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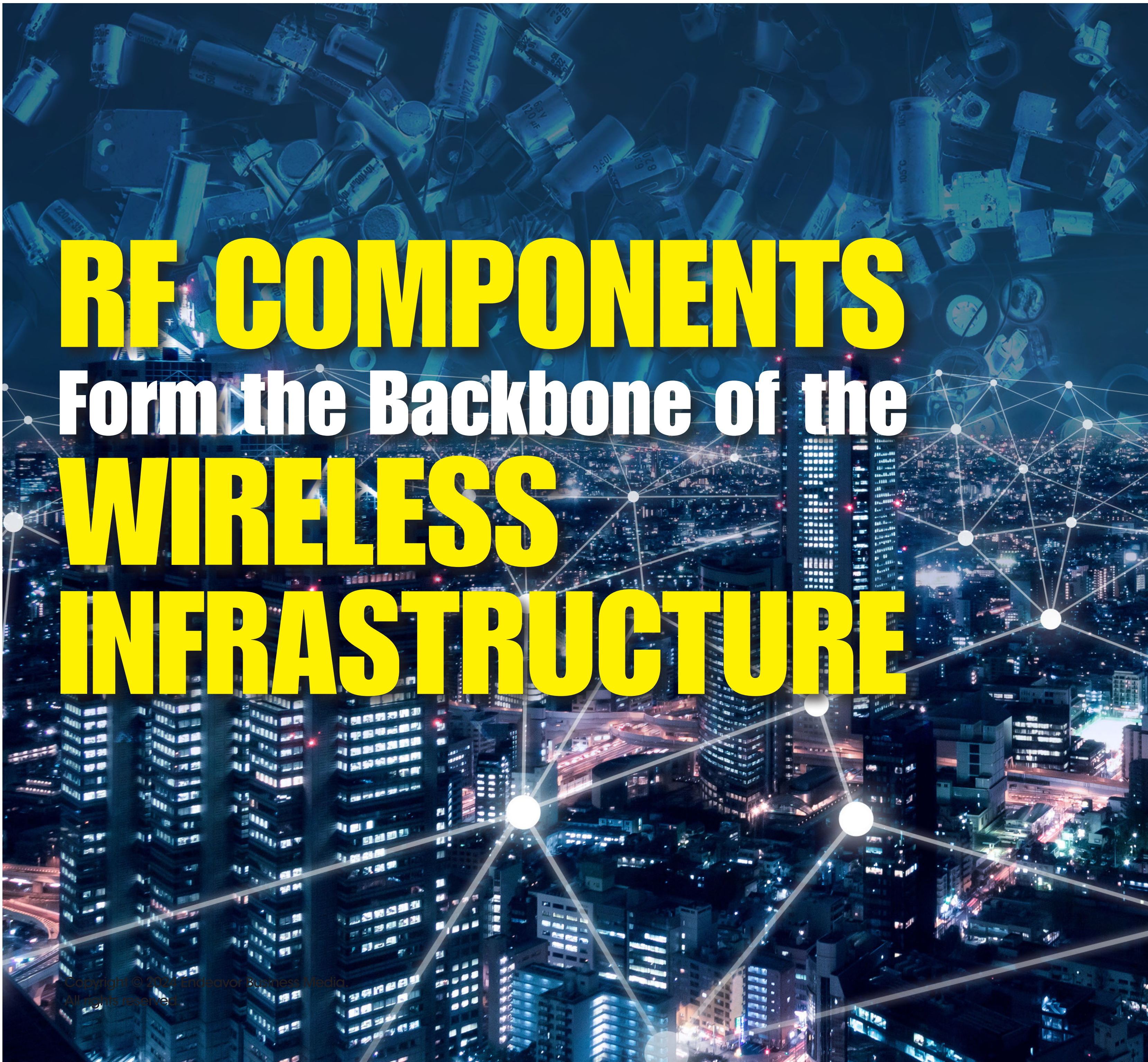
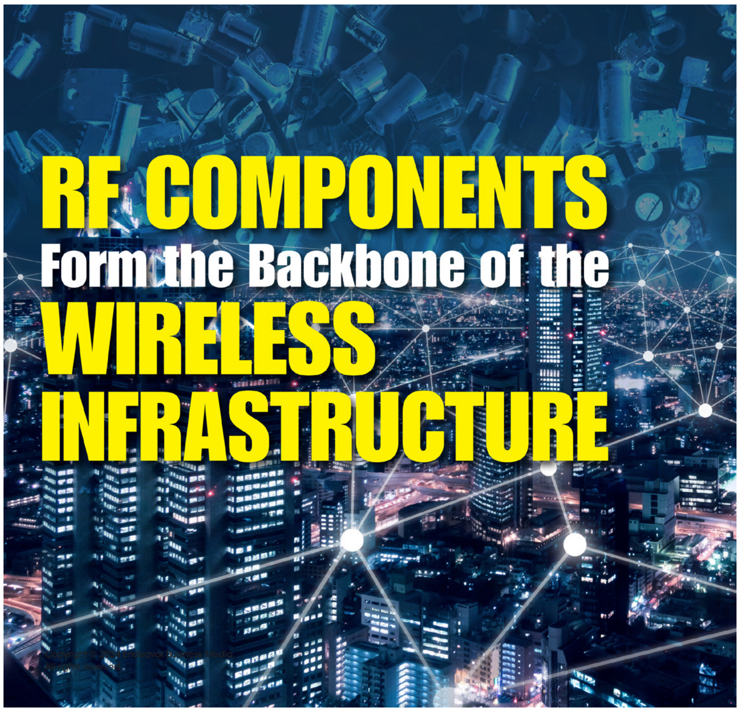


RF COMPONENTS Form the Backbone of the WIRELESS INFRASTRUCTURE



Alix Paultre
Editor-at Large
Microwaves & RF
Electronic Design

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The incredibly complex and crowded spectrum would be unmanageable without the RF devices and components that populate the circuit boards in systems supporting its functionality.

Wireless technologies have been a part of society since the invention of radio, but the current adoption and use of advanced cloud-based electronic products and services has made the RF ecosystem even more important to how we work, play, and live. The connectivity and ubiquity of wireless data and communications has transformed the world via powerful and functional solutions based on wireless connectivity.

This ecosystem of wireless interconnectivity and cloud-based systems and services would not be able to function without the RF components that populate the board and support its functionality. Although most of the attention in the industry seems to be on logic and software, if the RF filter isn't doing its job, nothing else matters. Every base station, modem, and endpoint in the cloud is made up of RF components that must work in harmony to make the system functional.

From the filters to the other passives on the board to the antennas, the need for the latest technologies and approaches in the current generation of advanced passive and active components is an imperative in modern designs. *Microwaves & RF* explores the state of the art in RF components—active and passive—with feature articles and other content from around the industry about this important topic.

CHAPTER 1:

Exploring the Possibilities—and Challenges—of Designing to 300 GHz

TUDOR WILLIAMS, Director of Technology, *Filtronic*, https://filtronic.com/

The challenges and complexities of designing and manufacturing at ultra-high frequencies like 300 GHz involve evolving technologies and the necessity for innovation in advancing RF and mmWave communications.

The world of radio-frequency (RF) and mmWave communications is rapidly advancing toward harnessing the potential of ultra-high frequencies, reaching 300 GHz and beyond. This journey, while filled with promise, is laden with challenges. Here, we'll explore the considerations involved in designing and manufacturing at 300 GHz, delving into the difficulties, evolving technologies, and the need for innovation to make this a reality.

The internet has become an integral part of our daily lives, facilitating activities such as information exchange, social networking, banking, and online shopping. As we step further into the era of the Internet of Things (IoT)—where a web of smart devices seamlessly connects—the possibilities are endless. These IoT applications are poised to reshape everything from the way that our households run to modern businesses and manufacturers.

To meet these needs and keep up with the ever-increasing demand for data, 5G and 6G wireless networks must push the boundaries further. The most likely early implementations of these higher-frequency bands will be in backhaul (effectively the data pipe between the base station and the core network simultaneously serving the data needs of all network users.

