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Microwaves&RF®

Sun, Fun, and Microwaves at IMS

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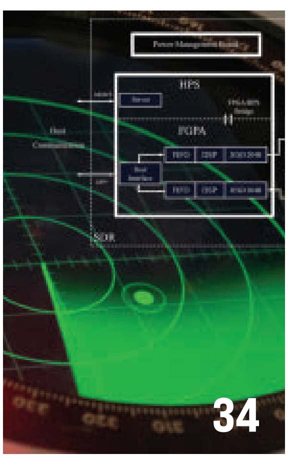

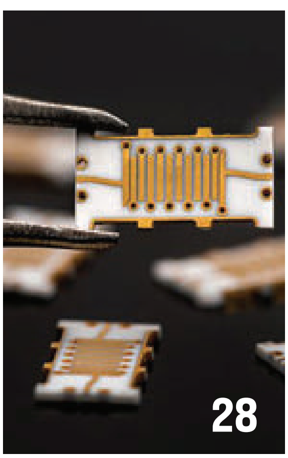

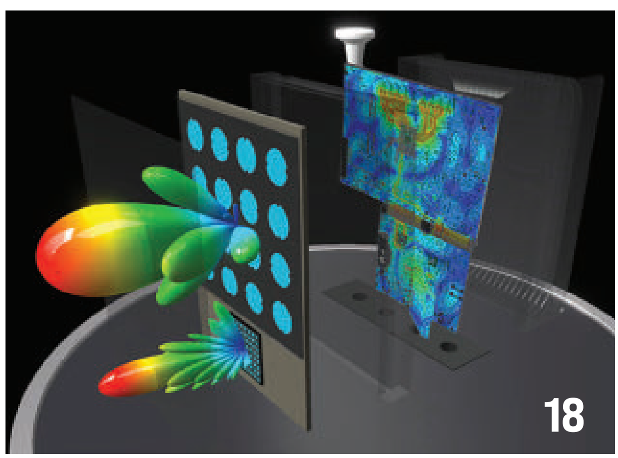

DAVID MALINIAK, Senior Editor

The "Rip and Replace" Cellular Infrastructure Debacle

The FCC's Rip and Replace Program, aimed at ridding the U.S.'s network infrastructure of risky Chinese-made equipment, is proving to be more difficult than it bargained for.

ALL THE WAY BACK in July 2021, the U.S. Federal Communications Commission (FCC) voted unanimously to institute a $1.9 billion "rip-and-replace" effort to subsidize the costs for smaller network operators to rid their networks of Chinese-made equipment, mostly from Huawei and ZTE. These firms' wares have been deemed to pose a national security risk, as the FBI found that the attractively priced Chinese gear was turning up atop cellular towers in unnervingly close proximity to a number of midwestern U.S. military installations.

This all sounds like a prudent plan, one that's attracting bipartisan legislative support especially in light of the Chinese spy balloons and "secret police stations" that have been exposed in recent months. If you can get Republican and Democrat members of Congress to agree on anything, it must be important. The prospect of Chinese intelligence using telecom gear to harvest military and/or commercial secrets is not to be taken lightly.

But as with many of the "best laid plans of mice and men," there are a few stumbling blocks. For one, as of about a year ago, the FCC reported to Congress that two-thirds of the applications it had received thus far from network operators for rip-and-replace reimbursements were "materially deficient," which is to say they weren't completed to the FCC's satisfaction.

However, the bigger problem was that the FCC's cost estimate to remove all of the Huawei/ZTE equipment was $5.3 billion, far higher than the $1.9 billion initially appropriated by Congress. Demand for the funding among small, rural telecom network operators quickly outstripped supply. Thus, the FCC began a triaging effort that had been mandated by Congress, allocating funding to approved applicants with 2 million or fewer customers. Yet, the FCC says it has received 126 applications for funding that go beyond its $1.9 billion appropriation.

Recently, the situation was well illustrated by a *New York Times* article that covered the plight of family-owned Pine Belt Cellular in Alabama. Small carriers like Pine Belt are struggling financially as it is. Now, amid a faltering rip-and-replace effort, it struggles technically as well, because its remaining ZTE equipment doesn't play nice with its new Nokia gear.

Deb Fischer, one of Nebraska's two U.S. Senators, has co-sponsored (with Colorado's U.S. Senator John Hickenlooper) emergency legislation to shore up the $3-billion-plus shortfall in funding for the nation's rip-and-replace efforts. Faced with insufficient funding, small regional carriers like Pine Belt Cellular will either sink under the weight of the burden, or, at best, end up with networks of reduced size. Either way, the rural regions of the U.S. that are most in need of wireless infrastructure will find themselves facing a setback.

Let's hope that Sens. Fischer and Hickenlooper's Defend Our Networks Act attracts the full bipartisan support it needs to do the right thing—helping small regional networks rid themselves of the Chinese-made equipment and, in so doing, strengthening our national security. ■

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LATEST NEWS

Multifunction Spectrum Analyzer Pushes 6 GHz to Support 5G FR1

Anritsu extended the frequency range of its Field Master MS2080A multifunction spectrum analyzer to better address interference hunting and network verification applications.

Anritsu

ANRITSU ENHANCED ITS Field Master MS2080A multifunction spectrum analyzer to operate up to 6 GHz. Combining nine instruments into a single solution, the extended frequency coverage enables the MS2080A to address the growing congestion in the 6-GHz spectrum.

The compact and portable device helps troubleshoot interference and intermodulation issues that can degrade network performance, addressing base-station installation and maintenance (I&M), as well as other applications. At 6 GHz, the MS2080A offers a sweep speed of 45 GHz/s to enable analysis over wider spans.

Advanced features include AM/FM audio demodulation, as well as best-in-class RF performance such as ±1-dB amplitude accuracy. It also supports cable and antenna analyzer, power meter, and 5G/LTE analysis to serve measurement tasks in both legacy and emerging wireless networks.

Furthermore, Anritsu offers an AM/FM-modulation-quality measurement option for all instruments in the Field Master family, enabling full characterization of broadcast transmitters. A single 10-in., 1280 -× 800-resolution screen displays RF spectrum, audio spectrum, and audio oscilloscope information, as well as modulation quality and distortion values. An optional real-time spectrum analyzer offers a 2-µs probability-of-intercept, with an analysis bandwidth up to 40 MHz and DANL of less than −150 dBm.

Capable of capturing intermittent and digitally modulated signals that are difficult to identify, its spectrograms allow for irregular and drifting signals to be captured, recorded, and displayed.

The MS2080A performs a variety of measurements for 5G FR1 radios supporting I&M of 5G NR and LTE base stations. Among them is gated sweep analysis for transmitter-quality measurements provided to verify FR1 carriers with 100-MHz bandwidth, and full-channel, power-based, and 5G/LTE-modulation-quality measurement-based coverage mapping for accurate over-the-air (OTA) testing.

A rugged device for the most challenging environments, its display meets the IK08 specification for direct knocks and drops, and it's presented as the only instrument in its class with 5 W of continuous RF input overload protection. This can prevent damage to the instrument's front-end when used close to high-power transmitters or in a high-signal-level environment. A soft case provides IP52 environmental protection to safeguard the lightweight (less than 4 kg) instrument during transport or rain. ■

Modular System Provides Adaptable EW Capabilities

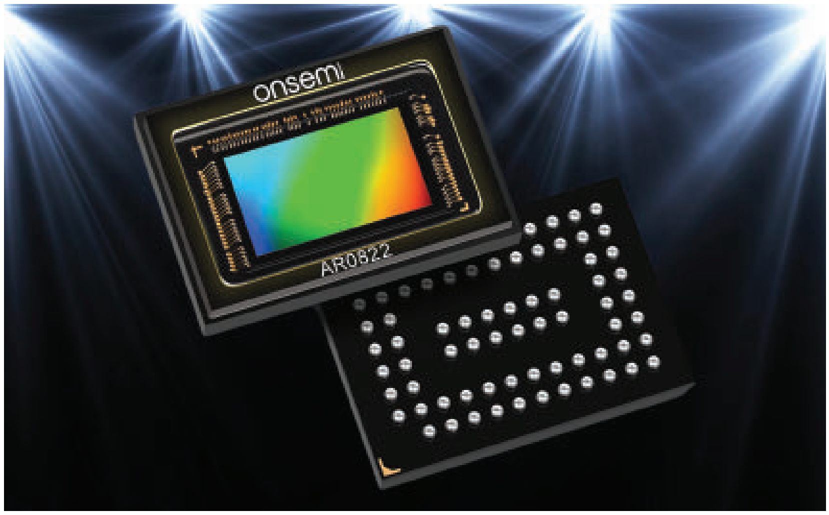
ELECTRONIC-WARFARE (EW) systems must evolve to be effective as in the case of the Prophet EW system from General Dynamics Missions Systems. The base system is designed for full-time, ground-based signal-intelligence (SI), surveillance, and EW duties under all environmental conditions.

When fielded with a Prophet Control (PC) and Prophet-enhanced sensors, the system brings these capabilities to armored fighting vehicles such as Stryker all-terrain eight-wheeled vehicles produced by General Dynamics Land Systems-Canada *(see image)*.

General Dynamics

When increased capability and intelligence-gathering capabilities are required for a wider range of tactical vehicles, the Prophet-Enhanced variant is a platform-independent modular system that's as effective installed onboard a vehicle as when used in mobile manpack applications. The system's wideband beyond-line-of-sight (BLOS) operation is based on its Project Manager Warfighter Information Network–Tactical (WIN-T) architecture.

Prophet-Enhanced EW systems recruit satellite communications (satcom) technology as part of extended data collection and distribution over long-range distances using its PC/Prophet Analytic Cell (PC/PAC) node of operation. The capabilities are provided by lightweight, integrated telecommunications and satcom systems that can be transported in the battlefield by armored vehicles and trailers. ■



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New 8-Mpixel Image Sensor Delivers 4K Video Quality

AN 8-MPIXEL IMAGE sensor from onsemi is capable of producing 4K video in harsh lighting conditions. The AR0822's embedded high dynamic range (eHDR) and optimized near-infrared (NIR) make it well-suited for applications in poor lighting conditions, including surveillance, doorbell cameras, body cameras, and robotics. The sensor also packs low-power and wake-on-motion features, reducing its overall power consumption.

The AR0822 was designed using a stacked 1/1.8-in. (8.81 mm diagonal) back-side illuminated (BSI) CMOS digital image sensor based upon a 2.0-µm pixel. This allows it to drive an active pixel array of 3840 × 2160, produce 4K video at 60 fps, and capture images in linear or eHDR modes (120 dB) with a rolling-shutter readout. This mitigates LED flicker effects when using multiple images and eliminates motion blur associated with multi-image HDR.

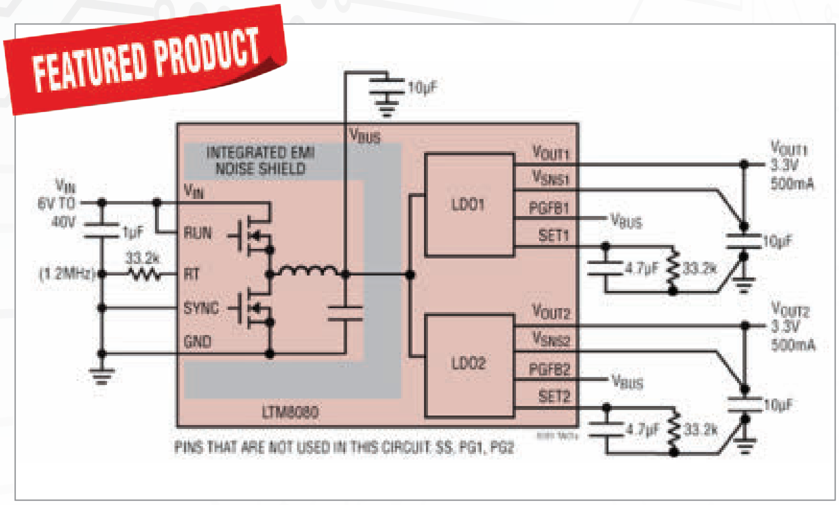
One of the main challenges of using modern imagers is operating in adverse lighting conditions, especially cameras that use HDR with prominent light and dark areas. Some HDR techniques rely on multi-exposure outputs or those that use three or more images with different exposures to create a scene.

