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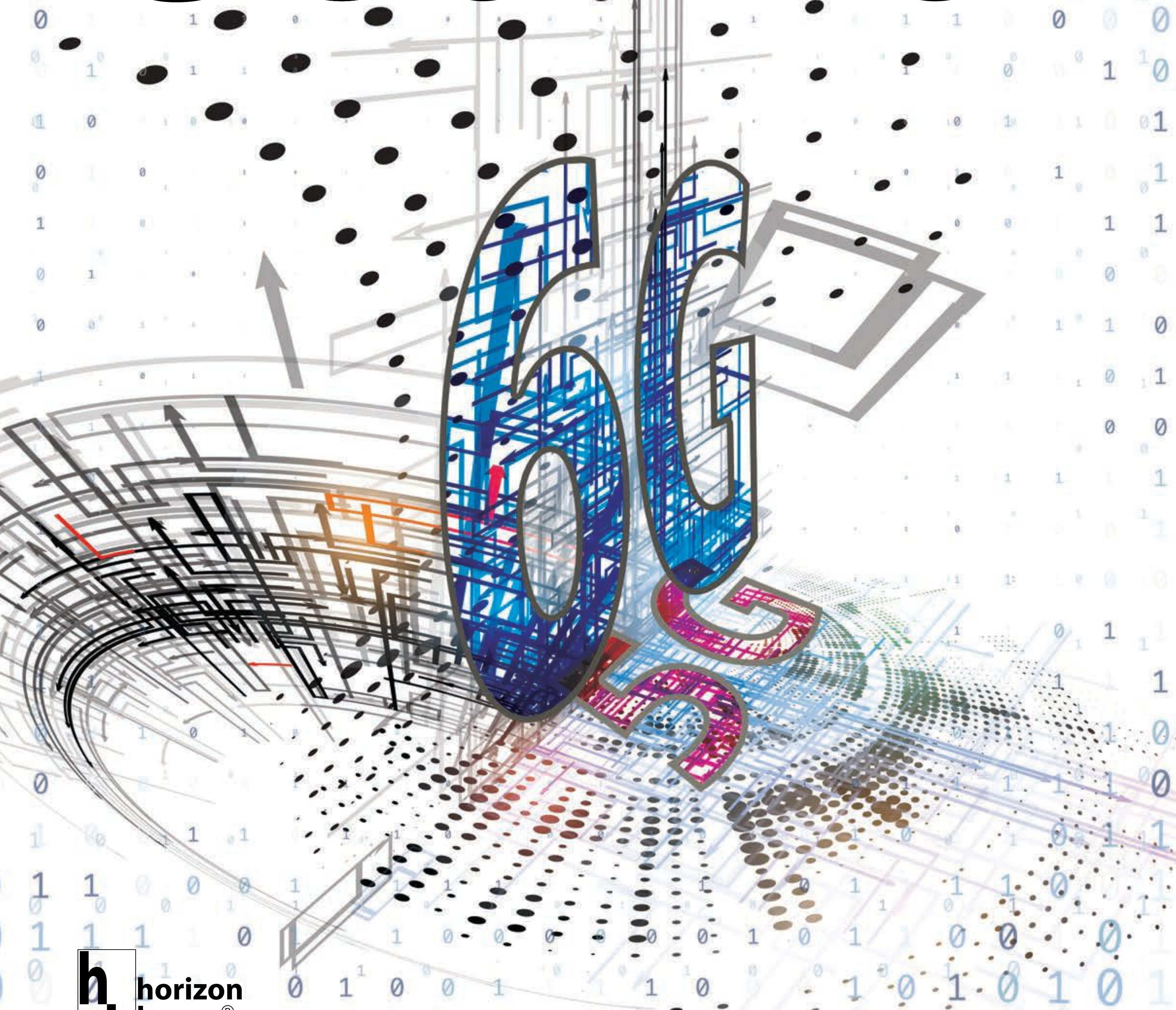