Although mmWave and E-band (71 to 86 GHz) have delivered major leaps forward with data rates in excess of 10 Gb/s, what comes next is now capturing people's attention and creating the biggest challenges. Let's explore some of these challenges in greater detail.

Manufacturing, Integration, and Packaging Challenges

Manufacturing tolerances stand out as a significant hurdle when dealing with high-frequency designs. As frequency rises, the demands increase for tighter tolerances on component placement, interconnects, and metalwork. Traditional manufacturing methods, such as CNC machining used to create the waveguide for signal conditioning, might lack precision. This forces the adoption of new production methods such as additive manufacturing to achieve the required tolerances.

Moreover, the journey from lower frequencies to 300 GHz involves the development of smaller semiconductor features, especially for high-power devices. For compound semiconductor devices, this progress is slower due to limited demand and increased complexity. The development of these processes is driven by the emergence of new applications and business cases, making it a lengthy and costly journey.

One of the paramount challenges in high-frequency design is the management of parasitics. A good example would be wirebonding at lower frequencies. The impact of parasitic elements can be mitigated with relative ease, but as we move to mmWave frequencies, it becomes necessary to design a matching network to cancel out the parasitic effects.

When moving to 300 GHz, this becomes impractical as manufacturing tolerances mean that a different matching network would be required for each new bond—clearly impossible in a volume production environment. To overcome these challenges, a shift toward alternative packaging and interconnect solutions for semiconductor devices becomes imperative. Work has already started on such designs, including flip-chip, hot vias, and chip-scale packaging.

At these high frequencies, semiconductors become a critical focal point in the overall design. Each semiconductor material has unique properties that can support the critical design requirements. At lower frequencies, a mix of performance and cost often leads to the integration of several individual semiconductors. For higher frequencies, the aim will be to integrate as much of the functionality as possible into a single chip to minimize interconnects and the related problems outlined above.

It's therefore likely that much of the integration will be in the form of a silicon chip with the high-performance elements, such as the power amplifier and LNA, having to remain in a compound semiconductor material to maintain the required performance. As it stands today, the processes don't exist with the performance to meet the power required to form wireless data links, but these will evolve in the coming years.

Thermal-Management Challenges

With each stride toward higher frequencies, the efficiency of electronic devices experiences a noticeable decline. This means that more DC power is required to achieve the same RF output power. It clearly calls for larger power supplies, but more critically, leads to the dissipation of more power in the form of heat.

Compounding this challenge is the continual miniaturization of electronic circuits. As components and devices become smaller and more densely packaged, the heat generated is concentrated within a reduced physical area. This concentration of heat amplifies the importance of effective thermal management. Failing to adequately dissipate this heat can lead to various issues, including reduced device performance, reduced lifetime, and even device failure.

To address these thermal-management challenges, the industry is actively exploring innovative solutions. This starts at the critical interface between the semiconductor device and the heatsink. It leads to a requirement for innovative materials in epoxies, sinters, and solders to remove heat from the device while maintaining an expansion coefficient with the other materials around it to remove stresses and strains, which can again lead to device aging or failure.

Once the interface is controlled, heat must be quickly spread. Here, heat spreaders are deployed with materials such as copper, molybdenum, and even diamond, used for its enhanced thermal properties. Once the heat is spread, it must be effectively removed, leading to requirements for forced air convection or liquid cooling.

Manufacturing Constraints: Precision Prevails

Manufacturing at high frequencies introduces a whole new realm of intricacies. Precision becomes the bedrock of this endeavor, with an unyielding demand for tight tolerances in critical areas such as component placement and epoxy dispensing.

The high-frequency landscape leaves little room for error, and even minuscule variations in component placement can result in severe consequences. The challenge, therefore, lies in the development of machinery capable of producing high volumes with impeccable precision.

The pursuit of precision in manufacturing for high frequencies often necessitates the creation of custom machinery. Off-the-shelf solutions may prove inadequate when dealing with the exacting requirements of these designs.

As a result, manufacturers are driven to invest in tailor-made, precision-focused equipment that can meet the stringent demands of high-frequency production. This tailored approach, while addressing the need for precision, adds an additional layer of complexity to the manufacturing process.

In essence, the challenge in high-frequency manufacturing extends beyond the design and engineering phases. It's not just about creating high-frequency designs, but making them viable for mass production. The intersection of precision, custom machinery, and evolving manufacturing techniques creates a nexus of complexity and opportunity.

As the industry strives to lead the way in RF and mmWave communications, it must navigate these manufacturing constraints with ingenuity and unwavering commitment to achieving the desired precision in high-frequency electronic systems.

In the high-frequency landscape, it's not merely a journey of technological progress—it's a relentless pursuit of precision; precision in design, manufacturing; and achieving the desired performance at these as-yet-unreachable frequencies. Although designing solutions to 300 GHz is possible, achieving production at scale for such high frequencies is still an elusive goal. It's not today's technology, but a vision for the future.

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CHAPTER 2:

Revolutionizing Vehicle Safety: The Role of UWB in Modern Automobiles

DAVID SCHNAUFER, Technical Marketing Manager, *Qorvo,* www.qorvo.com

In the ever-evolving landscape of automotive technology, ultra-wideband (UWB) stands out as a beacon of innovation, particularly in the domain of vehicle occupancy detection. This cutting-edge technology, known for its low-power wireless capabilities, is now paving the way for advanced safety measures and convenience in vehicles.

Technology continually enhances our daily lives, but for it to be truly effective, it must be straightforward, secure, reliable, and trustworthy. Radio-frequency (RF) technologies like Wi-Fi and Bluetooth have significantly improved connectivity in our homes and businesses. However, UWB emerges as a secure, reliable, and trustworthy RF technology with a unique capability to enhance our lives.

While UWB's applications are vast, this article will focus on its critical role in lifesaving vehicle applications, offering a glimpse into the future of safer and more interconnected driving.

As ultra-wideband technology continues to evolve, it promises to revolutionize vehicle functionality and driving efficiency, plus create a safer, more interconnected driving experience.

UWB: A Multifaceted Technology in Automotive Innovation

The automotive industry is rapidly integrating new technologies to improve safety, security, and the overall consumer experience. Addressing traffic safety, technology has evolved from standalone vehicle systems, like radar and cameras, to connected-vehicle technologies requiring standardization across manufacturers.

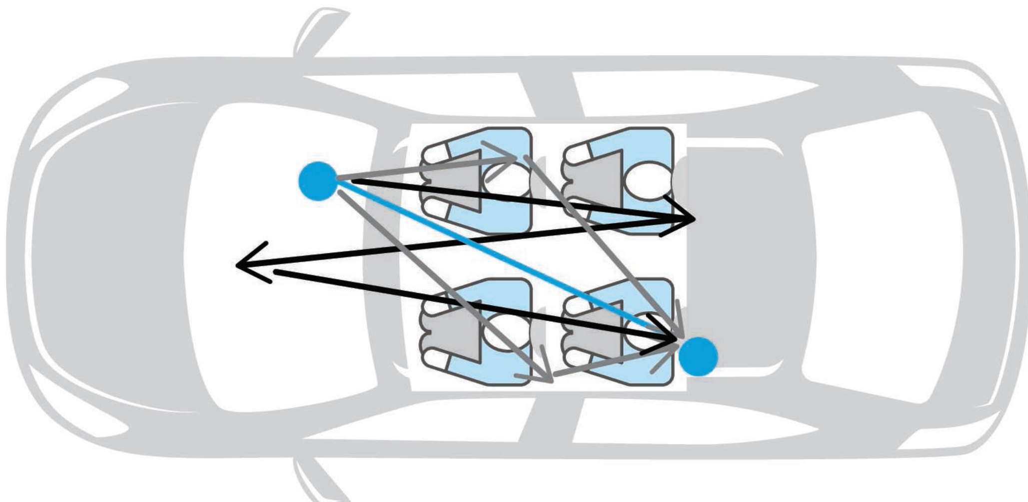
This shift toward vehicle-to-everything (V2X) communications opens the door for UWB technology, combining precise positioning, secure identification, and ultra-low latency to enhance advanced driver-assistance systems (ADAS), and connected and autonomous vehicles (CAVs).