Image signal processors (ISPs) combine those images to produce a final render, which eats bandwidth and time, certainly when higher resolutions are involved. The AR0822 is outfitted with embedded HDR technology on the sensor itself, which helps reduce processing power while producing exceptional images without the need for high bandwidth.

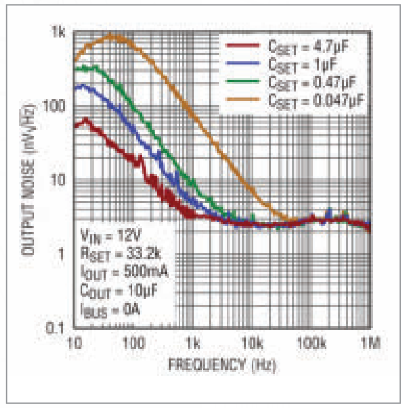
"The AR0822 delivers industry-leading performance in low-light conditions while enabling our customers to achieve the 120 dB of eHDR they need with lower system power and cost," stated Ross Jatou, senior VP at onsemi's Intelligent Sensing Group. "This combination creates a strong value proposition for our customers to meet market trends for more advanced imaging with energy-conscious solutions and longer battery life."

To achieve that low-power usage and long battery life, the AR0822 optimizes system power using features such as wake-on-motion, which places the sensor in hibernation until movement is detected within its field of view (FOV). That being said, the sensor also provides enhanced NIR sensitivity and additional functions such as binning and windowing. It's able to handle rugged environments and can operate in temperatures ranging from 30 to 85°C, making it ideal for industrial and outdoor use. ■

Micro-Module Regulator Counters Conventional Wisdom on Output Noise



1. Analog Devices' LTM8080 incorporates a combination of patented silicon, layout, and packaging innovations, resulting in an extremely low-noise, dual-output dc-dc µModule regulator. Analog Devices



2. This graph, one of many in the LTM8080 datasheet, shows the extreme low-noise performance despite the presence of a switching regulator in the design. Analog Devices

THE MESSAGES OF CONVENTIONAL wisdom and "rules of thumb" that were perhaps once true can take a long time to change. Consider the widely held view on step-down (buck) switching dc-dc regulators compared to all-analog low-dropout (LDO) regulators. After all, "everyone" knows that the former is far more efficient but has much higher noise than the latter. Furthermore, the difference is due to inherent architectural limitations; thus, there's little that can be done about it other than filtering and more filtering.

That may have been true up to a few years ago, but it isn't always the case. First, in the range of 0.5- to 1-A output, the LDO may be far less efficient than the switcher in the general sense. However, in some scenarios, such as when the duty cycle is low, the actual energy-usage difference may be small and even negligible.

Even more noteworthy is the change in switching-regulator noise performance, going far beyond just adding more output filtering (which brings a new set of issues related to dynamic performance). The LTM8080 from Analog Devices continues the advances as an extremely low-noise, dual-output dc-dc µModule regulator. It uses a combination of patented silicon, layout, and packaging innovations to achieve its specified performance to integrate the best of both switcher and LDO worlds without their downsides.

The LTM8080's front-end is a high-efficiency synchronous Silent Switcher step-down regulator that's followed by two separate, low-noise LDOs *(Fig. 1)*. The package includes the controllers, power switches, inductors, and support components. As an integrated solution comprised of a switcher and LDOs, it offers advantages of both while maintaining a small size and significantly reduced PCB layout sensitivity. To further suppress switching noise, the LTM8080's packaging incorporates an EMI barrier wall or shield.

The LTM8080 operates from inputs ranging from 3.5 to 40 V; the dual outputs can bet set from 0 to 8 V at 500 mA each or combined for a single 1-A maximum. It targets digital loads that are susceptible to switching-regulator noise such as data converters, RF transmitters, FPGA I/O and clock, op amps, transceivers, and medical scanners.

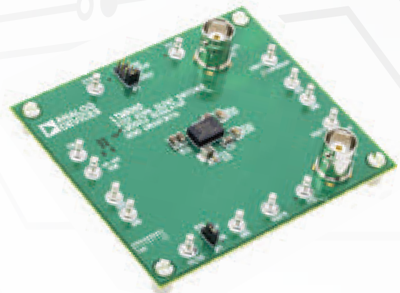
The result is exceptionally low noise values below1 μV_{RMS} (10 Hz to 100 kHz), 2 nV/√Hz spot noise (at 10 kHz), and 80-dB PSRR (100 kHz) *(Fig. 2)*.

Compared to discrete solutions without an EMI shield, the LTM8080 reduces output ripple voltage by up to 70% for a simplified and quiet design. It minimizes EMI emissions and enables the device to pass CISPR22 Class B and CISPR25 Class 5 without an input filter. In addition, the adjustable switching frequency (200 kHz to 2 MHz) and selectable operation modes minimize the risk of frequency interference for very-low-noise instrumentation and high-speed/high-precision signal-chain applications.

Compared to discrete solutions without an EMI shield, the LTM8080 reduces output ripple voltage by up to 70% for a simplified and quiet design.

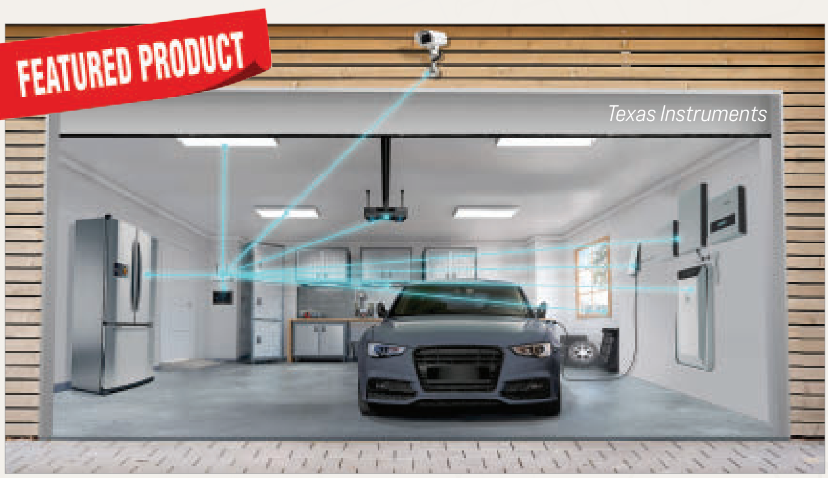
Furthermore, the LTM8080 has a built-in voltage tracking function that automatically sets V_{BUS} to either 2.5 V nominal or 1 V higher than V_{OUT1}, whichever is greater, to achieve superior noise performance and minimize power dissipation. It also has provision for external synchronization and offers a programmable "power good" indication.

The LTM808 is packaged in a thermally enhanced, compact (9 × 6.25 × 3.32 mm) overmolded ball-grid-array (BGA) package. The –40 to 125°C version is priced at $12.83 (1,000 pieces), while the wider range –55 to 125°C version costs $14.11. The devices are supported by the DC3701A demonstration circuit board *(Fig. 3)*, complete with its own 10-page User Manual. ■



3. The companion DC3701A demonstration circuit board enables users to exercise the LTM8080 and observe its performance under their operating conditions. Analog Devices

Wireless ICs Deliver Reliable Wi-Fi 6, Bluetooth LE Connections Anywhere



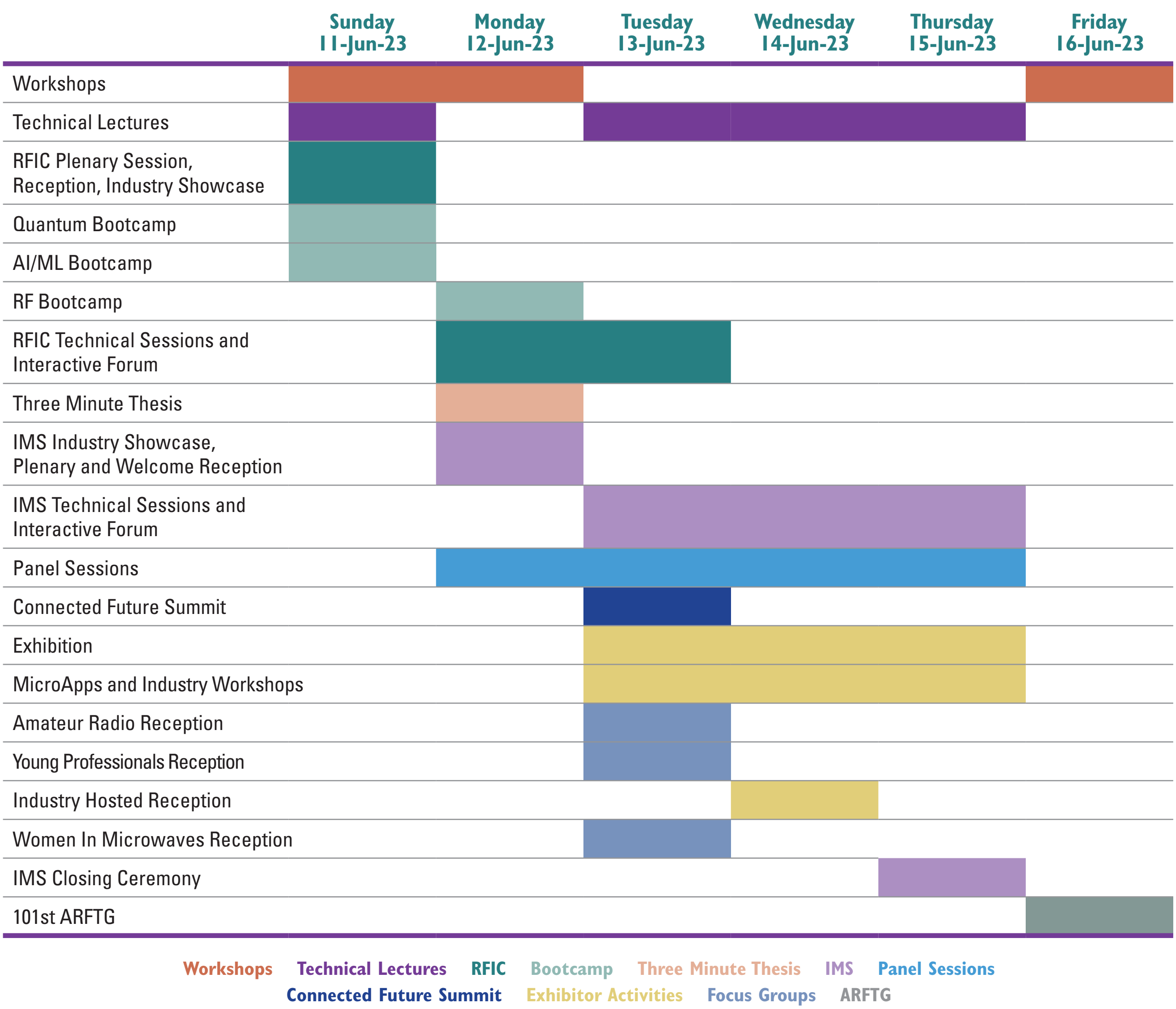
TEXAS INSTRUMENTS INTRODUCED its latest SimpleLink family of Wi-Fi 6 companion ICs that provide cost-effective, reliable, secure, and efficient Wi-Fi connections for applications in high-density or high-temperature environments. The CC33xx family includes devices for Wi-Fi 6 only, or for Wi-Fi 6 and Bluetooth Low Energy (LE) 5.3 connectivity in a single IC. The devices enable a secure IoT connection with reliable RF performance when attached to a microcontroller or processor.

The 2.4-GHz SimpleLink CC3300 Wi-Fi 6 companion IC and CC3301 Wi-Fi 6 and Bluetooth LE companion IC offer greater Wi-Fi network efficiency and a stable connection across more than 230 access points. Operating temperature ranges from –40 to 105°C.

