PCB with dimensions of ideally 70x70mm; however, that does not mean you cannot make this area larger or smaller. Increasing the size results in higher gain and a more directive antenna. Conversely, reducing the size of the ground plane leads to decreased gain and efficiency. Figure 5 demonstrates examples of GNSS ceramic antenna placement, illustrating that moving it towards the corner will necessitate tuning. Additionally, bandwidth and gain may also be affected. For applications requiring high precision, it is advisable to position the antenna in the middle. If you need to fine-tune the antenna you should reach out to an RF Engineer for assistance.

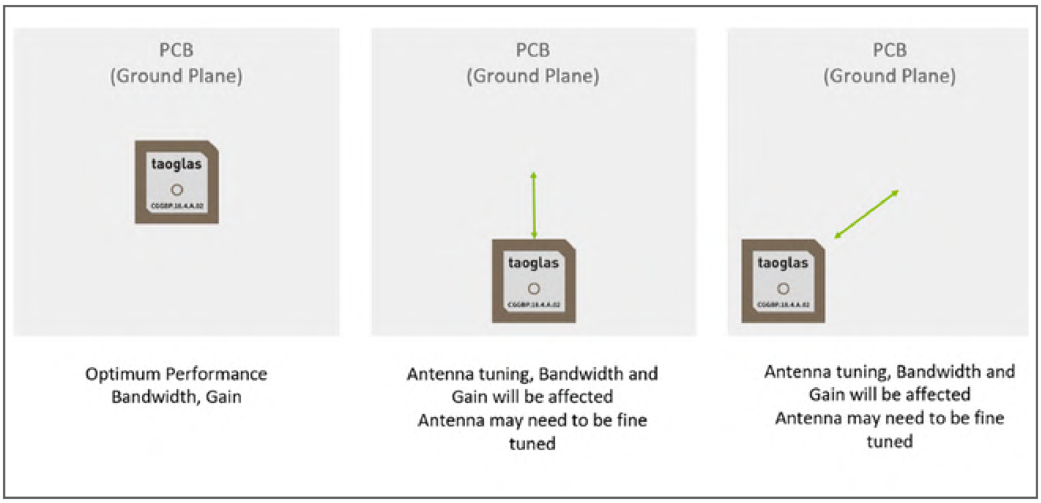

Figure 5. Examples of GNSS Ceramic Antenna Placement

Flex Antennas

Flex antennas offer an ideal solution for device designs where flexibility and space limitations are important considerations. These antennas can be easily mounted on nonmetal surfaces like plastic, glass, and screens using a simple "peel and stick" method, eliminating the need for drilling holes. When integrating the antenna, keeping it at least 1cm away from metal is essential to ensure optimal performance.

Chip Antennas

Chip antennas are tiny and compact. They can be tightly integrated into assemblies and PCBs. When working with chip antennas, it is important to consider a few key factors. Like most surface mount antennas, the visible portion of the chip antenna utilizes the PCB's ground plane as an integral component of the antenna. Consequently, both the PCB's size and the antenna's placement on the PCB can significantly impact its performance. The width of the PCB, especially when it reaches 80mm, becomes a critical dimension that must be maintained. If this area is reduced, it will noticeably degrade the antenna's performance. However, the length of the PCB has a different level of criticality. When placing the chip antenna, we recommend mounting it in the centre of the longest edge of the PCB. Remember that during the device development process, you may need to modify the values of the matching circuit to optimize the antenna's performance. Adjustments to these values are to be expected at some stage in the development of your device.