One of the critical applications of UWB in automobiles is its ability to detect occupancy, especially in situations that could lead to life-threatening scenarios, such as a child being left unattended in a hot car (**Fig. 1**). UWB leverages the unique property of channel impulse response (CIR) to distinguish whether a seat is occupied.

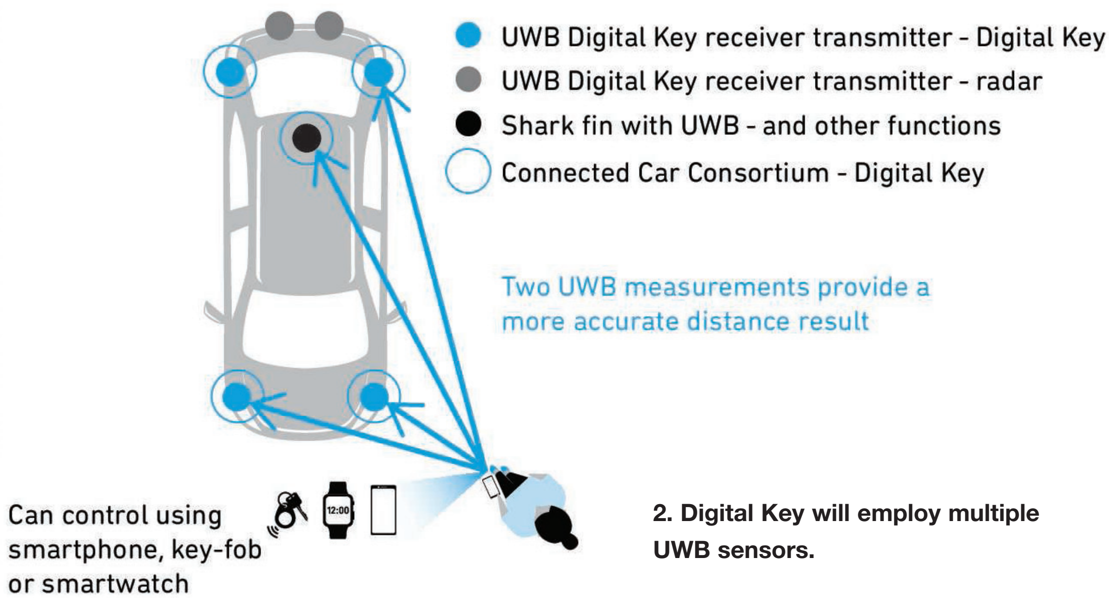
That's achieved by transmitting UWB pulses within the vehicle, where the signals reflect off surfaces until they reach a receiver. The key lies in the strategic placement of transmitters and receivers to ensure the signals traverse passenger seating areas. When a seat is occupied, the CIR signature changes, enabling the system to detect the presence of a person. This application not only enhances safety, but also introduces a new level of interaction between the vehicle and its environment.

Beyond Occupancy Detection

Beyond occupancy detection, UWB's utility extends to several other automotive applications, including keyless entry systems known as Digital Key. This implementation showcases



1. UWB is applied in vehicle occupancy safety detection systems.



2. Digital Key will employ multiple UWB sensors.

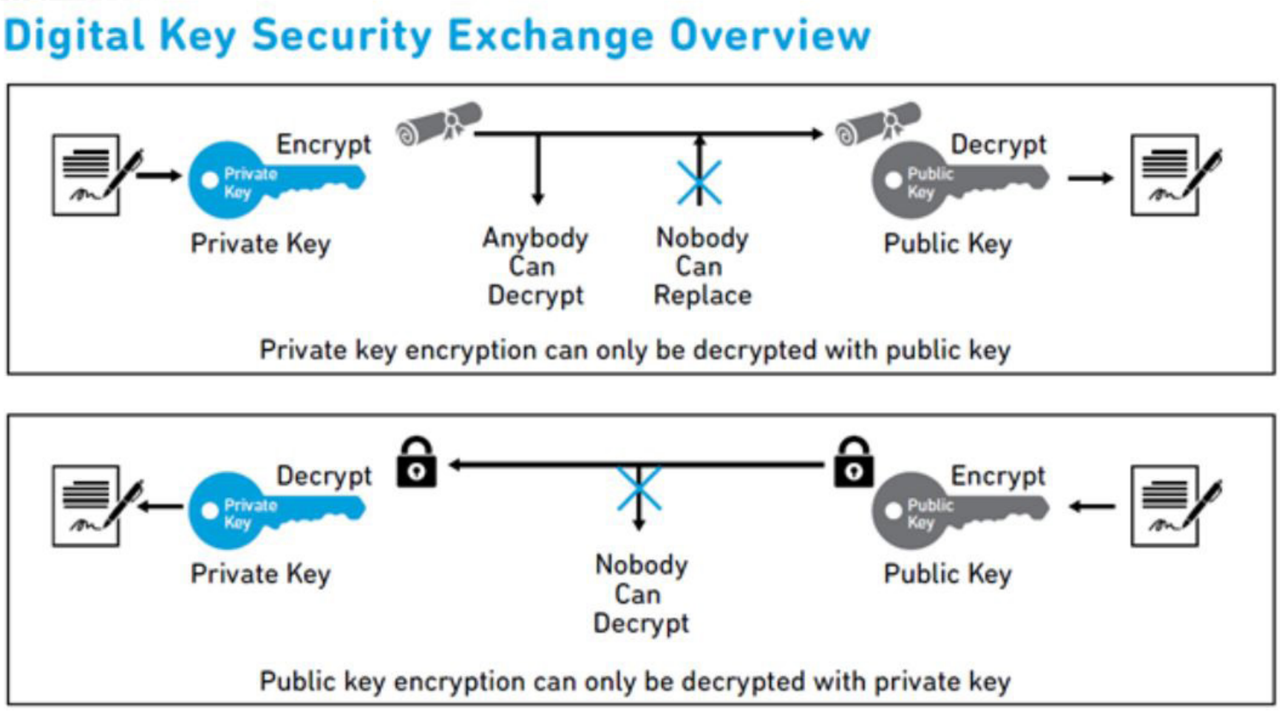
UWB's versatility in improving vehicle security, convenience, and situational awareness.

Digital Key, developed by the Car Connectivity Consortium (CCC), uses UWB for a secure, hands-free way to unlock and lock your car as you approach or leave, without taking your mobile device or smartphone out of your pocket. The Digital Key application, which combines UWB with Bluetooth Low Energy (BLE), exemplifies how vehicles can securely authenticate and communicate with a driver's smartphone or smartwatch (**Fig. 2**).

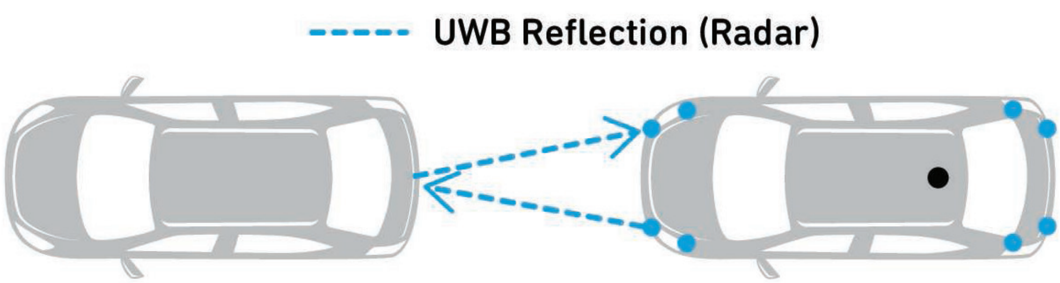
In this system, a UWB-enabled smartphone or key fob transmits signals received by multiple vehicle-mounted UWB anchors, which reply in sequence. In turn, the vehicle can calculate the precise distance to the smartphone or user.

This Digital Key process is safeguarded by a security feature that uses a scrambled timestamp sequence (STS) protected by the Advanced Encryption Standard (AES) protocol. The process is protected by a complex algorithm that refreshes the STS code after every transmission. This ensures that only authorized devices can communicate.