Able to connect to IoT edge nodes directly, to home or enterprise access points without additional equipment, the Wi-Fi 6 companion devices offer orthogonal frequency-division multiple access (OFDMA) technology and basic service set (BSS) coloring for reliable network performance. They can connect more devices simultaneously, without interference from congestion. In addition, they support Wi-Fi Protected Access (WPA) security features, including WPA3 cryptographic technologies and a secure-boot feature with firmware authentication.

SimpleLink CC3300 and CC3301 Wi-Fi 6 companion ICs easily attach to TI and many other companies' MCUs and processors that support Linux or real-time operating systems. Furthermore, the CC3300 can incorporate host MCUs such as TI's 2.4-GHz CC2652R7 SimpleLink multiprotocol wireless MCU or an AM243x MCU-hosted system to handle Wi-Fi 6, Bluetooth LE 5.3, Thread, Zigbee 3.0, and Matter protocols. ■

Week At-A-Glance & Plenary Speakers



RFIC SPEAKER
Prof. Mau-Chung Frank Chang
Wintek Chair in Electrical Engineering and Distinguished Professor, *University of California, Los Angeles (UCLA)*

RFIC SPEAKER
Dr. Todd Younkin
President & CEO, *Semiconductor Research Corporation (SRC)*

IMS SPEAKER
Ed Godshalk, PhD
Consultant and Engineer in Residence, *George Fox University*

For the latest on IMS and Microwave Week visit ims-ieee.org

IMS 2023 SAILS INTO SAN DIEGO

By David Maliniak, Senior Editor

Regarded as the flagship event dedicated to the RF and microwave world, IMS 2023 returns to beautiful San Diego in June with a host of technical sessions, workshops, boot camps, and social events.

EVERY INDUSTRY HAS ITS "biggest tradeshow and conference," and for the RF/microwave community, the International Microwave Symposium (IMS) is *IT*. Each year, as they have since 1952, speakers, exhibitors, and attendees from around the world gather to exchange ideas and assess where the industry is, and, more importantly, where it's going. For the first time since 1994, IMS 2023 returns to San Diego for what's known colloquially as Microwave Week, with the overall event spanning from Sunday, June 11 to Friday, June 16.

With an eye toward "the coolest ideas under the sun," IMS 2023 will take over the San Diego Convention Center on the bayfront for the week. It will be co-located with the IEEE MTT-S Radio Frequency Integrated Circuits Symposium (RFIC) and the Automatic Radio Frequency Techniques Group (ARFTG).

Alongside the packed schedule of sessions, keynotes, and workshops, the exhibit hall (open Tuesday to Thursday) will feature more than 500 exhibitors eager to show off their newest wares. That's up from 350+ exhibitors at IMS 2022 in Denver—providing further evidence that the industry is shaking off the pandemic blues.

IMS typically assigns itself a few themes each year, and this year is no different. The first, Systems & Applications, encompasses the continuing development of RF, microwave, mmWave, and THz systems from semiconductor design through the device/module level and up to overall systems and applications. The second, Space, includes such topics as satellite communications, design for reliability, radiation hardness, CubeSats, and Internet of Space systems. The third theme is Biomedical Applications, illustrating the use of RF and microwave technologies in the biomedical field.

These three themes will comprise what's called the Systems Forum, with special focused technical paper sessions, panel discussions, invited speakers, and workshops. They'll be broken out into daily technical themes:

IMS
Connecting Minds. Exchanging Ideas.
The Coolest Ideas Under the Sun
SAN DIEGO 2023

- **Tuesday:** Wireless Communications, Future Directions (AI/ML), and the Connected Future Summit
- **Wednesday:** Model-Based Systems Engineering and Space
- **Thursday:** Wireless Power Transfer and Biomedical

A Systems Pavilion will display several practical examples of systems and applications at frequencies from RF through THz.

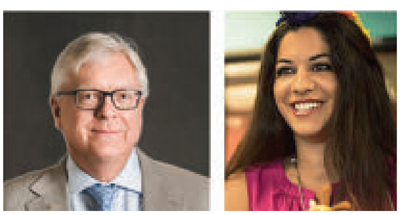
Highlights from the Technical Program

IMS 2023 will host an extremely broad, deep, and ambitious slate of technical presentations in various formats. At the outset, note that several events are intended for the future leaders of the RF/microwave industry, including Student Design Competitions, the University Booth Program, and the Three-Minute Thesis Competition.

Another highlight is a joint panel discussion in the Young Professionals Lounge sponsored by Women in Microwaves and Young Professionals, at which female tech leaders and entrepreneurs will discuss the role of young pros in the industry (Thursday, 2 pm, Sails Pavilion).

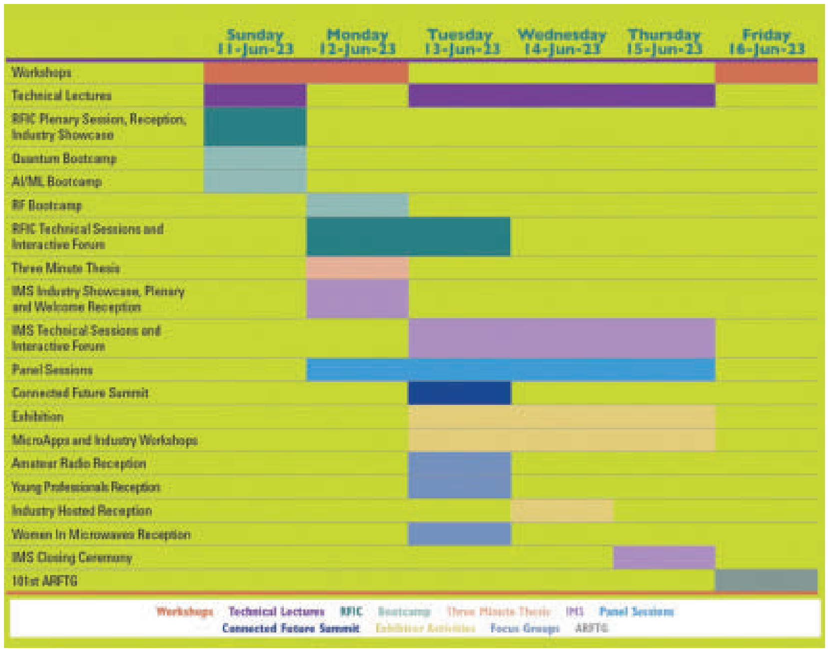
Plenary and Closing Sessions

Monday's Plenary Session (2:30, Ballroom 20), titled "The Role of the Transmission Line in Connecting People," will be delivered by Ed Godshalk, PhD *(Fig. 1, left)*, a consultant and Engineer in Residence at George Fox University with a long history of working at companies like Cascade Microtech, Maxim Integrated, and Tektronix. His presentation will cover the evolution of transmission-line technology from its role in the "Victorian internet" (telegraphy) to today's transoceanic fiber lines, the common thread being the smashing of data-rate barriers.



1. The Plenary and Closing Sessions will be addressed by Ed Godshalk (left) and Saura Naderi (right), respectively.

In the Closing Session (Thursday, 3:30, Ballroom 20), Saura Naderi *(Fig. 1, right)* of the Halicioğlu Data Science Institute at UC San Diego will give a talk titled "Inspiring the Next Generation into STEM/STEAM." She'll discuss the value



of encouraging young people into engineering careers and how her audience can help them succeed in STEM fields.

Workshops

IMS 2023 is replete with a whopping 33 technical workshops conducted by experts from academia and industry, spread over three days of the event (Sunday, Monday, and Friday). Each of the three days will present a range of workshops on a myriad of topics.

For example, Sunday's offerings range from the fundamentals of RF power amplifiers to 6G-related topics and high-data-rate interconnect technologies. Monday's workshops span the likes of synthesis-based filter design; quantum circuits, methods, and algorithms; and transitioning from microwave to mmWave acoustic-wave devices. Friday's schedule includes mmWave phased arrays and RF and mmWave biomedical radar technologies.

Connected Future Summit

Tuesday's Connected Future Summit is the fruit of a collaboration between the IEEE MTT-S and COMSOC and will center on the theme of connected transportation. Future Next G (6G) networks will comprise a seamless integration of communication, computation, and artificial intelligence. This comes in the context of rapid evolution in the wireless connectivity landscape, melding Wi-Fi and broadband non-terrestrial networks (NTNs) based on low-Earth-orbit (LEO) satellite constellations.

The Summit will outline how Next G technical specifications are being transposed into standards by 3GPP and the ITU's Radiocommunication Sector. It will also delve into how these standards for Next G deployment will impact future directions of connectivity through next-generation Wi-Fi technologies and broadband satellite networks.

In his Connected Transportation Keynote, Qualcomm's James Misener will speak about how link and network connectivity and their underlying technologies will spur acceleration of transportation-system management and individual traveler movement to portend how we'll collectively get around in the future. The parallel development of various radio-access technologies and their deployment in both vehicles and infrastructure will transform our way of traveling.

Boot Camps Abound

IMS's Boot Camps are a great way to jump-start your understanding of a dense thicket of technologies. Two Boot Camps will take place on Sunday this year: the AI/ML Boot Camp and the Quantum Boot Camp. The former will get you going with artificial intelligence and machine learning for microwave applications. What is AI/ML? How are these technologies relevant in microwave-system design? What are their benefits and limitations? These questions, and many more, will be answered for attendees.

Likewise, the Quantum Boot Camp will explore the nascent connection between MTT-S and the quantum-computing industry. For quantum computing to succeed, the industry needs multidisciplinary engineers with a handle on both quantum physics and microwave engineering. This Boot Camp will present the basics of quantum engineering to microwave engineers who want to make their marks in this emerging field of study.

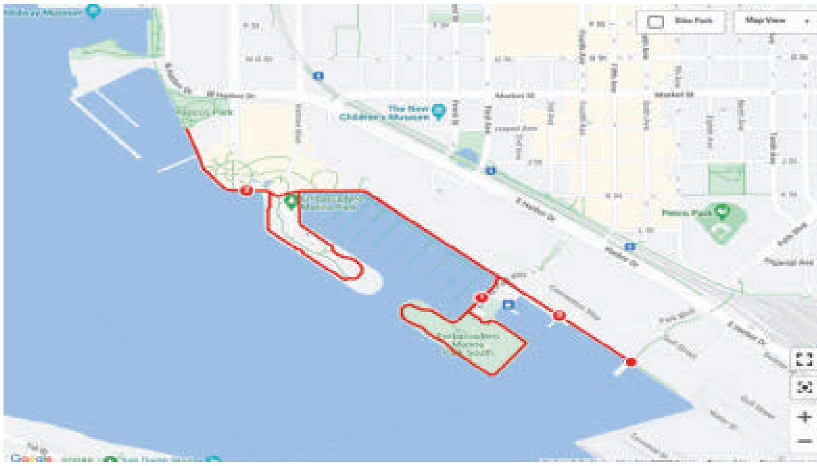
Monday's MTT-S RF Boot Camp will help you grow RF/microwave skills in an educational forum focused on the fundamentals of microwave theory and techniques. It's meant for those who are new to the field as well as those wishing to stay current with new technologies, and it's worth two IEEE continuing education credits to attendees.

Technical Sessions

On its Technical Sessions homepage, IMS divides the sessions into six topics:

- Field, Device, and Circuit Technology
- Passive Components
- Emerging Technical Areas
- Active Devices
- Systems & Applications
- Focus & Special Sessions

On Tuesday, Wednesday, and Thursday, the slate of technical sessions ranges through these broad topic areas, mixing and matching them each day in a panoply of subjects. For example, on Tuesday one can learn about advances in HBTs/HEMTs in RF applications, microwave and mmWave LNAs, and integrated passive devices.



2. *The inaugural IMS 5K Fun Run/Walk will take you on a tour of San Diego's Embarcadero. IMS*

Wednesday's lineup covers enabling technologies for sub-THz and THz systems, mmWave automotive radar systems, and emerging planar filters from L-band to mmWave. Sticking around through Thursday will avail you of sessions on wireless power transfer, advances in microwave acoustics, and biomedical radar-sensing techniques.