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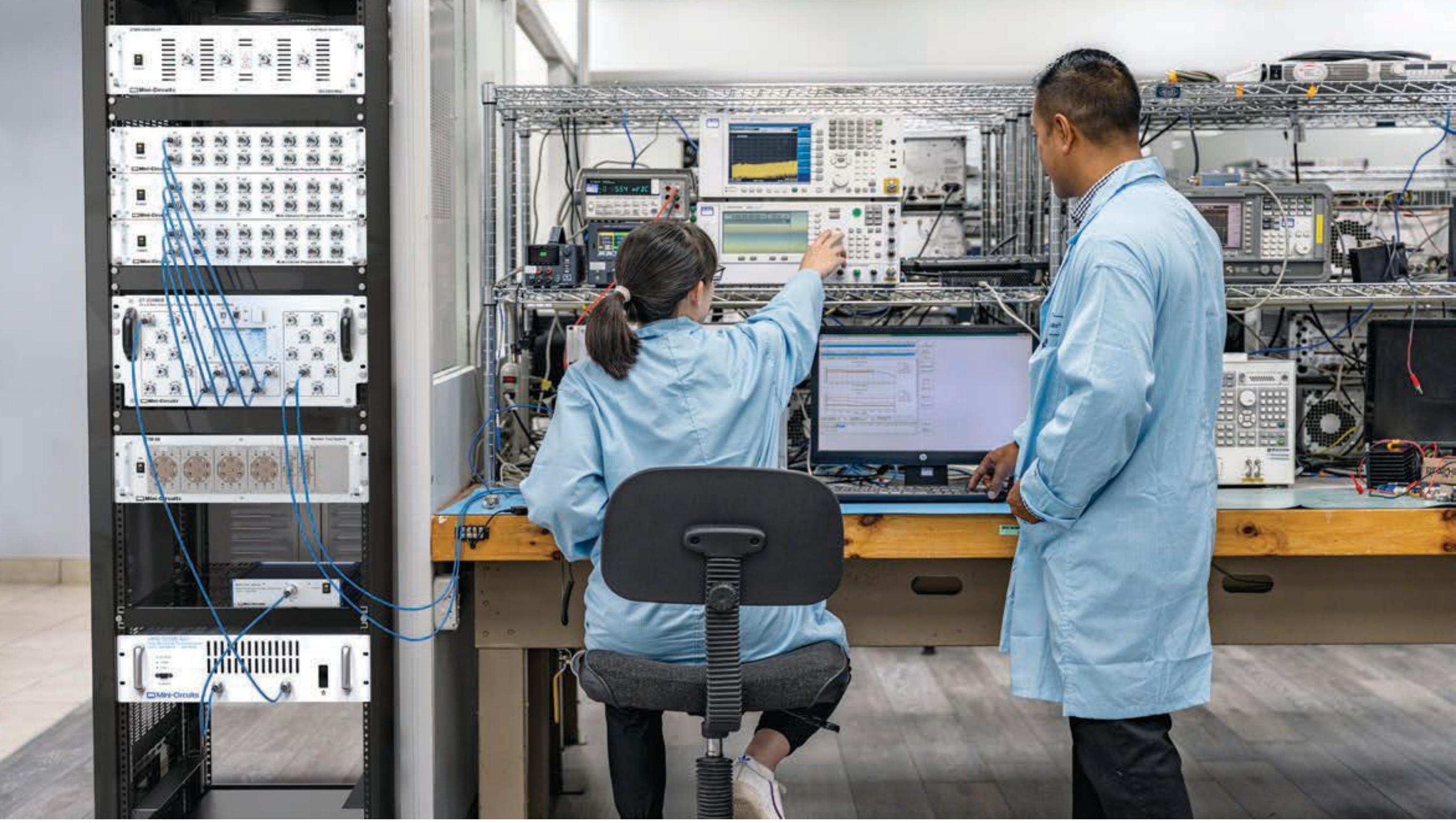

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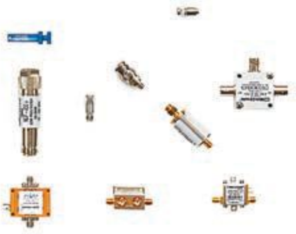

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CONTENTS

July 2023
Vol. 66 • No. 7
RF/Microwave
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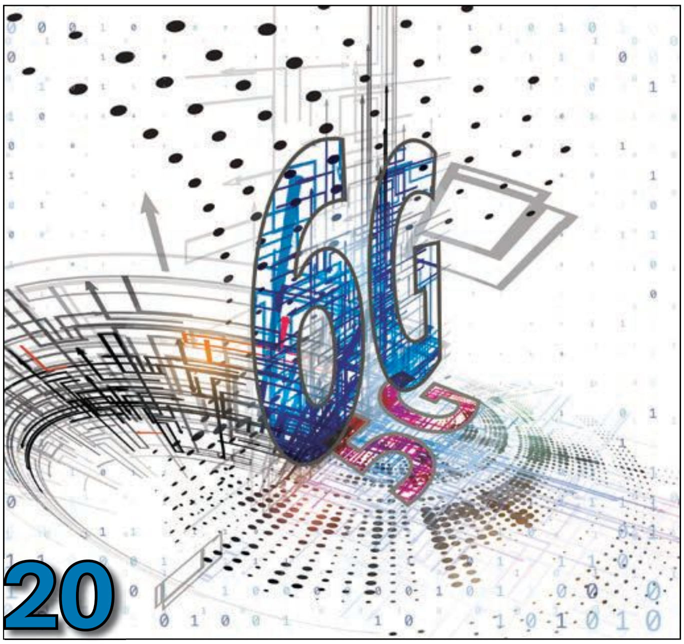