Furthermore, alongside UWB, BLE is utilized for initial high-level communication to exchange Digital Key IDs and verify user identity, further enhancing security and preventing



3. This represents the Digital Key security and exchange process.



4. Short-range radar detection using UWB.

unauthorized access. The innovative Digital Key vehicle entry and exit procedure offers a seamless and secure user experience (**Fig. 3**).

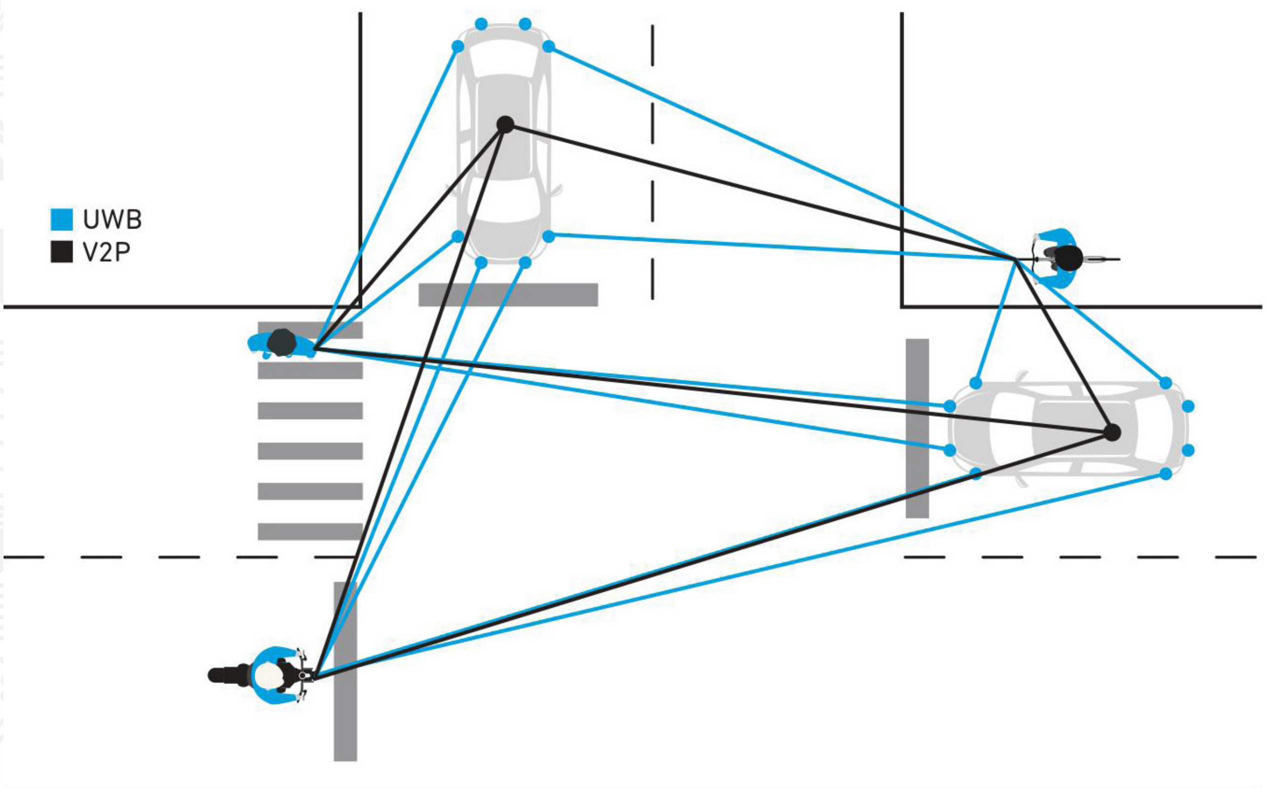
In high-speed situations with multiple vehicles, it's crucial that CAVs work flawlessly. One example is platooning, where vehicles move closely together to save fuel by reducing air resistance (**Fig. 4**). This method can make trucking safer and more efficient, lowering fuel expenses and emissions, easing traffic, speeding up deliveries, and even extending the distance electric vehicles can travel on a single charge.

Moreover, UWB's application in short-range radar systems illustrates its potential in collision-avoidance technologies. By analyzing the time of arrival of reflected signals, UWB can accurately determine the distance to nearby objects, enabling vehicles to alert drivers of potential hazards.

Improving Safety for Pedestrians and Cyclists

UWB technology can also significantly improve safety for pedestrians and cyclists by working together with vehicle-to-pedestrian (V2P) communication (**Fig. 5**). Just like vehicle-to-vehicle (V2V) communication, UWB helps the navigation system to identify if a vulnerable road user (VRU), such as when someone with a smartphone or any UWB-enabled device is nearby. It then measures the distance to the VRU accurately and checks if there's a risk of collision.

For example, at a three-way stop or any intersection, vehicles equipped with UWB sensors can detect the exact location of VRUs, helping to prevent accidents and keep the roads safer for everyone.



5. Here, UWB is leveraged in pedestrian safety scenarios.

As we look to the future, the potential applications of UWB in the automotive sector are vast and varied. From facilitating electric-vehicle charging alignment to enabling secure payments in parking garages and improving road safety for pedestrians, UWB technology holds the promise of transforming our driving experiences.

The integration of UWB into automobiles isn't just about enhancing vehicle functionality; it's about creating a safer, more convenient, and interconnected driving environment. With industry predictions suggesting that half of all new vehicles will incorporate UWB technology in the near future, the stage is set for a significant leap forward in automotive safety and innovation.

Looking Forward

UWB technology represents a critical step forward in the automotive industry. It offers enhanced safety and security, and opens the door to a plethora of innovative applications that promise to revolutionize the way we interact with our vehicles. As this technology continues to evolve, it will undoubtedly play a pivotal role in shaping the future of automotive design and functionality, making driving a safer, more efficient, and more enjoyable experience for all.

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CHAPTER 3:

High-Power SAW Filters Meet Demands of Modern Military, Space, and Commercial Systems

MARK THOMAS, Program and Product Line Director, *Spectrum Control,*
www.spectrumcontrol.com

Mitigating signal interference is increasingly critical in modern military, space, and commercial systems. Engineers must typically overcome three major design considerations to ensure their systems perform in today's complex environments.

The RF spectrum is becoming overcrowded due to the prevalence of commercial and military/aerospace systems utilizing multiple technologies, contaminating the spectrum. In addition, military, space, and commercial systems often integrate digital and analog technologies in the same package, creating greater interference concerns. Meanwhile, modern communications systems continue to become more compact and lightweight, with stringent size, weight, power, and cost (SWaP-C) parameters, leading to greater interference issues.

To address the challenges of our ever-more crowded wireless landscape, filtering techniques on the RF front-end take on a greater significance. Traditional surface-acoustic-wave (SAW) filters have been unable to address the high-power RF surges from many sources common in modern systems.

A new generation of SAW filters is breaking the old design paradigm and helping RF engineers effectively address interference. These high-power SAW filters are smaller, lighter, and more economical than comparable filter technologies such as lumped element, cavity, and suspended substrate.

SAW Filter Evolution

SAW filters have been used to mitigate interference for decades. They convert electrical energy into acoustic or mechanical energy on a piezoelectric material. A transducer generates a tuned acoustic wave to amplify the desired signal and attenuate all others. Each transducer consists of periodic interdigital electrodes connected to two bus bars.

One key advantage of SAW filters is they have large rejection bandwidths, so they can filter out closely adjacent signals. This filtering technology also offers low insertion loss and high selectivity.

While SAW filters have excellent performance in low-power applications, similar success has proven elusive in emerging high-power designs. As electronic warfare (EW), base stations, radar, and similar communications systems became digitized, operating at higher frequencies with greater bandwidth, conventional SAW filters were unable to address the associated high input power. RF energy increases the temperature of traditional SAW filters to such an extent that they would fail catastrophically.

1. Advanced materials science and substrates has led to a new generation of SAW filters

Advanced SAW Filter Technology for Today's Designs

A new generation of SAW filters (**Fig. 1**) that supports high input power is now available. These SAW filters leverage innovative material science and advanced substrates to meet the high input and output demands of modern systems.