Social Events

Numerous social events are scheduled from Monday through Wednesday, starting with the IMS Welcome Event (Monday, 7 pm; Sails Pavilion) that immediately follows the Plenary Session with a Latin American Street Party theme. A Ham Radio social (Tuesday, 6 pm, Hilton Bayfront) for all radio amateurs and the ham-curious will sport a complementary buffet and drinks. That event overlaps with the Women in Microwaves reception (Tuesday, 6:30 pm, Hilton Bayfront), which spotlights the work of female RF engineers and researchers.

Wednesday evening's Industry-Hosted reception (5 pm, IMS show floor) promises a beach-party-themed event with appetizers, drinks, and networking on the menu. Finally, the MTT-S Awards Banquet (Wednesday, 6:30 pm, Hilton Bayfront) will honor industry luminaries and present entertainment.

San Diego at Large

If this is your first visit to San Diego, be aware that you're visiting a jewel of a city with lots to see and do. The weather is great year-round, with June temperatures averaging between 62 and 72°F, and little chance of precipitation. Thus, you won't have much excuse to skip the inaugural IMS 5K Fun Run/Walk (Wednesday, 6:30 am, Embarcadero) along the San Diego Bay *(Fig. 2)*.

And for baseball fans, good news—the San Diego Padres are in town during Microwave Week. Their home, Petco Park, is located directly across Harbor Drive from the convention center. They'll be facing the Cleveland Guardians on Tuesday, Wednesday, and Thursday evenings. Be aware that it can get chilly at Petco on June evenings (ask me how I know).

Conclusion

In closing, there's a multitude of great reasons to make your way to San Diego for IMS and Microwave Week. You won't find a more relevant venue at which to learn about RF/microwave/mmWave technologies, techniques, and research. Formal and informal networking opportunities are plentiful, where you'll have access to technical experts, peers, and exhibiting vendors. And San Diego itself offers a great time to attendees. Looking forward to seeing you there! ■

Where Do You Engineer?

Although the events of the past few years have transformed how many of us work, the changes in the electronic test & measurement community aren't as deep as many believe.

By Alix Paultre, *Editor-at-Large*

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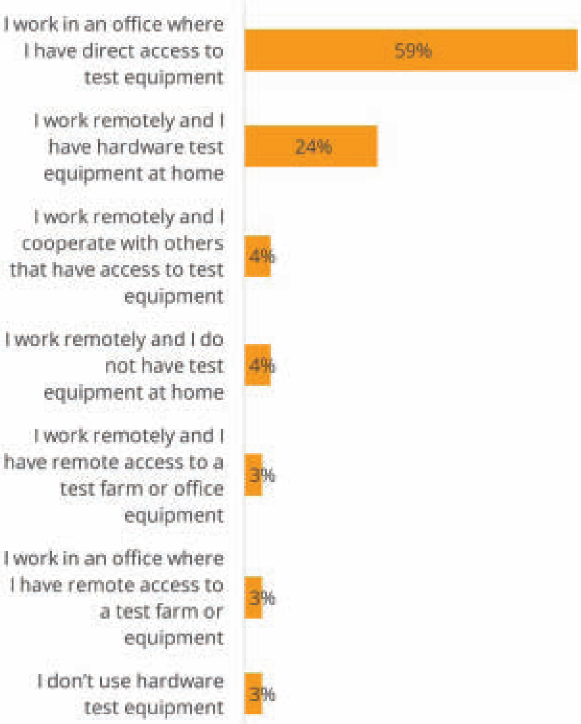
WHEN IT COMES to engineering, there are lots of ways to work remotely when your primary tool is a computer. However, not all design engineering tasks can be performed in that way. This is especially the case in the test & measurement arena, which may require a number of specialized (and expensive) devices. Such work can only be performed if the engineer in question either has those tools, or their organization has advanced devices that allow for remote access and operation.

We recently surveyed our engineering readership to tell us about how they use hardware test & measurement tools, and if they do so remotely or on-site. We asked if they worked in an office with direct access, if they worked with hardware at home, had remote access to equipment, or had on-site colleagues who used the equipment and worked with them. The answers we received were interesting and informative *(see figure below).*

Our hardware test & measurement survey revealed some interesting information on tool usage.



More than half of the respondents still work in an office where they have direct access to test equipment (59%), while 24% said they work remotely with hardware test equipment at home. This shows the importance of hands-on access to the tools needed to do the job. The surprise answer was the low number of engineers who aren't using networked equipment remotely to perform their tasks.

Such connected tools have been around for a while now, and with the pressure to work remotely, it's interesting that this solution hasn't been further explored. The issue of adoption could relate to the need to have someone at the remote device performing the hands-on aspects of probe placement and manipulating the device under test. These connected tools can be a powerful force multiplier in remote work, but procedures and methodologies must be developed to use them properly.

The big takeaway from this survey is the high percentage of engineers that have the test & measurement hardware at home. This makes sense, as the hands-on aspect of testing hardware makes it a challenge to use such gear remotely. By having the test equipment at home, an engineer can work comfortably and effectively at home.

However, such an approach is also the most expensive for the organization involved, and it can create inventory-management issues and upgrade challenges. Remote tools are able to address this issue, but methods and means must still be worked out for those who could benefit from that approach.

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THE 7 PILLARS of 5G/6G RF System Design (Part 1)

Designers of 5G/6G systems must take into account the seven major "pillars" critical to their successful creation, which center around antennas, receivers, and RF power, among other key issues.

By Shawn Carpenter, *Program Director – Electronics Product Management, Ansys*

In the Old Testament's Book of Proverbs, the first verse of the ninth chapter is simultaneously enigmatic and captivating: "Wisdom has built her house; she has set up its seven pillars." The verse has been referenced frequently and in a broad variety of ways over the centuries.

Regardless of how interpretations of the verse may vary, all reflect an underlying understanding—that creative success requires planning, expertise, insight, inspiration, using the proper instruments, and above all, a commitment to achieve value that's both exceptional and unique.

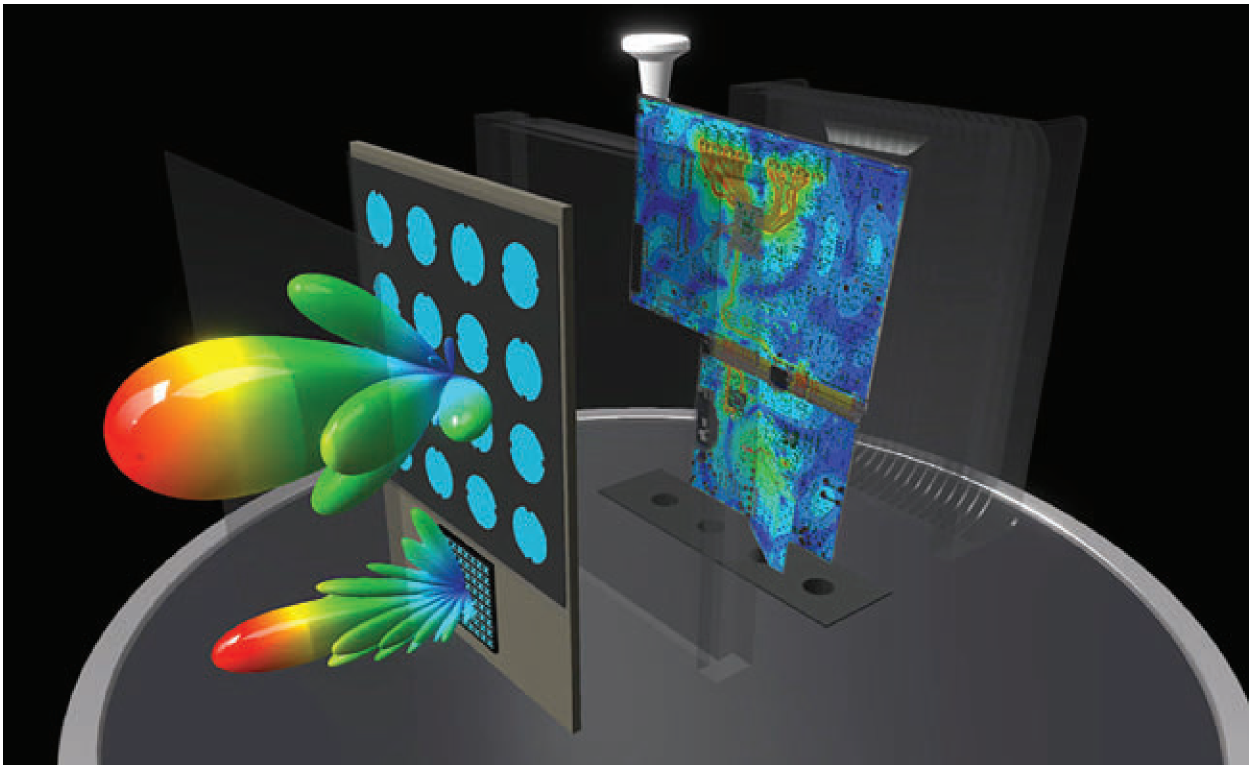
We can logically extend the above to any endeavor in High Technology, and particularly to one of the leading sectors for innovation at the chip, system, and software level: RF communication systems in 5G/6G. At the heart of these communications systems lies the physical layer, involving modulation, transmission, and demodulation of signal and data content over the wireless channel. Operating the physical layer reliably has implications on the total cost of ownership (TCO) of the equipment, which is the single overriding concern for the customer service provider (CSP) purchasing, operating, and maintaining that equipment.

What, then, are the pillars that serve as major considerations in 5G/6G physical-layer design?

1. RF power

This is usually a major driver for both the design and operating cost of the base station or mobile device. RF power is what enables the communication system to be heard at increasing ranges—more RF power from the transmitter usually results in more range.

RF power received by a mobile device is usually a combination of the base-station transmitter power and the relative directivity of the antenna on each end. This



This 5G base-station diagram is a telescoped system view with electromagnetic capture. Ansys

leads to an interesting tradeoff between an antenna's ability to focus the RF power that's radiated, and the RF power generated in the antenna. Generating RF power also results in generating heat, which leads to other multi-physics challenges like mechanical expansion and stress.

Allowable RF power radiated by an access point or device is subject to regulatory control, too, which governs topics like exposure safety and potential for interference to other RF systems.

2. Antenna sizing

There's nothing trivial about deciding how big an antenna will be. In general, a larger antenna will exhibit higher directivity, and it can offer an operational RF link with lower RF power than a smaller antenna. Indeed, base-station antenna systems consist of multi-element antenna arrays, leading to beamforming capabilities that enable the antenna to focus the signals spatially on subscribers. These antenna systems may be arbitrarily large, but considerations such as wind loading, tower mount weighting, and multi-band service also drive size and weight considerations.

Heavier antenna systems require more costly towers and installation mount points. Larger arrays with more elements require more supply power, driving up the operational electric bill. Generation and distribution of RF power across these arrays can be costly, and they will incur power loss from source to antenna that must be made up by the RF transmitter. Passive cooling and heatsinks must be considered in the overall size and weight.