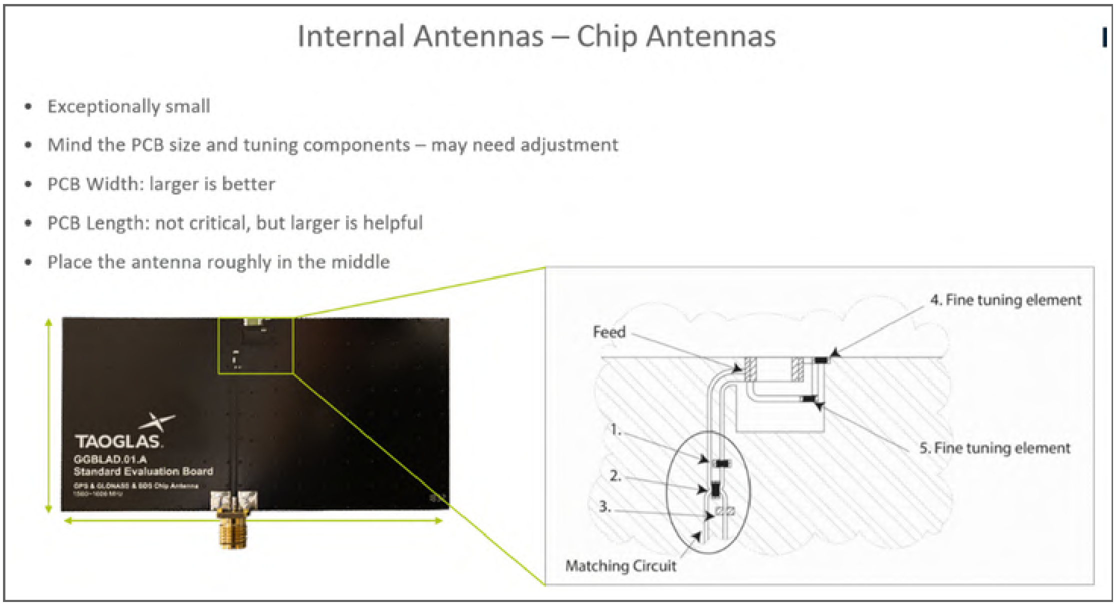

Figure 6. Example of Internal Chip Antenna Placement

External Antennas

External antennas are often considered plug-and-play. However, a key consideration includes a good sky view. Additionally, the ground plane can often be helpful (for example, the vehicle roof) as some antennas expect the ground plane to be there and having a ground plane in place can help negate the multipath.

Commercial Considerations

The most accurate and sensitive antennas and receivers tend to cost more. Therefore, weighing the cost against the benefits is essential to determine whether your application requires the investment. Additionally, consider whether an augmented service from Wi-Fi or cellular could be a viable alternative. The decision depends on your commercial application and what you hope to achieve with your device. By choosing a module and antenna that can support multiple constellations and has a higher performance, a device could give its product a competitive edge, futureproofing the design and gaining added value for your customers.

Seek Expert Advice on Integration

If you are still deciding which GNSS antenna to choose, consult expert advice from an antenna manufacturer, such as Taoglas, who can provide guidance and recommendations based on your specific application. Device OEMs often need more in-house RF resources to integrate the correct module and antenna into their design to ensure reliable performance. Choosing an antenna manufacturer that can help design and optimize RF and antenna performance can significantly benefit device OEMs time to market. Such manufacturers offer design support that allows customers to achieve even greater positional accuracy (down to the cm level) by testing their high-precision GNSS antennas in anechoic chambers and in an open sky view environment to simulate the expected values that an end-user may expect in a field test. These engineering services can significantly improve product performance and reduce the likelihood of design flaws.

GNSS

Featured Products

Lightweight high-precision GNSS Antenna for cm-level positioning

Taoglas is committed to product innovation and the ADFGP.60A is a market leader for multiband GNSS performance. Included in the u-blox XPLR-HPG-2 evaluation kit, the ADFGP.60A is designed for applications where sub meter accuracy is required, such as robotics and precision agriculture. Covering all global GNSS bands, it is optimized to mitigate multipath interference in a simple, lightweight form factor, providing better quality signals to the receivers.

Taoglas

Smart GNSS Antenna for Precise Positioning

The TW5794 is a multi-band (L1/L2), multi-constellation integrated GNSS receiver/antenna with integrated L-Band augmentation receiver for stand-alone PointPerfect® PPP- RTK applications. The TW5794 can provide sub 6 cm PPP-RTK accuracy and sub 1 cm RTK accuracy to support the most demanding navigation, automation and precision mobility applications. Two TW5794s may be combined as a Moving Base and Rover arrangement to offer a Precise Heading solution.

Tallysman Wireless Inc

Cost-effective GNSS antenna module rich in low-power modes

The AG cost-effective series by OriginGPS includes the 10x10mm antenna modules ORG1510-AG05, and the super-thin ORG1511-AG05, and also the 7x7mm ORG4572-AG05. Built with MediaTek's AG3352B chip and designed with 22nm technology, the multi-constellation solutions provide >30% power reduction. All modules enable near real-time information and are ideal for apps requiring high noise immunity

Origin GPS

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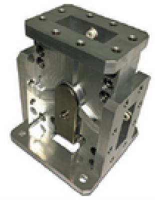

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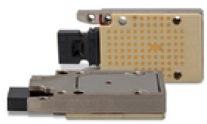

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