The new high-power SAW filters can handle up to 5X as much power as legacy SAW filters. Improved performance is created by these design/manufacturing techniques:

Innovative materials formula: An advanced materials formula along with an additional metallization layer creates improved thermal conductivity at higher power levels while maintaining bandwidth and low insertion loss.

Advanced substrates: The main substrates used in the new SAW filters are lithium niobate ($LiNbO_3$) and lithium tantalate ($LiTaO_3$). These inorganic compounds are highly effective options to mitigate alkali-silica reaction (ASR) and make the filters very durable and rugged. For certain higher-frequency requirements, synthetic diamond, thin film, and glass substrates can be used, too.

Packaging: Filters and oscillators are hermetically sealed in the SAW filter. Oscillators have fundamental frequencies up to 1,200 MHz, which provides superior phase-noise performance and vibration sensitivity. This method maintains environmental integrity to pass the rigors of MIL-STD-883 Method 1014 Conditions A and C for both gross and fine leak detection.

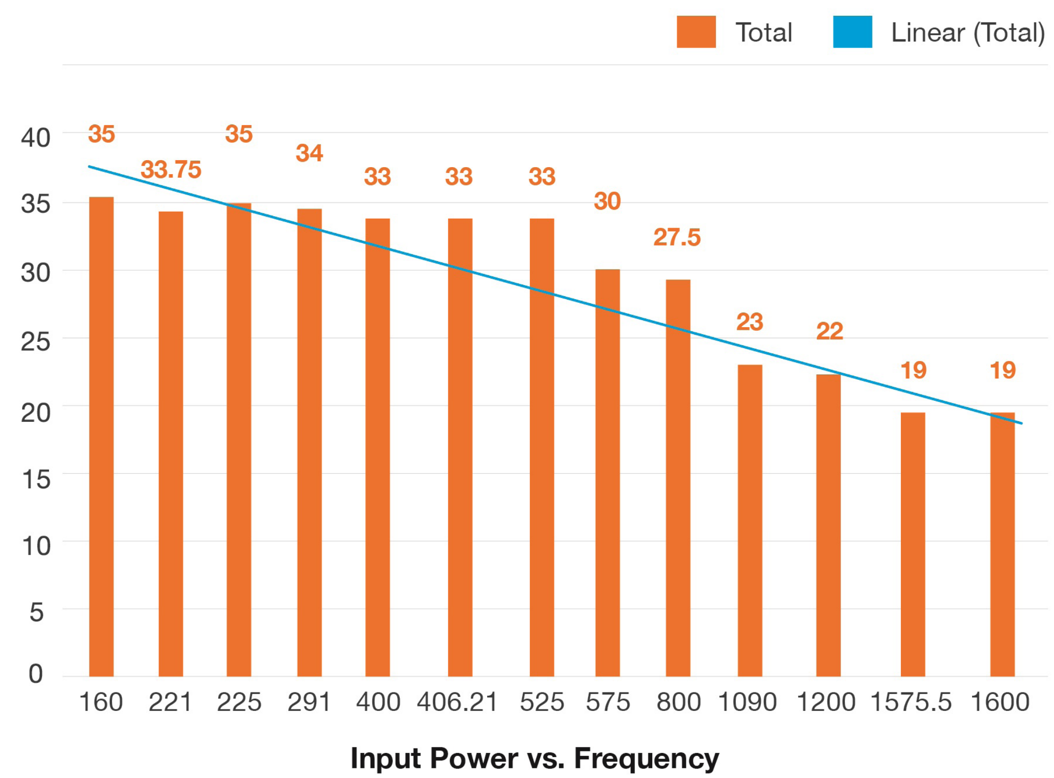
By taking such an approach, the SAW filters can serve as a time- and money-saving drop-in replacement for current low-power-handling SAW filters. No custom PCB layouts for thermal considerations are required and standard reflow profiles could be used. For new designs, the small footprint can also lead to smaller board designs. This leads directly to a reduction in components, lower BOM costs, faster assembly, and lighter weight.

High-Power Performance, High-Quality Standards

The innovative design and materials science help the SAW filters achieve high power input up to +35-dBm continuous wave (CW) at +125°C and cover narrow, wide, and fractional bandwidths across frequencies of 20 MHz to 1.6 GHz (**Fig. 2**). This level of performance is achieved without degradation of the filter's key parameters, including center frequency, bandwidth, insertion loss, and ripple.

It's important to note that the SAW filter's high input power should be tested at CW. Since peak power is pulse-based, it's not an accurate depiction of real-world environments. Because CW is constant, it more precisely replicates how the filter will handle power when integrated in a system.

The highest quality-control standards should be maintained at every stage of the product ecosystem, from initial design through manufacturing and delivery. All processes must have a high level of quality assurance to ensure the filters will operate according to specification when designed into a system.



2. New high-power SAW filter power-input-handling capabilities vs. center frequency.

To ensure reliability and consistency, every SAW filter needs to be electrically tested for critical parameters, such as center frequency, insertion loss, bandwidth, and rejection. Characterizing SAW filters at 125°C and CW for 1,000 hours gives engineers confidence that they will meet commercial, military, and space specifications.

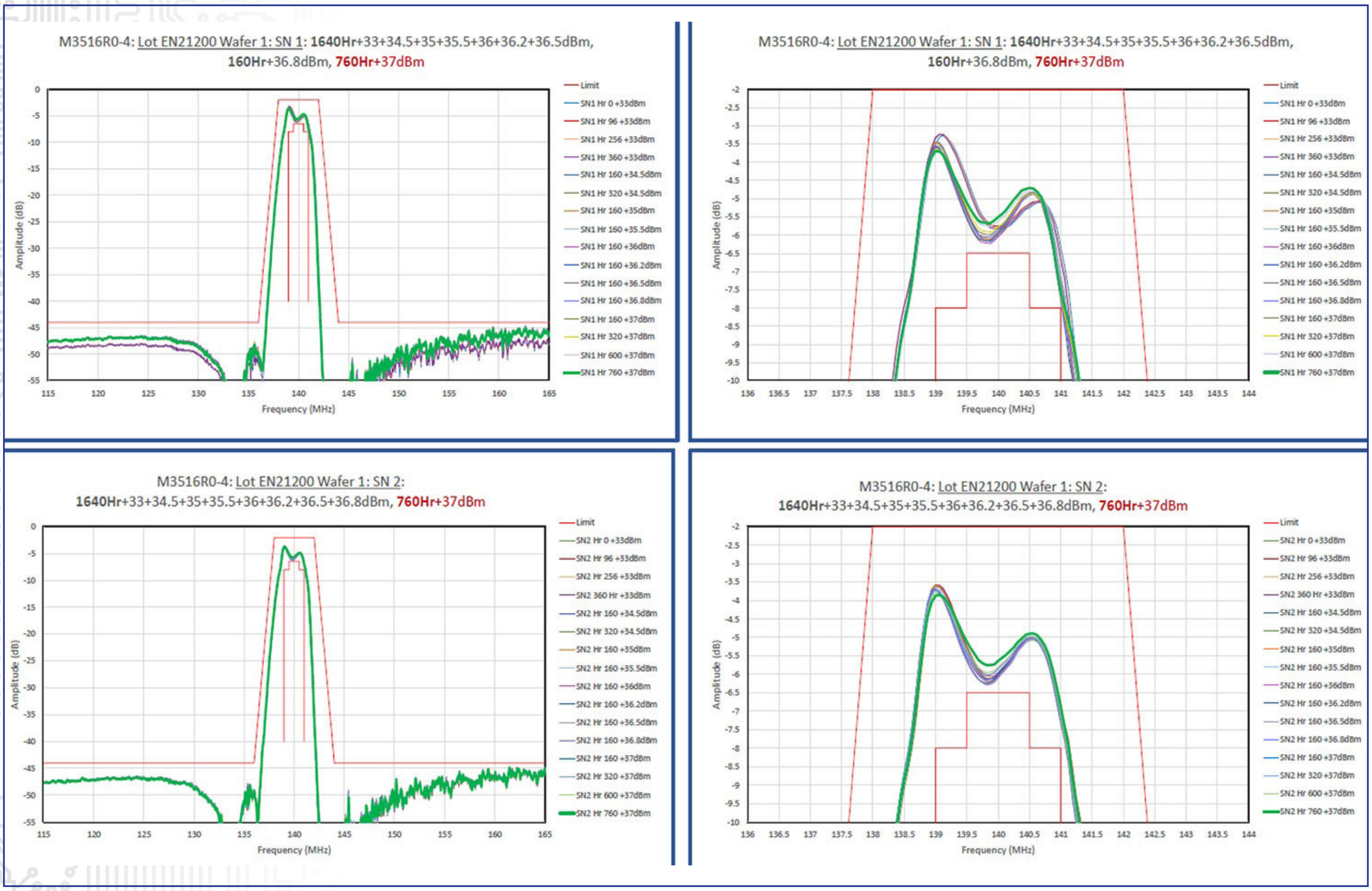
Figure 3 shows results of SAW devices that went through rigorous testing. The devices were tested for 760 hours at +37 dBm (5 W) at 125°C. Input power for both samples was initiated at +33 dBm. Power was steadily increased, as shown in the plots on the right side, until +37 dBm was reached.