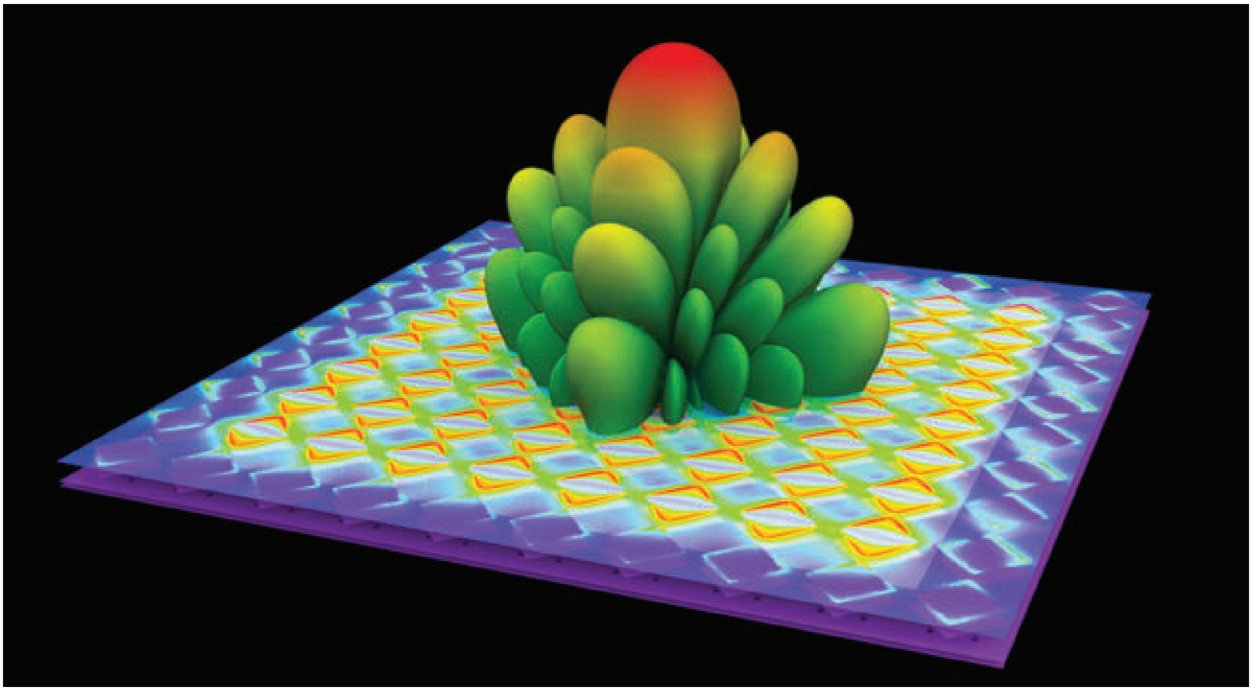
Antennas in mobile devices must fit tight form-factor requirements, which often drive difficult design and integration challenges. Further, the package integration may reduce radiation efficiency—power loss that must be made up by increasing power at the expense of battery life. Mobile device antennas also are subject to strict emissions standards for personal health, safety, and coexistence with other RF systems.

3. Antenna agility and beamforming

Antennas form the interface that matches the radio electronics to the physical environment, which forms the wireless channel. Choose that antenna poorly, and the receiver on the other end of the channel will fail to detect the signal. Design the antenna well, and you can minimize the cost you invest in both the transmitter and the receiver.

Antenna systems composed of many antenna elements (phased arrays) offer the ability to shape the way RF power is physically projected into the environment. By using techniques such as polarization diversity and beamforming, we can enhance the number of simultaneous pathways for RF signals to traverse the environment to serve more users with better throughput.

Methodologies like multi-user massive multi-input/multi-output (MU-mMIMO) are gaining traction in enabling base-station arrays and mobile devices to support high levels of service. These agility tech-



This 5G antenna array showing active radiation was captured using EM field capture by Ansys HFSS. Ansys

niques don't come for free—they require a great deal more baseband processing, putting pressure on the power and complexity of the packaged digital and RF electronics within the base station or mobile device.

4. RF bandwidth

It's true—there's a direct relationship between the bandwidth of an RF communication channel and the amount of data that can be sent over it. Double the RF channel bandwidth and you double the data that can be sent over it. Expanding bandwidth leads to new challenges acutely felt by the RF and antenna system designer.

Compact, efficient antennas are naturally narrowband devices—they must be carefully designed to be efficient radiators over wide bandwidths, or multiple antenna systems will be required to serve each band (another tradeoff!). Availability of wideband RF channels is scarce at low microwave frequencies, but more widely available at mid-microwave and mmWave frequencies (where wideband is easier to manage in a fractional bandwidth of carrier frequency sense).

Higher-frequency systems require more cost and care to design and exhibit reduced power-added efficiency (the ability of the transmitter to efficiently convert supply power to RF power). Wider bandwidths drive the need for digital receivers to sample at considerably higher rates, leading to elevated power consumption, more digital data to process, and added complexity to the packaged electronics in the baseband processor.

5. RF waveform selection

Developing RF systems to leverage an available or licensed bandwidth is one thing, but how that spectrum is used is another. The RF modulation technique (how we put information onto an RF carrier for transmission) will drive a metric called "spectrum efficiency."

Spectrum efficiency is usually expressed in bits/hertz (b/Hz, or b/MHz), and tells us something about how much digital data our RF system can push through the available RF channel bandwidth at a prescribed error rate. This depends on factors like the digital modulation scheme, the number and spacing of reference or data subcarriers used in the waveform, signal-to-noise and signal-to-interference ratios in the channel, and the transmission symbol rates employed in both time and frequency division.

It's an area of extensive research. In 6G systems, it may be possible for future RF systems to dynamically adjust their waveforms through artificial intelligence and machine learning (AI/ML) to reactively counter dynamic wireless channel behavior as the physical environment changes and as users (or other independent bodies) move.

6. Receiver design

Good receivers have two salient characteristics: they detect weak signals, and they reject unwanted signals (interference). Today's receivers are increasingly digital, and architectures are coming forward that place one at each base-station element or at sub-groups of elements for enhanced flexibility.

Mobile device receivers must contend with noisy RF environments, small and inefficient form factors for integration and must operate continually to moni-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tor the channel for incoming calls or targeted data. Low-noise RF front ends often require high current bias, making continual operation an enemy of the battery.

7. Bespoke wireless channel modeling

Legacy RF communication systems employed in 3G and 4G systems have been constrained to bands ≤ 2500 MHz. The past 40 years of wireless telecommunications have provided us with voluminous measurement data for characterizing RF wireless propagation through dense urban and terrestrial settings.

At these frequencies, signals tend to propagate with reasonable predictability through and around buildings and terrain. Many proven empirical and statistical channel models have provided RF communication system designers with the utility they need to test RF chain and signal-processing concepts.

As 5G and 6G systems arise, they're using high-frequency bands where RF propagation models are less reliable. Higher frequencies make wider bandwidths possible and usable. The environment becomes more reflective and less penetrable by RF signals, leading to stronger multi-path and diffraction effects. Propagation losses mount over physical distance with increasing frequency, leading to the need for larger antennas.

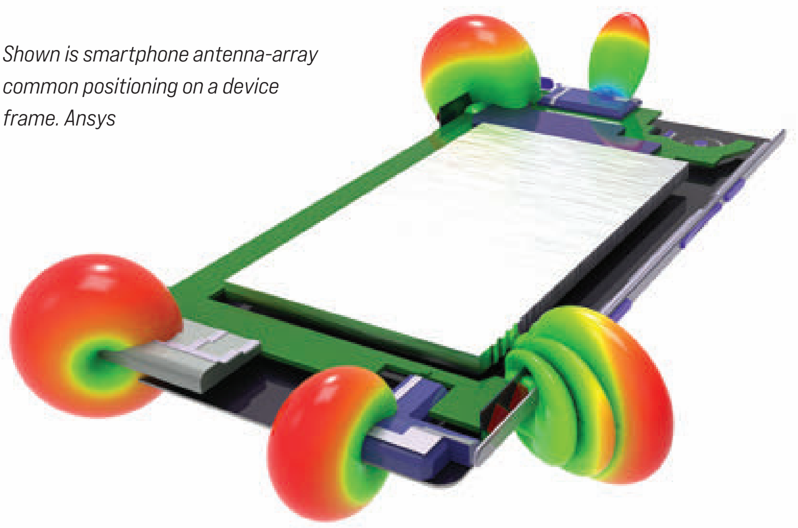
The lack of reliable wireless channel models at higher frequencies necessitates modeling the physics of RF scattering at the specific base-station location, and to the locations of subscribers (and interferers). With accurate wireless channel modeling customized to a specific location, telecom system providers can customize all aspects of a wireless access point for the lowest total cost of ownership. This would optimize all six of our previous categories to meet key performance indicators for minimum total design and operational cost.

What's the Prognosis?

One can readily discern that these pillars are significantly more complex in terms of instantiation than for most problems because of their evident dynamic interactivity and interdependence. Furthermore, many advanced design options and their attendant issues are subject to significant repercussions from these primary design pillars.

One can readily discern that these pillars are significantly more complex in terms of instantiation than for most problems because of their evident dynamic interactivity and interdependence.

Such repercussions include channel latencies, the "densification" of hierarchical networks (from femtocells and microcells up to base stations and the extension to air- and space-based non-terrestrial/satellite nodes), edge processing, the downstream impact on 6G, implications for optical backhaul and consequences to processing support (including asymmetric heterogeneous multiprocessing), to name a few. ■



Shown is smartphone antenna-array common positioning on a device frame. Ansys

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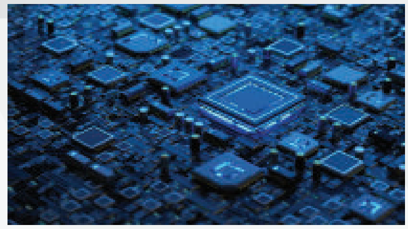
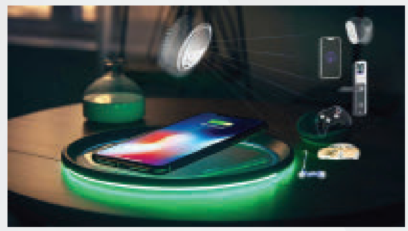


What Designers Should Know About iSIMs

iSIM technology, or the integrated version of SIM and its functionality, is broadening the path for secure embedded design. What are the differences between iSIM, eSIM, and SIM? **www.mwrf.com/21266005**



Introduction to Wireless Power Technologies

Wireless charging, which is finally transitioning from labs into commercial deployments, means different things to different people. This article provides an overview and comparison of the various technologies and market approaches. **www.mwrf.com/21265790**

What's the Difference Between Wi-Fi HaLow and Bluetooth?

As the IoT's reach into daily life is extended, it's important to understand the various wireless protocols that meet the unique needs of IoT environments. **www.mwrf.com/21265152**

RF/mmWave Filters Simplify Spectrum Management

There's no underestimating the importance of filtering in RF system design. This report contains the latest innovations in the art of RF filtering and spectrum management.

By Jack Browne, *Technical Editor*

The electromagnetic (EM) spectrum may be wide, but it's not unlimited, and engineers depend on high-frequency filters to help keep EM signals in place. Filters gain in importance as the applications within RF, microwave (MW), and even millimeter-wave (mmWave) frequencies continue to expand, protecting signals of interest from noise and preventing nearby signals from causing unwanted interference. High-frequency filters are available in many technologies and package styles, and this special report facilitates the task of finding a filter that enables many EM signals to coexist.

RF/MW filters are frequency-control components that help squeeze the greatest number of applications into the least amount of spectrum possible. They can be fixed or tunable, active or passive. They're simple in nature, designed to transfer some signals and stop others, such as for a radio channel. Such filters can be implemented on a printed circuit board (PCB) with essential lumped elements of a resistor (R), inductor (L), and capacitor (C), and they shrink in size

HIGH-FREQUENCY RF/MW FILTER SUPPLIERS AT A GLANCE

COMPANY	WEBSITE	FILTER TYPES
Anatech Electronics	www.anatechelectronics.com	cavity, ceramic, WG
Benchmark Lark Tech.	www.bench.com/lark	tunable filters, assemblies
Broadcom	www.broadcom.com	FBAR
Cernex	www.cernex.com	coaxial diplexers
Coleman Microwave	www.colemanmw.com	tunable WG
Crystek Corp.	www.crystek.com	crystal
Eastern Wireless TeleComm	www.ewtfilters.com	coaxial
Eravant	www.eravant.com	WG
ES Microwave LLC	www.esmicrowave.com	suspended substrate
Fairview Microwave	www.fairviewmicrowave.com	cavity
Filtronetics Inc.	www.filtro.net	ceramic, crystal, LC, SAW
Johanson Technology	www.johansontechnology.com	ceramic SMT
K&L Microwave	www.mpgdover.com	cavity, ceramic, coaxial, WG
KR Electronics	www.krfilters.com	coaxial, WG
L-COM	www.l-com.com	coaxial
MACOM	www.macom.com	CATV (75 Ω)
Marki Microwave	www.markimicrowave.com	LC, MMIC
MCV Microwave	www.mcv-microwave.com	LC
Microlab FXR	www.microlabtech.com	low PIM
Micro Lambda Wireless	www.microlambdawireless.com	YIG
Microwave Circuits, Gowanda Components Group	www.diplexers.com	coaxial diplexers
Microwave Filter Co.	www.microwavefilter.com	coaxial, WG
Mini-Circuits	www.minicircuits.com	ceramic, coaxial, SMT, WG
Murata	www.murata.com	BAW, SAW SMT
Networks International Corp.	www.nickc.com	printed circuit SMT
Qorvo	www.qorvo.com	BAW SMT
Raditek Inc.	www.raditek.com	cavity, ceramic
Raltron	www.raltron.com	ceramic
Reactel	www.reactel.com	cavity, LC, WG
RF-Lambda	www.rflambda.com	cavity, WG
RF Microtech	www.rfmicrotech.com	design, test services
RLC Electronics	www.rlcelectronics.com	coaxial, SMT, WG
RS Microwave Co. Inc.	www.rsmicro.com	coaxial, WG
Shanghai AT Microwave	www.atmicrowave.com	WG
Smiths Interconnect (Lorch)	www.smithsinterconnect.com	cavity, ceramic
Skyworks Solutions	www.skyworksinc.com	coaxial assemblies
Spectrum Control	www.spectrumcontrol.com	cavity, ceramic, WG
Synergy Microwave Corp.	www.synergymwave.com	SMT
Teledyne Defense Electronics	www.teledynedefenseelectronics.com	YIG
Telewave.io	www.telewave.com	cavity
3H Communication Systems	www.3hcommunicationsystems.com	low PIM filters
TTE Filters	www.tte.com	coaxial
Wainwright Instruments	www.wainwright-filters.com	coaxial, WG
Werlatone	www.werlatone.com	coaxial

relative to the wavelength of the frequencies of interest.