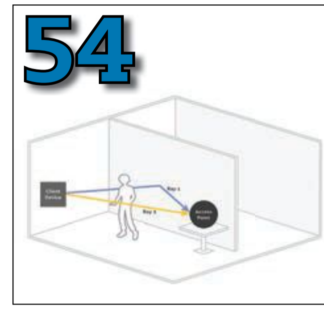

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Overcoming Prior 3D Electromagnetic Simulation Limitations For Electrically Large Bodies

Cover Feature

20 **Enhancing Sub-Terahertz RF EDA Workflows for 6G Challenges**
Daren McClearnon, Keysight Technologies, Don Dingee, STRATISET

Perspective

32 **To Unleash Tomorrow's Open Radio Networks, Testing Must Evolve**
Anil Kollipara, Spirent Communications

Special Report

54 **Wi-Fi Sensing – The Next Big Evolution of Wi-Fi**
Taj Manku and Oleksiy Kravets, Cognitive Systems

Application Note

58 **The Impact of Topology and Parasitics on SMT Bandpass Filters**
Daniel Swanson, DGS Associates

66 YEARS OF PUBLISHING EXCELLENCE

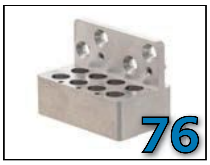
Microwave Journal

CONTENTS

mwjournal.com

Product Feature

73 **3D Geometry Workflows for Substrate-Integrated Waveguide Filters**
SynMatrix Technologies Inc.



Tech Briefs

76 **VITA 67 Multi-Port Connector Blocks Enhance Reliability**
Fairview Microwave

78 **Adjustable Control Components Address Multiple Applications**
Pasternack

80 **2-18 GHz Coaxial Combiner/Divider is Rated to 200 W CW**
Werlatone, Inc.

Departments

17	Mark Your Calendar	83	New Products
41	Defense News	86	Book End
45	Commercial Market	88	Ad Index
48	Around the Circuit	88	Sales Reps
82	Making Waves	90	Fabs & Labs

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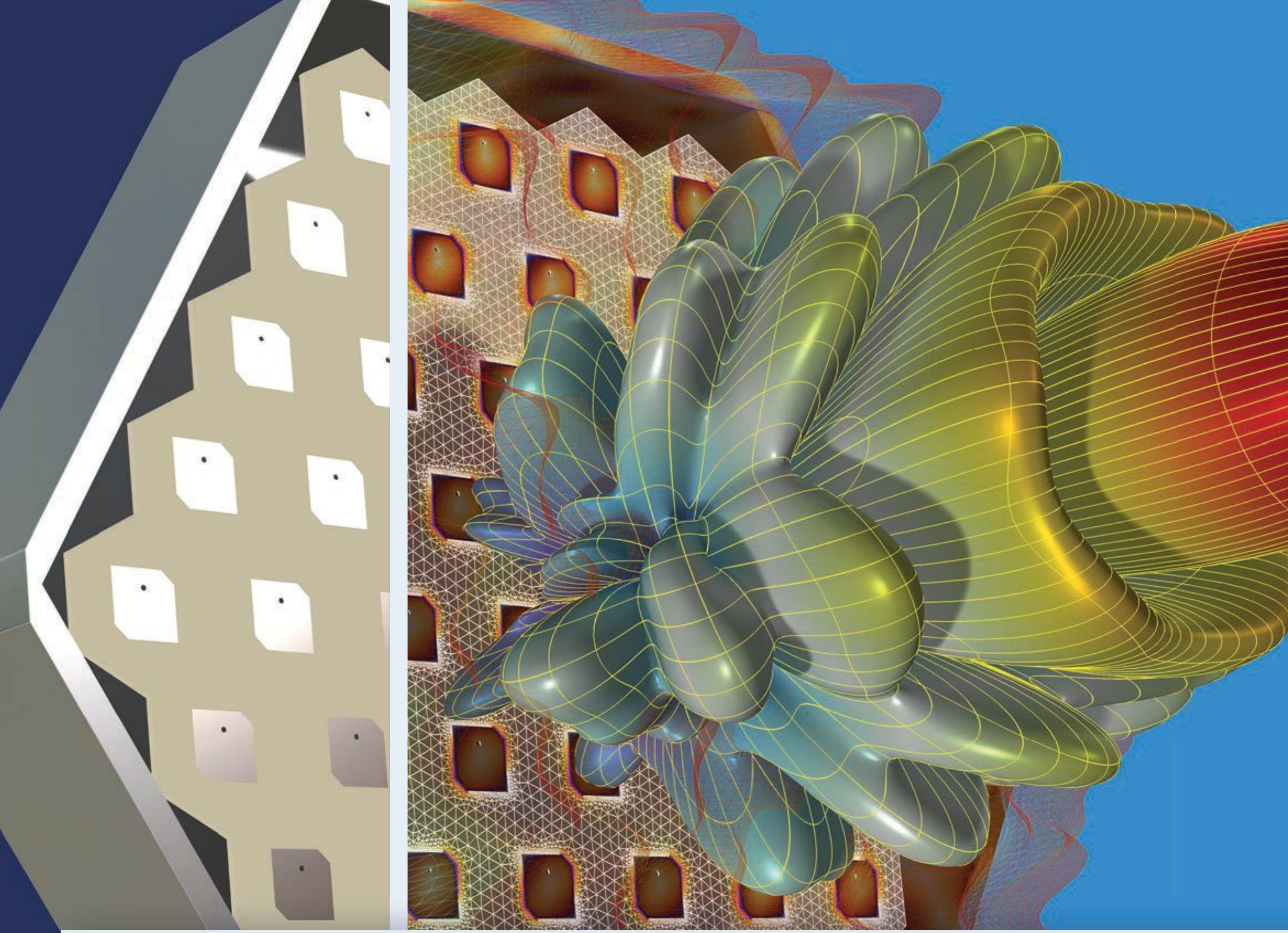