SAW vs. Alternative Filtering Techniques

The new high-power SAW filters can be an attractive design choice compared to other filtering options, such as bulk-acoustic-wave (BAW) filters, hybrid filters, and lumped elements:

BAW filters: A common alternative, BAW filters support frequencies above 1.4 GHz. BAW performance has been known to suffer at lower frequencies, limiting the applications in which they can be used. In addition, BAW filters handle power by channeling the acoustic wave through the bulk of the substrate, requiring the metallized structures and substrates to be stacked on top of each other. In a SAW filter, the acoustic wave is channeled across the top of the substrate surface.

3. High-power SAW filters undergo extensive testing to verify performance.



Antenna Arrays	Military Radar
Commercial Critical Infrastructure (EMS/Fire/Police)	Military Radio Communications
Base Stations	Satellite
Electronic Warfare (EW)	Smart Grid Communications

Common applications for high-power SAW filters.

Hybrid filters: A hybrid solution integrates a passive filter with an active filter. The passive power filter addresses the low-order harmonic current while the high-order harmonics are addressed by the active power filter.

Lumped elements: Lumped-element filters are passive filters that consist of the necessary inductors (Ls), capacitors (Cs), and resistors (Rs) for the specific design requirements. These technologies can handle the input power requirements but have other design tradeoffs.

All of these are much larger than a SAW filter, and typically occupy up to 10X more space compared to a SAW filter. SAW filters are also lighter and more cost-efficient compared to the other filter technologies. Considered together, these features offer system designers significant advantages for using high-power SAW filters.

Meeting Today's Systems Needs

The ability of the new SAW filters to achieve input power of up +35 dB (compared to +20 dB for conventional SAW filters) make them ideal for emerging space, commercial, and military systems (**see table**) that rely on digital technologies and clean transmissions. High-power SAW is also an attractive complement for designs using low-noise amplifiers (LNAs) that integrate analog technologies.

Overcoming Signal Interference with SAW Filters

Increased RF clutter from an overcrowded RF spectrum, coupled with a mixture of analog-digital technologies in smaller designs, are creating increased signal interference challenges for a growing number of commercial, military, and space designs. A new generation of high-power SAW filters enables higher power and tighter bandwidths in a compact design with a wide temperature range, providing an efficient solution to modern interference concerns.

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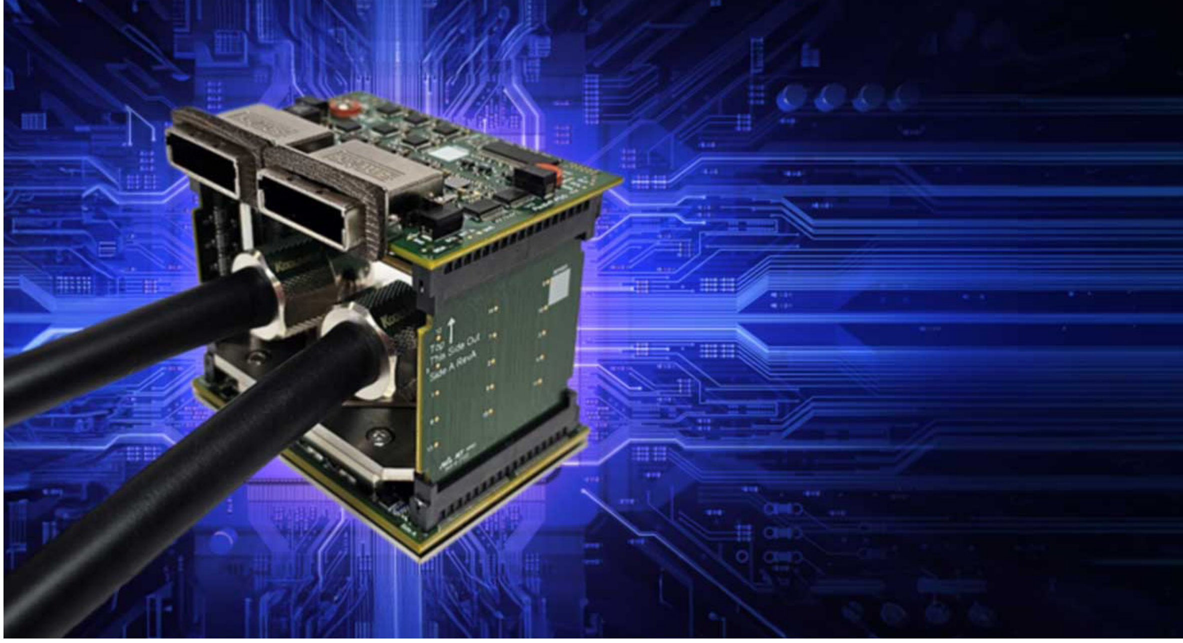

CHAPTER 4:

Advanced Load Test Solutions Address Next-Gen Product Development

BY ALIX PAULTRE, Editor-at-Large

Taking RF components from a concept to a product in volume production is a lengthy process, but it can be accelerated with the latest automated testing and validation solutions.

The embedded electronic landscape is evolving and developing in a period of rapid disruptive growth, driven by advances in core technologies as well as the increased implementation of software-driven functionality. Fomented by these advances and supported by an increasingly capable wireless infrastructure, today's devices are becoming smarter, more highly integrated, and more connected than ever before.

This presents both challenges and opportunities to the electronic design engineering community, as the new products and services created must be developed and manufactured in an optimum and cost-effective manner. High levels of integration demand advanced test and measurement tools to properly evaluate, validate, and determine compliance in smart cloud-enabled things. This is especially critical when it comes to active RF components, which must be tested for performance and compliance.

The Challenges in Advanced Electronic Test

When it comes to electronic design and development, the test and measurement tools you use must be more capable than the devices they evaluate. Test equipment must be faster and more precise than the device under test (DUT), while capturing huge amounts of information and storing it for analysis. And this has to be done in a rapid, accurate, and cost-effective manner.

There are a few things to consider regarding system development and prototyping in terms of the design's electrical requirements, and the testing and validation to ensure it meets them. One of the challenges here is that it's getting harder, longer, and becoming more protracted to meet the amount of testing required to ensure that the solutions are

Pactiv transient and DC load testing tools help empower your product development process, accelerating evaluation, characterization, and validation of power-delivery schemes.

validated. ProGrAnalog aims to eliminate or to compress that testing significantly.

The second issue is development cost. A company can spend a significant amount of money on device development, and the time to discover problems is not when it comes out of the foundry and gets packaged to ship. A manufacturer wants to find out that the board its putting the chip down on meets the power requirements specified before the chip is available. ProGrAnalog's solutions offer a way to emulate the power consumption of the board, and the chips that will go down on it. This reduces critical system development and validation time.