An RF/MW filter with an ideal signal-transfer function exhibits minimal passband distortion and high attenuation in the stopband or bands. Physically, a filter can handle as much signal power as possible in the smallest of packages. As modern trends push toward RF/microwave filters with reduced size, weight, and power (SWaP), filters in drop-in and surface-mount-technology (SMT) packages have been gaining in popularity as they continue to increase in frequency and power-handling capabilities.

High-frequency filters perform spectral management via four basic response types: low pass, high pass, bandpass, and band-reject filters (also known as notch filters). (An easy-to-follow blog from Mini-Circuits, "Understanding Lumped Element Filters," reviews the four filter responses and how they can be implemented with passive circuit elements.)

and band-stop filters. A filter's center frequency typically divides a bandpass filter's 3-dB low-loss passband and a band-stop filter's 3-dB high-rejection stopband.

Bandpass and band-reject filters are also defined by their qualify factor (Q), which is equal to the filter's center frequency (f_0) divided by its 3-dB bandwidth. Q values rise for filters at increasing operating frequencies with narrower passbands: the higher the Q, the narrower the passband. Operating conditions will impose specific sets of performance requirements on RF/MW filters, including how they process signal amplitude, phase, and group delay as functions of temperature.

High-frequency filters are evaluated in terms of standard performance parameters. These include passband insertion loss, stopband rejection, selectivity (how quickly the response changes between low loss and high rejection), power-handling capability, return loss (or VSWR),

High-frequency filters are available from many suppliers in a variety of technologies and package styles. Performance levels can be customized when standard models don't meet the requirements of an application.

In addition, the "Terms & Definitions" section of the online 136-page product catalog from K & L Microwave shares that company's long experience and expertise in the design and fabrication of custom RF and microwave filters for aerospace, defense, and commercial applications. It provides text-book-like explanations of high-frequency filter terms and characteristics.

A high-frequency filter's response includes regions with minimal loss versus frequency and spectral regions where high attenuation is applied to signals. Changeovers from regions with no loss to regions with high signal rejection are typically denoted by a single 3-dB or half-power point for lowpass and high-pass filters and two 3-dB points for bandpass

group delay (also known as envelope delay), and temperature effects. Filters can suffer distortion in amplitude, phase, and group delay (nonconstant delay with frequency) with changes in temperature, whether due to the environment or from heat dissipated when operating at high power levels.

A filter's characteristic impedance, typically 50 Ω for high-frequency applications, can be determined by L/C, where L is the filter's total series inductance and C is its total shunt capacitance. High-frequency filters should closely match an application's source and load impedances at input and output ports, respectively, to maintain response linearity and minimize some forms of distortion, such as passive intermodulation (PIM) distortion.

High-frequency filters are available from many suppliers *(see table on page 28)* in a variety of technologies and package styles. Performance levels can be customized when standard models don't meet the requirements of an application.

Making Filters Fit

As electronic designs are made smaller and more power-efficient, miniaturization remains an ongoing trend for high-frequency filters, although larger filters are still required at higher power levels.

Waveguide Filters

Waveguide filters are one of the larger types of high-frequency filters. The cavity contained within the physical structure provides the physical dimensions required for conductance of EM fields at specific wavelengths and frequencies. The size of a rectangular waveguide (WR) is identified by number, with decreasing numbers signifying smaller wavelengths and higher frequencies, such as WR-28 for 26.5 to 40.0 GHz and WR-10 for 75 to 110 GHz.

Waveguide (WG) bandpass filters are commonly used in higher-power systems such as communications transmitters and radars. They're capable of low insertion loss and return loss (VSWR) to minimize heat at high power levels.

WG bandpass filters are available from numerous suppliers for applications typically reaching 110 GHz. Pasternack, for example, maintains a large inventory of WG bandpass filters in different sizes and frequencies for applications such as test, where a component may be needed without delay. Mini-Circuits has partnered with Virginia Diodes to develop rectangular WG bandpass filters through mmWave frequencies in addition to high-frequency filters based on other technologies, including lumped-element, microstrip, and stripline filters.

Long-time supplier of coaxial and waveguide components, Coleman Microwave, offers WG filters in fixed and tunable forms. Fixed filters cover a total frequency range of 4.40 to 16.95 GHz, all in packages measuring 7.50 × 2.50 × 4.375 in.

Bandpass models FWB1050 and FWD1050 both operate from 9.6 to 10.5 GHz with 3-dB bandwidths of 17 MHz. The former has a 40-dB passband of 200 MHz with a maximum passband 3-dB insertion loss of 1.60 dB, while the latter has a 40-dB passband of 70 MHz with a maximum passband 3-dB insertion loss of 2.30 dB. Thus, specifiers can select the abruptness of attenuation around the center frequency.

The company also supplies WG filters with tunable center frequencies, such as the model TWD960 bandpass filter with a tuning range of 8.5 to 9.6 GHz *(Fig. 1)*.

1. Model TWD960 is a coaxial bandpass filter in which the center frequency can be adjusted by a user. Coleman Microwave

It has a nominal 3-dB bandwidth of 15 MHz and 40-dB bandwidth of 60 MHz with maximum passband insertion loss of 2.25 dB at the center frequency. The ability to reset the frequency of these filters is quite impressive, at 0.02%.

For satellite communications (satcom) systems, the eBPF-C series of C-band WG bandpass filters from Norsat International is designed to install between an antenna feed and receiver low-noise block downconverter (LNB). This helps minimize interference from terrestrial signal sources in radar and 5G wireless communications systems.

One member of the series, model eBPF-C-1, has maximum insertion loss of 1.4 dB within a passband of 3.7 to 4.2 GHz, with at least 60-dB rejection at 3.682 GHz and at least 25-dB rejection at 4.230 GHz and above. There's a 3-ns maximum group delay variation within any ±0.5-MHz span in the passband. The filter measures 7.28 × 3.94 × 2.79 in. (185 × 199 × 71 mm) and weighs 970 g.

To further save space in a system, the company also integrates LNBs with WG filters in a single, slightly larger package. When adapting WG filters within a system using coaxial and other component configurations, companies such as Ducommun and Lieder Development offer suitable interconnections from 18 to 110 GHz.

Coaxial Filters

Coaxial-packaged filters still represent the greatest number of high-frequency filters currently in use. They house many technologies between the connectors, including bulk-acoustic-wave (BAW), cavity, lumped-element (LC), microstrip, stripline, and surface-acoustic-wave (SAW) filter structures.

RF-Lambda, for example, offers WG filters to 110 GHz, but also a variety of coaxial filters. Its model RBPF33G04G06 is a suspended-substrate-stripline bandpass filter in compact enclosure with female input and output connectors. It has a passband of 4.2 to 5.7 dB with 0.85-dB typical insertion loss and 1.50:1 VSWR. Lower stopband rejection is typically 52 dB from dc to 3.4 GHz and upper stopband rejection is typically 60 dB from 6.9 to 9.5 GHz.

A good match for radar and wireless communications, the filter meets MIL-E-5400 standards and comes in a hermetic housing as an option. It handles as much as 15-W CW input power over an operating temperature range of −55 to +85°C.

Werlatone offers coaxial filters for large-signal applications, such as its lowpass filter model AF9960 *(Fig. 2)*. The absorptive filter has a passband from dc to 500 MHz and stopband from 750 to 3,000 MHz, with power-handling capability of 600 W CW in the passband and as much as 25 W CW in the stopband, where a large amount of signal energy is dissipated as heat.

2. The AF9960 is an absorptive low-pass coaxial filter capable of handling 600-W CW power in its passband from dc to 500 MHz. Werlatone

The compact filter handles the heat with an aluminum housing measuring 4.20 × 1.75 × 1.13 in. and a choice of connectors: two female N, two SMA, or one of each. Passband insertion loss is low, typically 0.5 dB, while stopband rejection is a respectable 45 dB. The low pass has an operating temperature range of −55 to +75°C.

In terms of high coaxial power, cavity bandpass filter model RCBPF-900-920M-Sf-65W-c14 from Raditek handles 65 W or more signal power across a 20-MHz passband centered at 910 MHz. It achieves the high power-handling capability via extremely low passband insertion loss of 0.4 dB or less, yet still provides 40 dB or more stopband rejection, such as for an upper stopband range of 1,800 to 2,700 MHz. The RoHS-compliant filter is equipped with SMA female connectors.

Compared to other filter technologies, cavity filters offer high power-handling capabilities in small packages. The LA-37N series bandpass filters from Microlab/FXR *(Fig. 3)* are designed for identify-friend-or-foe (IFF) and navigation applications with a passband of 1,030 to 1,090 MHz.

Insertion loss across the passband is no more than 0.7 dB with low 20-ns group delay. This enables power-handling capability of 100-W CW power and 3-kW peak power with pulsed signals for a coaxial package with N connectors measuring 4.9 × 3.3 × 1.6 in. (124.5 × 84.0 × 40 mm) and

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Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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weighing 1.9 lbs. (0.86 kg). The compact filters achieve 80-dB rejection across a lower stopband from 100 to 600 MHz and the same high rejection across an upper stopband of 1,520 to 6,600 MHz.

3. Coaxial bandpass filters in the LA-37N series target IFF applications from 1,030 to 1,090 MHz with passband power-handling capability of 100 W CW and 3 kW peak. Microlab/FXR

With its long history of RF/MW filter design and development, K & L Microwave backs its designs with some of the industry's most comprehensive testing, using the latest microwave and mmWave signal generators and analyzers and comprehensive environmental and temperature test chambers. Offering drop-in, coaxial, and waveguide filters from RF through mmWave frequencies in all high-frequency filter responses, the company also has developed a unique software tool called Filter Wizard. Available online, it helps users more quickly and effectively meet the filtering needs of a particular application.

Getting Smaller

As electronic products are being designed and manufactured for greater mobility and miniaturization, RF/MW filters are among the many components shrinking in size (where signal power levels will permit it) and fitting into SMT configurations. Especially as filters are moving higher into mmWave frequencies, filter suppliers are exploring the use of different material substrates to enable high performance at high frequencies and in small packages.

Benchmark Lark Technology, for example, has applied liquid-crystal-polymer (LCP) substrates to the construction of bandpass filters through 40 GHz. These LCP filters are a fraction of the size of microstrip SMT bandpass filters *(Fig. 4)*, with enhanced performance.

The thermoplastic LCP material can be applied to single- and multiple-layer SMT filters. It has a low dielectric constant (3.16) and dissipation factor (0.0045) that make it a candidate for low-loss miniature filters to 110 GHz. In addition, LCP's low material coefficient of thermal expansion (CTE) of 17 ppm/°C supports stable performance with temperature.