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ERAVANT ENHANCES A&D PRESENCE WITH AS9100 REV. D CERTIFICATION

Eravant announced it has been certified to the AS9100 Rev. D quality management standard for both engineering and manufacturing operations. As a U.S. designer and manufacturer of custom and COTS components, sub-systems, and test equipment for millimeter wave and sub-THz applications (18 to 330 GHz), becoming certified for all business operations signals commitment and readiness to serve the aerospace and defense community along with Eravant's heritage customers in commercial and scientific markets.

"All credit for this significant milestone goes to our amazing team," said Wendy Shu, CEO. "Becoming one of the few AS9100D certified millimeter wave and sub-THz suppliers signals our commitment to delivering quality products and services reliably and repeatably to our entire customer base. The AS9100 certification ensures that we are holding ourselves to a higher standard of execution year after year."

Becoming AS9100D certified strengthens Eravant's competitive position through systematic continuous improvement and business monitoring processes. AS9100 certification sets the worldwide aerospace quality standards as well as the quality requirements of the Department of Defense (DoD) and National Aeronautics and Space Administration (NASA). The standard provides manufacturing suppliers with a comprehensive quality system for providing safe and reliable products. AS9100 is managed by the International Aerospace Quality Group (IAQG) and based upon ISO 9001.

About Eravant
Eravant, located in Torrance, California, operates from a 60,000-square-foot design, manufacturing, assembly, and testing facility focused on supplying a global customer base with millimeter wave and sub-THz (18 to 330 GHz) components, subassemblies, and test equipment. Eravant is known for supporting the customer every step of the way from lab set-up, to R&D and prototype, and through program or volume production.

We are an AS9100D certified, ITAR-registered, women-owned small business designing and manufacturing in the United States. The company's vision is to make millimeter wave and sub-THz accessible by lowering budget, knowledge, and experience barriers so more engineers and scientists can work to realize the technology of the future.

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Cover Feature
Invited Paper

Enhancing Sub-Terahertz RF EDA Workflows for 6G Challenges

Daren McClearnon
Keysight Technologies, Santa Rosa, Calif.

Don Dingee
STRATISET, Canyon Lake, Texas

5G systems have been a proving ground for advanced RF electronic design automation (EDA) tools. These tools showcased multi-domain simulation with accurate, robust behavioral models and authentic waveforms. Teams embracing design-for-context in a trusted, high-fidelity virtual workspace were able to address challenges more efficiently with fewer hardware re-spins.

6G brings a significant multidimensional leap in performance requirements for components, modules and systems. Everything we think is known today about real-world mmWave effects such as complex modulation, channel propagation, signal-to-noise, energy efficiency and power delivery, starts to look different. ***Figure 1*** illustrates potential sub-Terahertz (THz) frequency ranges with higher contiguous bandwidths targeted by 6G researchers, although specifications are still in flux.