Increasing power density is another industry trend. One way to address that and get power savings is by squeezing the silicon closer to each other, whether it's side-by-side or stacked silicon. This increases power-management issues in the package, which becomes harder to manage, as well as thermal issues and the need to get the heat out. These aspects must also be tested, optimized, and validated in as efficient, and cost-effective, manner as possible.

Power Emulators Address Validation Issues

Solutions like high-performance, large ASIC load power emulators enable systems integrators to test and validate their designs in a cost-effective manner. Because of the pseudorandom nature of various IC load profiles, the entire power-delivery system needs to be tested exhaustively. The complexity and nonlinearity of the system means that simulations must be verified against real-life testing, as there's no substitute for actual testing of a power-distribution network.

Addressing each of the stages in a product's development cycle, LoadSlammer tools provide a comprehensive testing methodology in conjunction with hardware- and software-based functionality for consistent and exhaustive testing.

LoadSlammer tools used in transient load testing can change the voltage load rapidly, with a fast and controllable step transition rate, frequency, and duty cycle. They're also able to handle arbitrary load profiles, with a low-impedance connection to the circuit board and adequate dissipation capability. When it comes to the issue of accurately measuring a current transition rapidly, current probe loops introduce far too much inductance to allow for fast transients, and even chip resistors for current sensing must be compensated for their internal inductance.

Part of the solution used is a form-factor-equivalent device that provides the same socket as the chip interface to ensure complete validation of the power circuit. A chip's package design is often determined late in the design process, putting more pressure on the system designer. Using a form-factor-equivalent interface that looks like the device and behaves like the device from a transient and DC power perspective can speed development and lower costs. The form-factor-equivalent device can emulate thermal characteristics as well.

For example, Pactiv transient and DC load testing tools help empower the product development process, accelerating evaluation, characterization, and validation of power delivery schemes (**see figure**). Providing a platform for comprehensive testing, Pactiv brings together the flexibility and ease of use of the Passive LoadSlammer adapter and the functionality, power, and rise/fall times of the Active FFED solution.

Another is a programmable load cell array that makes it possible to perform fast AC and DC measurements to develop a sophisticated understanding of behavior of a given solution before implementing it into a system. Because LoadSlammer is vendor-agnostic, fair comparisons can be made against various solutions quickly and accurately. Using the LoadSlammer API enables third-party developers to test and optimize a product with minimal interaction from the client.

Mounting time-to-market pressure brings more gravity to the complexity of testing. The ability to emulate the power supply and its transient performance without the actual ASIC in hand is critical to make sure that their power is validated for that product before getting direct support from their distributor or from the manufacturer.

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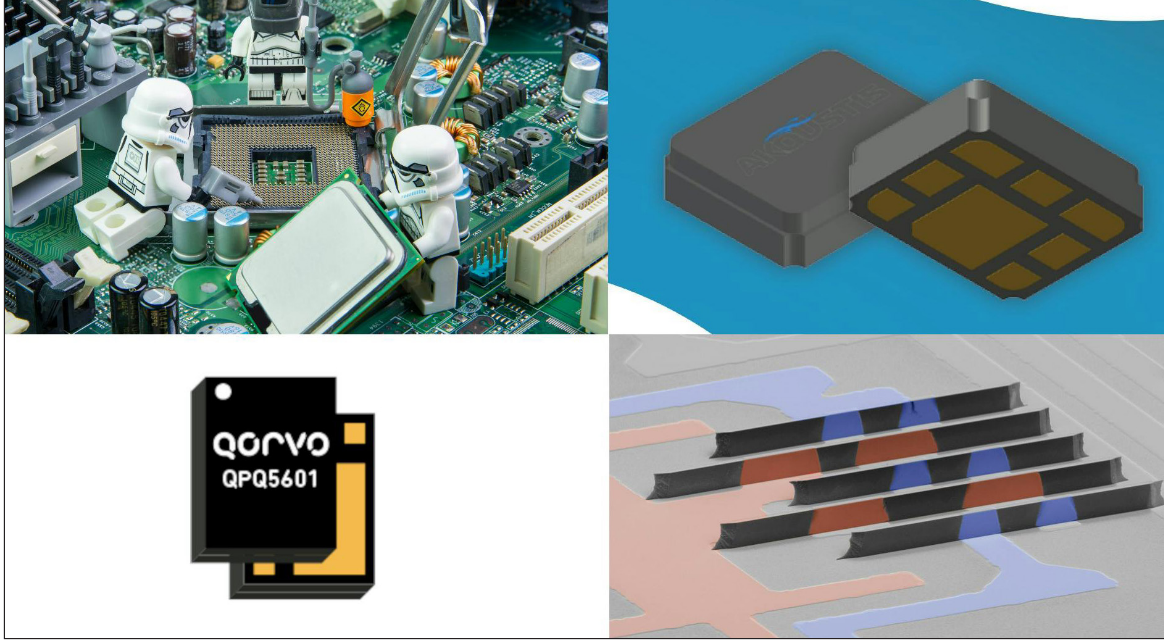


CHAPTER 5:

RF Filters: Critical Components in the Wireless Ecosystem

BY ALIX PAULTRE, Editor-at-Large

RF filters are used by wireless systems to filter and receive only the required RF signal from the wide range of transmissions crowding the spectrum.

RF and microwave filters are electronic components used to reject or accept a specific selected frequency signal. This is done to eliminate noise or unwanted signals.

A filter should have a low insertion loss (IL) in the passband, high isolation and rejection out of band, a high Q factor, excellent passive-intermodulation (PIM) performance, and, of course, be presented in a small cost-effective package with efficient power handling, A sharp transition slope wouldn't hurt either.

Depending on the material and technology used, many types of filters are available. Among them are cavity filters, dielectric filters, coaxial filters, planar filters, electroacoustic filters, and a host of others.

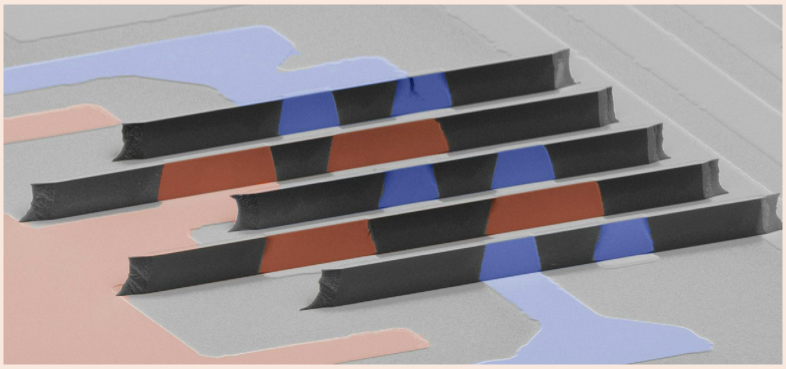
The worldwide RF front-end module market size was valued at $24.56 billion in 2023, and is expected to rise to $83.21 billion by 2033, according to research done by Spherical Insights & Consulting. This reflects the keystone functionality provided by RF filters and their importance in the wireless industry. As the cloud and the devices that rely on them continue to expand in reach and functionality, it will only escalate their importance.

These critical components in wireless communication systems such as satellite, mobile, radar, and IoT not only enable a device to use a specific frequency, they also block the transfer of unwanted signal frequencies that can degrade signal quality. Every wireless device must have some form of filtering to pass or reject specific or multiple frequency bands. Generally using one or more coupled resonators, they can be made by using transmission lines, waveguides, or passive components.

Selecting the right filter for the communications system circuit will lead to a higher-quality RF signal.

3D Devices Offer Promise to Advance Wireless Communications

Scientists at the University of Florida developed technology that uses CMOS processes to create three-dimensional devices that can significantly enhance the efficiency of RF filtering. As such, they could ultimately transform the landscape of wireless systems. Unlike planar processors, which are limited by their two-dimensional structure and can only operate within a limited portion of the spectrum, three-dimensional structures could address more and different parts of it.



Led by Dr Roozbeh Tabrizian, an associate professor in UF's Department of Electrical and Computer Engineering, the team developed the 3D device to enhance the ability to transmit data more efficiently and reliably. Tabrizian and his colleagues at the Herbert Wertheim College of Engineering leveraged semiconductor technologies in integration, routing, and packaging to integrate different frequency-dependent processors on the same chip.