Ceramic materials from Johanson Technology have paved the way for tiny SMT bandpass filters for Wi-Fi 7 and 802.11ax/be wireless applications. Though in packages measuring 0.217 × 0.126 × 0.087 in. (5.50 × 3.20 × 2.20 mm), the filters can handle as much as 3 W of signal power. The filters are available with low-loss passbands of 5,150 to 5,835 MHz, 5,170 to 5,825 MHz, 5,925 to 7,125 MHz, and 5,945 to 7,125 MHz.

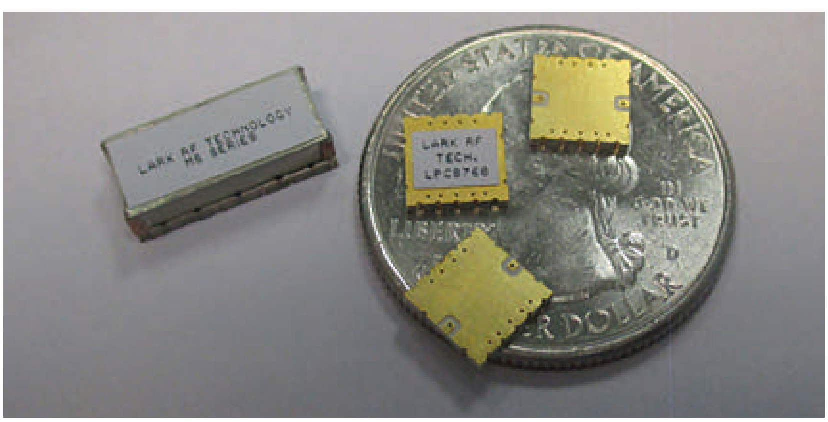
For instance, the model 5492BP46A0685001E has typical insertion loss of 2.9 dB from 5,150 to 5,785 MHz and 4.2 dB across the upper end of its passband from 5,785 to 5,835 MHz. It rejects signals by 60 dB below the passband from dc to 2,500 MHz and by 48 dB from 2,500 to 4,000 MHz, and by 43 dB above the passband from 5,925 to 5,990 MHz, with rejection rising to at least 45 dB to 17.5 GHz. The compact filters are designed for operating temperatures from −40 to +85°C.

Synergy Microwave Corp., perhaps best known for its low-noise oscillators and frequency synthesizers, supports its signal sources with lines of crystal lowpass, high-pass, and bandpass filters in low-profile SMT packages.

Its model FNS-10.7 bandpass filter has a center frequency at the reference of 10.7 MHz with 3-dB passband of 10.2 to 11.2 MHz and maximum passband insertion loss of 1.7 dB. The low loss and passband VSWR of 1.50:1 account for its capability to handle as much as +30 dBm (1 W) signal power in a package measuring just 0.945 × 0.945 × 0.440 in. The SMT filter has an operating temperature range of −40 to +85°C.

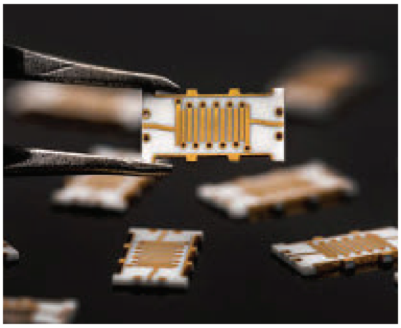
Employing standard substrate materials such as alumina, Networks International Corp. has succeeded in shrinking thin-film high-frequency filters from 1 to 26 GHz with bandwidths from 1% to 60% into SMT packages with low 0.05-in. heights.

The model TR-139 printed bandpass filter *(Fig. 5)* measures 0.4 × 0.2 × 0.075 in. with a 3-dB bandwidth of 2,350 MHz centered at 8,200 MHz, making it a candidate for blocking interference from desired signals in radar, electronic-warfare (EW), and unnamed-aerial-vehicle (UAV) sensor communications links. Passband insertion loss is 2.5 dB or less while return loss is typically 15 dB. Out-of-band rejection, from 1.0 to 5.8 GHz



4. LCP materials are the basis for the SMT bandpass filter (right) through 40 GHz, which is a fraction of the size of a microstrip SMT filter (left). Benchmark Lark

High-frequency filters will continue to shrink in size as operating frequencies rise, so package sizes can be expected to continue to shrink.



5. *Model TR-139 is a thin-film SMT bandpass filter centered at 8,200 MHz. Networks International*

6. *The BFHK-1072+ is a bandpass filter based on proprietary LTCC material and distributed architecture for low loss from 9.2 to 11.3 GHz. Mini-Circuits*

7. *The BBFCG1-252+ is a SMT bandpass filter for 2.4 to 2.5 GHz with integrated balun for biasing active components. Mini-Circuits*

below the passband and 10.2 to 12.8 GHz above the passband, is typically 50 dB.

Packing its BAW filter technology into a miniature SMT housing, Qorvo has targeted IFF applications centered at 1,090 MHz with its model 880374 bandpass filter. The package measures just 3.74 × 2.59 × 0.889 mm but employs a sapphire base with alumina lid for hermeticity. For ease of use, it can be installed on a PCB without impedance-matching components.

The bandpass filter has a 22-MHz-wide 3-dB passband centered at 1,090 MHz with 3-dB maximum insertion loss across the passband and 40-dB points at 1,073 and 1,107 MHz. The tiny filter can handle as much as+24-dBm CW RF input power and as much as +42 dBm for 200-ms pulses across an operating temperature range of −40 to +85°C.

Based on proprietary LTCC substrate materials, Mini-Circuits has developed families of high-frequency filters with power-handling capability of 1 W in tiny SMT housings. The model BFHK-1072+ *(Fig. 6)* bandpass filter features a distributed filter topology for 3.1-dB typical passband insertion loss and 12-dB typical return loss from 9.2 to 11.3 GHz. Stopband rejection is typically 90 dB, across a lower stopband of 2 to 6 GHz and an upper stopband of 15.1 to 30.0 GHz. The LTCC filter fits in an 1812 SMT case style measuring 0.177 × 0.126 in. (4.5 × 3.2 mm) but handling as much as 1-W input power at operating temperatures from −55 to +125°C.

The LTCC material system also forms the foundation for the company's model BFCQ-4302+ mmWave bandpass filter in a 1008 SMT enclosure measuring just 2.5 × 2.0 mm but capable of handling 1-W signal power across a passband of 36.5 to 50.0 GHz. Passband insertion loss is typically 2 dB with an upper stopband that extends to almost 70 GHz. Lower stopband rejection is 20 dB or more from 0.1 to 27.0 GHz while upper stopband rejection is typically 15 dB from 57.3 to 59.0 GHz and typically 10 dB from 59 to 67 GHz.

For the widely used ISM/Wi-Fi passband of 2.4 to 2.5 GHz, Mini-Circuits' model BBFCG1-252+ *(Fig. 7)* integrates a balun for biasing active devices at its output port. It has maximum passband insertion loss of 3.5 dB and typical passband return loss of 15 dB from 2.4 to 2.5 GHz. The typical lower stopband rejection is 35 dB from dc to 1.8 GHz while minimum upper stopband rejection is 20 dB from 3.5 to 8.0 GHz.

And for circuit designers who may not have finalized a filter's characteristics for a design, Mini-Circuits offers SMT thru-lines allowing signals to pass that point in the circuit with minimal loss and take the place of an 0805 LTCC filter until its required characteristics are known.

High-frequency filters will continue to shrink in size as operating frequencies rise, so package sizes can be expected to continue to shrink. As wireless networks such as 5G and 6G develop at these higher (mmWave) frequencies, filters will play key roles in ensuring reliable communications and prevent interference from a growing number of devices on 5G/6G networks, such as Internet of Things (IoT) devices and "flocks" of drones with sensors that rely on wireless connectivity for internet access. ■

The World of RF for Military and Defense

In the world of RF for military and defense, SDRs bring much to the table for applications like radar transceivers, spectrum monitoring, and electronic warfare.

*By **Brendon McHugh,** Field Application Engineer & Technical Writer, Per Vices Corp.*

THE MILITARY AND DEFENSE industry relies heavily on advanced radio technology to carry out its operations effectively and securely. From communication systems to radar equipment, understanding and interacting with radio frequencies plays a crucial role in maintaining national security.

In recent years, software-defined radios (SDRs) have emerged as the next generation of wireless systems, revolutionizing the way military and defense organizations operate. With their versatility and adaptability, SDRs are having a significant impact on key markets such as radar, spectrum monitoring and recording, and electronic warfare.

This article will delve into the world of RF for military and defense, exploring the capabilities and advances that SDRs bring to fundamental applications of this industry, including radar transceivers, spectrum monitoring, and electronic warfare. It also discusses the basic concepts and main features of state-of-the-art SDRs.

At the end of the article, the reader should be able to understand what are SDRs and how they work, how these transceivers fit into each application, and the main RF parameters that must be considered when selecting or designing SDRs for the military industry.

How RF Devices Fit into Defense Roles

Since the early days of analog radio, RF transceivers have been an integral part of warfare and defense operations, especially considering the tremendous strategic advantage introduced by wireless communications in tactical missions.

With the advancement of radio to modern software-based systems, SDRs became a crucial device for uses beyond telecommunication systems and into highly specialized and complex RF applications. Such apps require not only exchange of data through the air, but also detailed analysis of the electromagnetic signals, high levels of reconfigurability/adaptability, and high-throughput data interfaces for integration with host computers to allow for remote control and monitoring.

In military radar systems, RF devices represent the heart of the operation. A radar system transmits a custom waveform that's broadcast to all directions of the region of interest. It then receives/decodes the reflected signals to obtain position and velocity information about a certain target. Therefore, it must implement at least one transmitter chain, one receiver chain, a duplex switch, and a digital back end for waveform generation and signal processing.

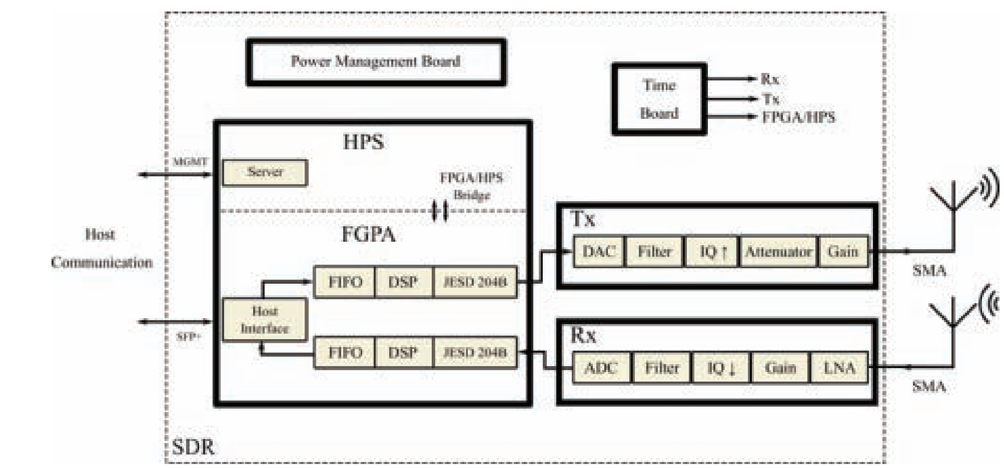
At the transmitter side, several parameters can limit performance, including the resolution of digital-to-analog conversion of the waveform, the specific frequencies that are broadcast through the transmitter, and the antenna's output power distribution. At the receiver side, the radio chain must have excellent phase stability and coherency to accurately receive and mix the signal. In addition, it must provide a high dynamic range and low noise figure to dynamically attenuate/amplify the received reflection to eliminate clutter/jams and reduce noise.

Furthermore, beamsteering/beamforming techniques have been widely implemented to reduce the effects of jamming and interference, diminishing the received power at certain points. In this case, multiple-input, multiple-output (MIMO) systems with powerful parallel computing and high phase stability are crucial to leverage performance and precision.