One immediate concern jumps out; precious little commercial hardware is available in these higher frequency ranges today. Hardware is scarce in D-Band (110 to 170 GHz), but almost none ventures into H-Band (220 to 330 GHz). Furthermore, much of the prerequisite advanced science, including semiconductor processes, test and measurement equipment, modeling and simulation technology and various facets of artificial intelligence (AI), is not entirely in place yet to cope with lofty 6G expectations.

The implications for RF EDA are immense. Research projects and proof-of-concept designs that once relied on some simulation before serious physical prototyping efforts will, out of necessity, shift significant resources into the virtual space until a broader selection of components and test and measurement gear arrives. Eventually, everything will be measured, but not before the next generation multi-domain simulation delivers crucial insights needed for predictable hardware designs meeting stringent requirements.

Several years ahead of formal 6G specification releases and perhaps as much as a decade before initial 6G network rollouts, predicting all the demands on RF EDA workflows remains a topic for debate. However, progress in mmWave EDA helps identify areas where sub-THz innovation, preceding earnest 6G system design initiatives, will prove extremely valuable. Prime examples include channel modeling, mixed-signal contexts and scalable, enterprise-class solutions to 6G challenges.

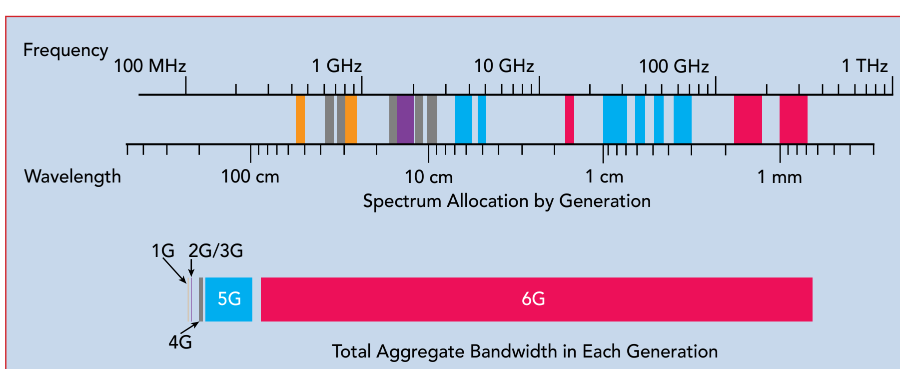
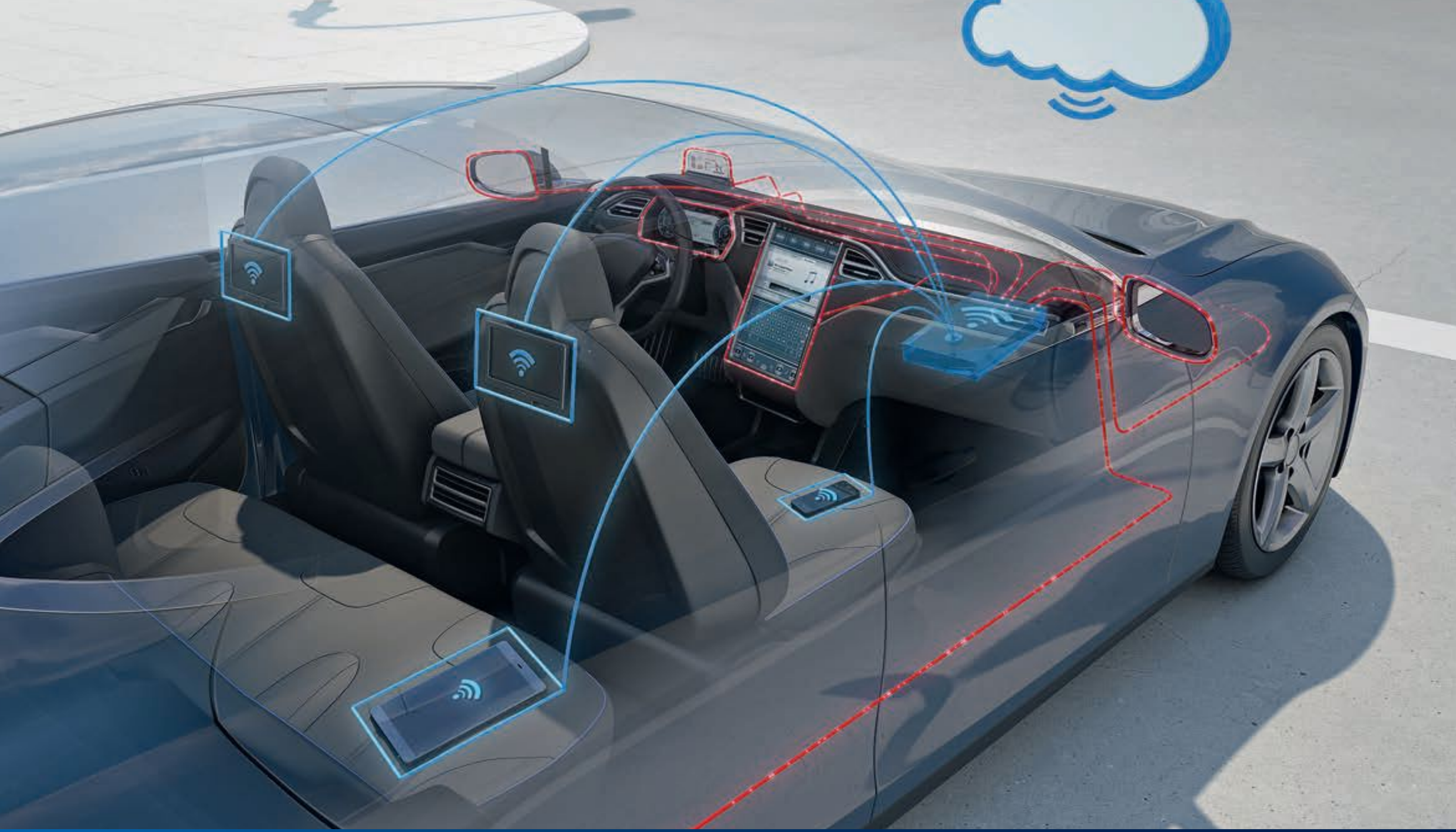