Taking up less physical space while delivering enhanced performance, 3D processors have the potential for near-indefinite scalability. The ability to integrate different frequencies on one monolithic chip would enable the creation of multiband, frequency-agile radio chipsets and empower new communication strategies. ••

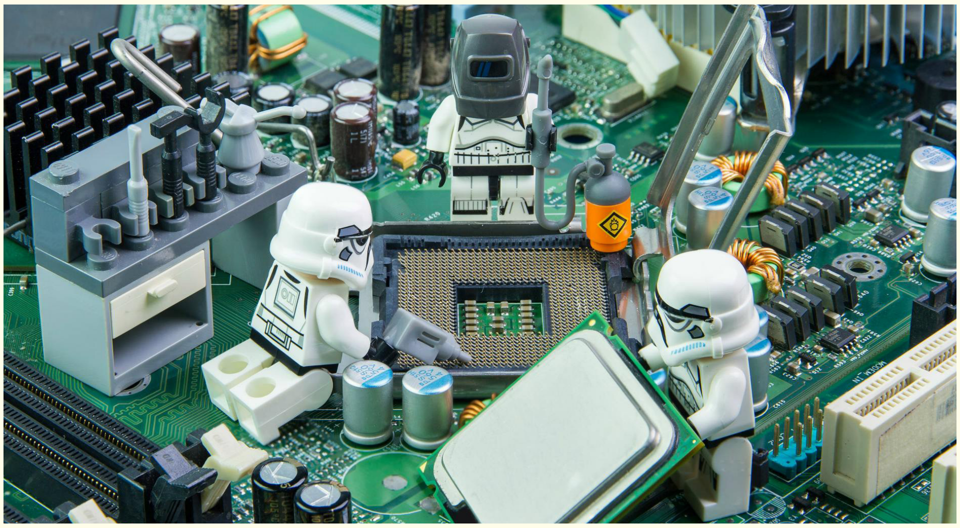
Lego-Like Photonic Chip Expands Bandwidth and Filter Control

A novel semiconductor architecture that integrates traditional electronics with photonic components was developed by a team led by Dr Alvaro Casas Bedoya in the School of Physics at the University of Sydney Nano Institute. The chip could have applications in advanced radar, satellites, wireless networks, and 6G telecommunications, and significantly expands the ability to operate in the RF bandwidth.

This expanded bandwidth capability also allows for advanced filter controls, creating a versatile new semiconductor device with applications in advanced radar, satellite systems, wireless networks, and telecommunications, as well as open the door to advanced sovereign manufacturing. Built using an emerging technology in silicon photonics that allows integration of diverse systems on semiconductors less than 5 mm wide. Pro-Vice-Chancellor (Research) Professor Ben Eggleton, who guides the research team, likened it to fitting together Lego building blocks, where materials are integrated through advanced chiplet methodologies.

Designed in collaboration with scientists at the Australian National University, the prototype was created in the Core Research Facility cleanroom at the University of Sydney Nanoscience Hub, a purpose-built $150 million building with advanced lithography and deposition facilities. The photonic circuit in the chip is able to address a 15-GHz bandwidth of tunable frequencies with spectral resolution down to just 37 MHz.

This innovative approach of integrating advanced functionalities into semiconductor chips, leveraging the heterogeneous integration of chalcogenide glass with silicon, paves the way for a new generation of compact, high-resolution RF photonic filters with wideband frequency tunability. This is particularly useful in air and space-borne RF communication systems, enabling enhanced communications and sensing capabilities. ••

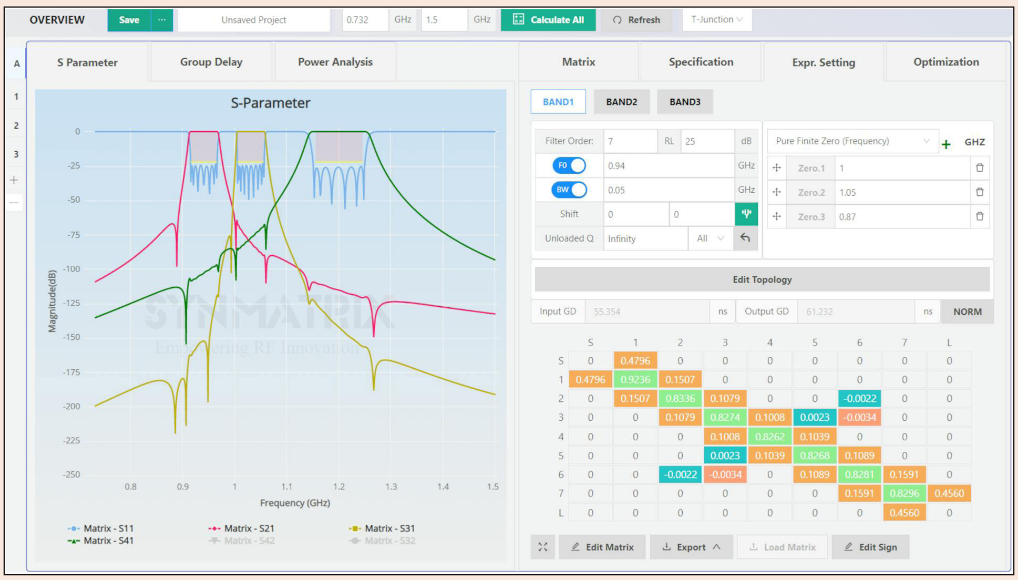


Partnership to Accelerate RF Filter Design

Ansys announced an OEM partnership with SynMatrix to address RF filter design workflows, using SynMatrix's RF filter design and optimization tools with HFSS electromagnetic simulation. Enabling accelerated development, the solution helps reduce project risk, and frees designers to more easily explore new filter technologies.

The SynMatrix partnership will help simplify the development process while reducing the number of software tools required, automating HFSS integration and AI optimization workflows to cut design time by more than half. Automatically generating parameterized HFSS 3D models of common filter types, it delivers predictively accurate simulation results.

Integrating SynMatrix RF filter design into the Ansys portfolio ensures accessibility and reliability, and it empowers innovative design exploration. Support is proactive and efficient.



SynMatrix capabilities go beyond filter design, addressing the development of complex solutions with demanding requirements for shape, size, and electrical specifications. It's also accessible to students and educators through the SynMatrix partnership with the Ansys Academic Program, and to qualified participants in the Ansys Startup Program.••

BAW RF Filters Serve Wi-Fi Automotive and Access-Point Applications

Akoustis Technologies released two new band-edge RF filter products for Wi-Fi automotive and access-point applications, which are expected to ramp into production in the second half of calendar year 2024. The Wi-Fi/LTE coexistence BAW RF filters are designed specifically for the Wi-Fi 2.4-GHz band, covering channels 1 to 11, using XBAW technology for minimal insertion loss with ultra-steep skirts at the band edge. Housed in a ceramic package measuring 1.1 x 0.9 mm, they can extend Wi-Fi range while ensuring coexistence with LTE band 7, 38, 40, and 41. The filters can be used in Wi-Fi routers, access points, extenders, mesh systems, mobile hotspots, ISM, and automotive.

Offering high performance, robust power handling, and high out-of-band rejection, the A10124 will be AEC-Q200 qualified for automotive, providing reliable connectivity for vehicular applications. ••

Wi-Fi UNII 5-8 Filter Features Low Insertion Loss

The Qorvo QPQ5601 is a high-performance, high-power, bulk-acoustic-wave (BAW) bandpass filter (5945 to 7125 MHz) that offers steep skirts while also exhibiting low loss in the Wi-Fi UNII 5-8 band, with high near-in rejection in the UNII 1-3 band. Features include a power handling to +28 dBm and an operating temperature range from -20 to +95°C.

Specifically designed to increase performance in Wi-Fi applications than systems with no or traditional filter solutions, it offers better capability to take advantage of sub-banding the 6 GHz from 5-GHz Wi-Fi spectrum in use cases such as tri-radio Wi-Fi mesh applications.

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