In terms of software, the DSP capabilities of the digital back end must provide very-low-latency computation and a high-throughput data interface with the host network to prevent information lost while tracking fast targets. For anti-jamming techniques, such as frequency hopping, the digital back end must be able to quickly detect power thresholds and adapt the waveform and modulation scheme accordingly.

Spectrum Monitoring

Another application of RF devices that's crucial to modern warfare is spectrum monitoring, especially considering that most tactical endeavors rely heavily on wireless communication and electromagnetic attacks. Spectrum monitoring is the process of



A high-level diagram of an SDR shows the main functions of each board, including the RFE, digital back end, power distribution, and clock generation. Per Vices

analyzing and monitoring the usage of the electromagnetic spectrum for the purpose of detecting RF interference, monitoring adversarial communication and radio activity, and obtaining situation awareness in the battlefield.

RF devices must provide several key features to ensure spectrum coverage and high-performance detection. First, the receiver of the radio front end (RFE) has to provide a wide tuning range and high instantaneous bandwidth, so that the same device can be used to cover a wide range of signals.

Moreover, MIMO devices with independent channels can significantly expand the spectrum coverage by assigning a bandwidth portion to each channel, which increases the effective spectrum coverage and maximizes the probability of detecting signals. Spurious-free dynamic range (SFDR) of the radio device significantly impacts the accuracy of measurements; thus, selecting SDRs with high SFDR will certainly improve performance.

On the software side, a powerful digital back end is fundamental in handling the huge amounts of data involved, especially if implementing multiple channels. In this case, FPGAs with on-board DSP capabilities are the way to go, as they provide very-low-latency computation and can handle parallel computing without major hardware specialization. Furthermore, the FPGA must offer high-throughput interfaces with host computers and storage solutions to ensure the integrity of the measured data.

Electronic Warfare

Because RF devices are so intimately connected to military applications, the electromagnetic environment has become a battlefield of its own, with its rules and players. Electronic warfare (EW) was created to fight these battles, specifying devices, techniques, and strategies to gain the upper hand in the RF realm.

EW devices play a crucial role in ensuring the success of military operations by protecting against and exploiting enemy communications and radar systems. They typically consist of three elements: attack, protection, and support. The attack element uses radios to interfere with and disrupt enemy communications and devices, creating confusion and reducing the effectiveness of their operations. Such devices typically implement high-power transmitters and advanced jamming techniques to interfere with enemy signals.

For protection, EW systems use RF devices to detect and protect against incoming enemy electronic attacks, typically involving highly sensitive receivers and advanced signal-processing techniques to detect and counter enemy signals in time to react. The support element of EW systems employs RF devices to gather information and provide situational awareness to military operations—spectrum-monitoring devices and radars fit into this category.

In any case, EW RF devices must not only offer lots of output power and receiver sensitivity, but also provide a high level of reconfigurability to adapt their RF performance according to the scenario and flexible size, weight, and power (SWaP) characteristics.

What's an SDR?

An SDR is basically an RF transceiver with two main parts: a RFE and a digital back end. The RFE contains all of the receive (Rx) and transmit (Tx) RF chains, including amplification, filtering, and antenna coupling interfaces. The RFE must be able to receive signals over a wide frequency range (typically 0 to 18 GHz, upgradable to 40 GHz), while also providing a high instantaneous bandwidth. Some of the highest-bandwidth SDRs offer up to 3 GHz/channel.

Each channel of the RFE is connected to the digital back end via high-performance analog-to-digital and digital-to analog converters (ADCs/DACs) that are independent for each Rx/Tx chain, enabling parallel operation that makes MIMO SDRs a "several-in-one" type of equipment.

Digital back end

The digital back end of an SDR contains an FPGA with onboard DSP capabilities for tasks such as modulation, demodulation, upconverting, downconverting, and so on. It's also highly configurable and upgradable, allowing for the latest radio protocols and DSP algorithms to be incorporated into the system. Thus, SDRs are ideal for military and defense applications in which adaptability, performance, and reliability are critical.

Furthermore, the digital back end offers embedded data packaging and high-speed optical interfaces for high data-throughput communication with the host and storage solutions, making them ideal for spectrum-monitoring systems. The *figure (p. 35)* shows a high-level diagram of the SDR, specifying the main functions of each board, including the RFE, the digital backend, the power distribution, and the clock generation.

Radio front end

The RFE of an SDR is a critical component that plays a vital role in the device's performance. The Rx chain includes multi-stage chains (such as low/baseband and high band), LNAs and power amplifiers, attenuators for dynamic adjustment of signals, IQ downconverters, anti-aliasing filters, and ADCs that connect to the FPGA via JESD204B.

At the Tx side, the signal path also goes through multi-stage chains, beginning at the FPGA, passing through the DAC, anti-imaging filters, frequency synths and local oscillators, IQ upconverters, and RF gain blocks. High-performance SDRs typically include completely independent Tx and Rx chains for optimal signal processing and parallel configuration.

Timing and power boards

To support these functions, SDRs also rely on other boards for timing and power *(see figure, again)*. Timing boards provide clocks for ADCs, DACs, local oscillators, mixers, and the FPGA, while power boards ensure stable power supply to all other components. These elements are essential to achieving high performance and reliable operation in these transceivers.

FPGA

The digital back end of a high-end SDR includes an FPGA equipped with onboard DSP capabilities that can be optimized for a range of functions including modulation, demodulation, and up/downconverting. These capabilities are used to perform tasks like CORDIC mixing, data packetization, and FIFO buffers, as well as any application-specific requirements such as channelization, security schemes, and artificial-intelligence/machine-learning algorithms.

The FPGA also allows for ultra-low-latency communication, and is responsible for communicating with the host system, network, or storage solution. This communication, done through Ethernet (SFP/qSFP+) ports and MGMT ports, enables the host system to remotely configure and control the SDR.

Through these interfaces, the host also can send, receive, capture, and monitor raw IQ data, using proprietary, open-source (GNU-Radio), and custom software. With achievable data rates of 10 to 400 Gb/s, the FPGA plays a crucial role in optimizing the SDR's performance.

In the current RF landscape, defense systems require a variety of RF devices and systems to meet their needs for spectrum monitoring, EW systems, and radars. SDRs provide a flexible solution for these needs by enabling the RFE and digital back end to be adapted and upgraded on-the-fly and remotely.

The radio front end of an SDR contains one or more receive and transmit channels, capable of working with signals in a wide tuning range. The digital back end implements an FPGA with DSP capabilities for modulation, demodulation, up/down-converting, and more.

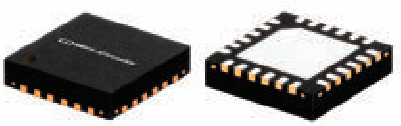
In modular SDRs, all components can be customized to comply with a variety of SWaP requirements, from powerful ground station racks to onboard radars for light aircraft. The FPGA also communicates with the host system and the Ethernet ports to transport and capture data, enabling storage solutions and fast, reliable communication with the operator. The combination of flexibility, modularity, and RF performance makes SDRs the ideal choice for any military and defense situation.

Conclusion

In this article, we've explored the world of RF military and what specifications are key to solving most of the challenges in crucial applications, including EW systems, radars, and spectrum monitoring. SDRs have revolutionized the world of radio, as they allow for software-based adaptability across a wide range of frequencies and waveforms.

SDRs consist of two parts—a radio front end and a digital back end, with the RFE handling the reception and transmission of signals, and the digital back end performing DSP functions such as modulation, demodulation, and data packetization. The use of FPGAs with onboard DSP capabilities has further advanced SDRs, providing ultra-low-latency communication and the ability to optimize the radio for different applications.

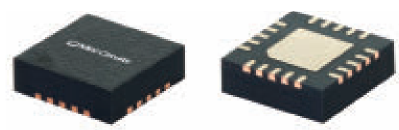
The versatility of SDRs makes them a crucial component in meeting the ever-changing needs of the RF landscape in defense. These devices have proven to be a game-changer in the field, and their importance in meeting the challenges posed by the rapidly evolving RF landscape can't be overstated. ■



MMIC Amplifier Gains 0.05 to 18 GHz

Mini-Circuits' model AVA-183MP+ is a surface-mount-technology (SMT) GaAs MMIC amplifier with high gain from 0.05 to 18 GHz. A fit for EW, ECM, and radar, the compact amplifier delivers typical gain of at least 16.2 dB at all frequencies with typically +24-dBm typical output power at 1-dB compression. The noise figure is typically 1.5 dB or less at 10 GHz. Internally matched to 50 Ω, the amplifier measures just 4 × 4 mm in a 20-lead QFN package.

MINI-CIRCUITS
https://tinyurl.com/2ptdze96



Surface-Mount Amp Boosts 15 to 45 GHz

Mini-Circuits' model PMA3-15453+ is a GaAs MMIC amplifier for signals from 15 to 45 GHz. It features typical gain of 18.9 dB at 15 GHz, 16.7 dB at 30 GHz, and 14.9 dB at 40 GHz, with typical noise figure of 2.6 dB at 15 GHz, 3.2 dB at 30 GHz, and 3.7 dB at 40 GHz. Ideal for mmWave links and testing, it runs on a single +5-V dc supply and fits a 3 × 3 mm, 12-lead QFN housing.

MINI-CIRCUITS
https://tinyurl.com/2qacnm7e

Rugged Edge Computer Supports AI, Intelligent VR, and AR Applications

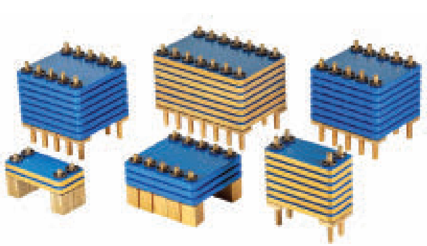
The JetSys-5330 rugged edge computer from Elma leverages the NVIDIA Jetson AGX Orin system-on-module to address artificial intelligence (AI) as well as intelligent virtual reality (IVR) and augmented reality (AR) applications. Available in versions offering up to 2,048 NVIDIA CUDA cores and up to 64 (64 GB) Tensor Cores, the GPU can run up to 1.3 GHz on the 64-GB model, providing up to 275 TOPS and 5.3 FP32 TFLOPS of CUDA computing power. It has wireless connectivity via Wi-Fi or 4G/5G LTE, and high-speed networking via 10GBASE-T. Qualified to IP67 and optimized for extended temperature, shock, and vibration, the device is also qualified to MIL-STD-810G, MIL-HDBK-704F, MIL-STD-1275D, and others, with 204 GB/s of memory bandwidth and 32 or 64 GB of DRAM. It can handle up to six GMSL2/GMSL1 cameras in x2 or x4 CSI, and up to three additional 1000BASE-T with PoE cameras. An accessible drive bay can take up to two removable 2.5-in. solid-state drives, with support for up to three mPCIe modules (one doubles as mSATA) and 8x GPIOs.

ELMA
https://tinyurl.com/2m89o7gs

Enhanced Perimeter Defense Solution Simplifies Network Security

Emerson is improving perimeter security for the DeltaV distributed control system with its NextGen Smart Firewall, designed to provide easy-to-install and easy-to-maintain perimeter security. The ruggedly constructed solution offers increased bandwidth with role-based access to provide more granular access control. It features a user-friendly HTML5 web-based user interface, setup menus, and pre-defined DeltaV application rules to help those with no security or IT expertise create secure connections for DeltaV applications. Gigabit connections serve applications that require higher bandwidth, and features include virtual private networks, network address translation, and more granular user roles, where administrators have full control, engineers may add or modify application rules, and auditors have read-only access to logs.

EMERSON
https://tinyurl.com/2mq5nrya



Large Capacitor Assemblies Leverage MLCC Technology

Knowles Precision Devices' large capacitor assemblies offer very high capacitance and very high voltage in a small area, with large-diameter pins that offer low loss and high stability. The mechanically decoupled ceramic elements enable the assembly to withstand severe shock and vibration for automotive, aerospace, or military applications. Features include high capacitance (nF to µF); high-voltage operation from 500 V to 5 kV; an ultra-stable, low-loss dielectric; high resilience against vibration and temperature variation; and a high ripple-current capability.

KNOWLES PRECISION DEVICES
https://tinyurl.com/2h6znzww

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