Fig. 1 6G sub-THz frequencies have substantially wider bandwidth than previous wireless generations.



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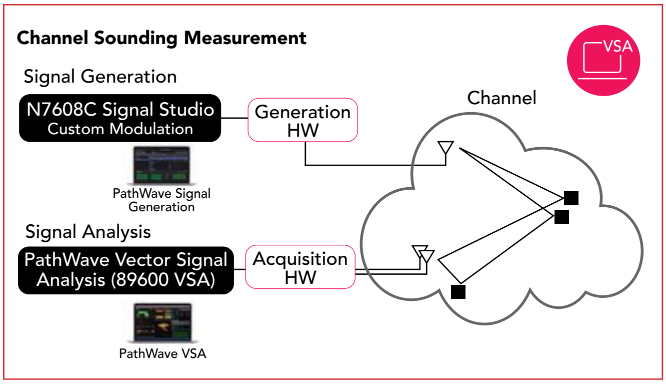


▲ Fig. 2 Custom modulation driving channel sounding to determine impulse response and other metrics.

▲ Fig. 3 Channel sounding results portrayed by the 89600 VSA software in both frequency and time domains.

CHANNEL SOUNDING AND END-TO-END CHANNEL MODELING

Wireless communication systems once enjoyed the luxury of selecting the optimum carrier frequency for propagation through the air. This was before spectrum scarcity and complex digital modulation schemes emerged. Managing channel behavior meant creating a link budget with enough margin to overcome routine disruptions.

6G transforms the channel equation. Data rate expectations for a single connection rise to hundreds of gigabytes per second, connection density grows to millions of devices per square kilometer and lower frequencies are occupied, forcing systems into the sub-THz spectrum. The environment is not ideal. Propagation losses climb as frequencies move higher in sub-THz ranges. Reflections from objects like buildings, vegetation and terrain add to atmospheric effects like rain and dense fog. When designs operate in lower signal-to-noise environments with tighter link budgets due to transmit power constraints, any interference creates the potential for error vector magnitude (EVM) degradation and a corresponding jump in bit error rates.

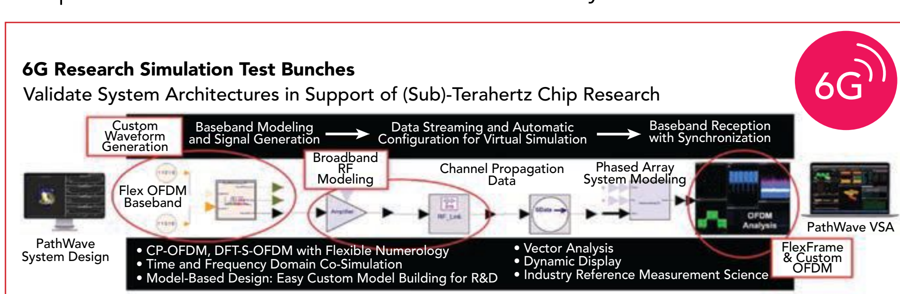
Dynamic channel evaluation and modeling become crucial tasks for 6G research and are not as simple as they might seem. Carrier frequencies, transmit power, the number of transmit channels in simultaneous use and the modulation scheme and waveforms influence the outcome. At this stage, 6G waveforms remain unknown, but with insight from 802.11ay, it becomes possible to synthesize a broadband sub-THz waveform with the appropriate complementary cumulative distribution function (CCDF) and other properties needed to explore options.

Deriving useful 6G virtual channel models starts with physical measurements. Channel sounding measures impulse response by sending a complex signal into the channel, capturing it after channel effects and comparing the results. Antenna configurations and reflective paths staged in the environment contribute to an understanding of the impairments. ***Figure 2*** depicts a basic measurement setup with an anechoic chamber that provides a best-case environment without atmospheric effects.

Pre-configured routines in the PathWave Vector Signal Analysis (89600 VSA) software automate channel sounding. ***Figure 3*** highlights the channel impulse response (bottom trace) with a time-domain view which helps assess delays, reflections and phasing.

Ensuring alignment between simulation and test instrumentation is vital for reliable results. A notable advantage of the Keysight RF EDA environment is its use of the same analysis engines, the core measurement science, from corresponding test and measurement platforms. PathWave System Design reuses waveforms from PathWave Signal Generation and integrates measurement feedback from the PathWave 89600 VSA and other analyzers. Virtual models created in PathWave System Design can represent 6G RF signal chains end-to-end, including detailed channel modeling as shown in ***Figure 4***.

Early 6G research reveals accurate performance simulation demands, comprehensive modeling and digitally-driven control of the antenna structures in lockstep with the RF signal chain. Decisions unfold on a millisecond scale, adapting the configuration and processing as channel behavior shifts and devices move. One challenging modeling problem is capturing more interaction between power amplifiers and antenna elements as the antenna scans in different directions with one or more beams. PathWave Advanced Design System (ADS) models, combined with measurements from a PNA-X network analyzer, will offer a detailed view of how impedance and power amplifier efficiency change. Incorporating that model into the RF system-level simulation in PathWave System Design increases fidelity.



▲ Fig. 4 6G research begins on a virtual platform, allowing the exploration of modulation options against channel models.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EVALUATING RF PERFORMANCE IN MIXED-SIGNAL CONTEXTS WITH NONLINEAR BEHAVIOR

Historically, RF design has been primarily an analog discipline. However, modern communication systems feature more mixed-signal characteristics. Digital modulation, already a mainstay, takes on increased complexity in 6G with larger constellations and tighter spacing. Demands increase on 6G RF front-ends, power amplifiers, mixers, filters, switches and other components to perform predictably across a much wider bandwidth. This makes accurate simulation crucial.

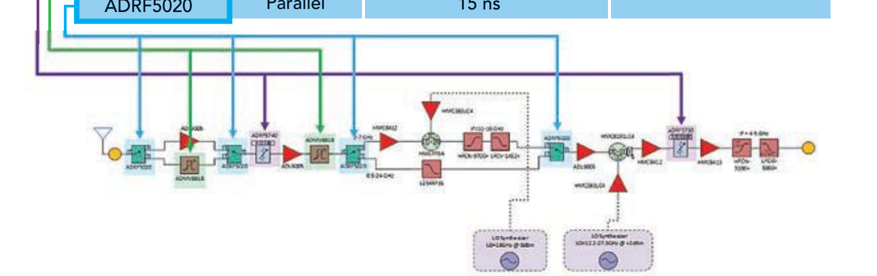
RF performance can change at the flick of a digital switch in these mixed-signal chains. Techniques such as adaptive gain control, switching between alternate signal paths under certain conditions, phased arrays and beamforming, along with digital impairment compensation are necessary to pull signals from noise more effectively. RF EDA must simultaneously address these implications:

- Simulators must adhere to complex sequences of events and keep pace with rapid changes in behavior as inputs and signal chain states vary.
- Point sampling at selected frequencies misses anomalies as bandwidth increases.
- Single-domain simulation is insufficient, with anomalies appearing as domains interact.
- Model complexity must expand to accurately portray behavior, effect detail and interactions.

The days of using a few cherry-picked frequencies for detailed simulation and validation with measurements are gone. That approach only works in narrow bandwidths when interpolation between points tracks linearly without surprises. Under wideband excitation, nonlinear behavior and cross-domain interactions between power, frequency, time, temperature, load and DC bias can combine unexpectedly to disrupt mixed-signal chains at any point across their bandwidth. (See the article "Solving EM Densification at the Point of Design" pp. 52 to 64 in the July 2022 edition of *Microwave Journal* for more on RF cross-domain effects and simulation with authentic signals.)

Nonlinear behavior modeling is essential in state-of-the-art RF front-ends, where digital timing and control knobs adjust performance while preparing signals for analog-to-digital conversion. The Analog Devices ADMV8818 tunable filter, for example, stores up to 128 states for its state machine overseeing preset filter configurations. Analog Devices had a concept for modeling their front-end reference design and sought Keysight's help to construct a lookup table to coordinate states in PathWave System Design simulations. ***Figure 5*** shows some of the variables in each state, including RF settling time. With these details add-

Digital Step Attenuators	Control Interface	Attenuation Range & Resolution	RF Settling Time (to < 0.1 dB of Final)
ADRF5730	SPI or Parallel	31.5 dB in 0.5 dB Steps	250 ns
ADRF5740	Parallel	22 dB in 2 dB Steps	175 ns
Tunable Filters	Control Interface	Amplitude Settling Time (to < 1 dB of Final)	Phase Settling Time (to < 2° of Final)
ADMV8818	SPI	1 μs	2 μs
RF Switches	Control Interface	Switching Time (to < 0.1 dB of Final)	
ADRF5020	Parallel	15 ns	



▲ **Fig. 5** Controlling digitally-driven states accurately for RF front-end simulation (Courtesy of Analog Devices).

ed to the simulation, Analog Devices tuned digital settings and achieved a flatter frequency response across the 2 to 24 GHz operating range, matching physical measurements.

More nonlinear behavior is likely in store for 6G antennas. Achieving higher spectral density, which correlates to the number of bits that can be put in the air for a given channel, requires a combination of techniques. Advanced higher-order modulation packs bits of data more tightly into symbols, but these symbols are only valid if they arrive within acceptable error limits at the RF front-end.

6G researchers are looking at three technologies to break through channel interference and deliver more bits to more user equipment (UE), the devices in a 6G network, reliably. These three technologies are:

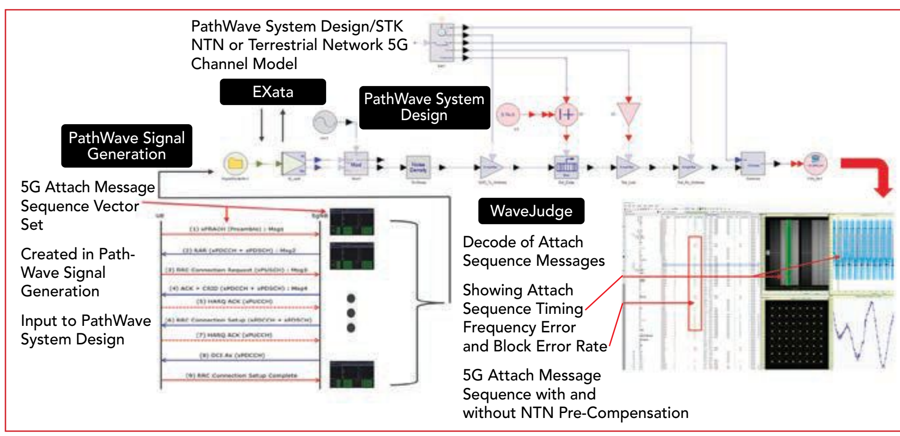
- Holographic beamforming that optimizes the shape of a beam using passive electronically steered arrays (PESAs) to increase the energy directed at a recipient with higher resolution compared to traditional phased arrays.
- Ultra-massive MIMO that utilizes thousands of antenna elements in coordination with beamforming to help improve the odds of signals overcoming significant sub-THz propagation loss and interference over greater distances.
- Reconfigurable intelligent surfaces (RIS) that incorporate reflective antenna elements in a programmable structure, possibly in 3D IC form. RIS aims to simplify designs by reducing the per-element RF signal chain processing requirements.

A mixed-signal context change is brewing overhead in non-terrestrial networks (NTNs). Bouncing signals off low earth orbit (LEO) satellites and other high altitude platforms injects a bulk delay due to extended distances and a Doppler shift resulting from satellite motion. Maintaining connections requires continuous pre-compensation for these effects at several points in the signal chain, including each UE.

Addressing these challenges means system-level RF EDA tools must generate accurate 5G and, eventually, 6G messaging sequences and channel models for NTNs. End-to-end digital twins, enhanced with implementation measurement feedback, can help unlock suitable pre-compensation algorithms. ***Figure 6*** illustrates initial research into this challenge, combining PathWave Signal Generation for creating authentic waveforms, EXata for core network timing simulation, PathWave System Design and Ansys STK for channel and kinematics modeling and WaveJudge for message decoding and timing analysis.

SUB-THZ CHALLENGES AND SCALABLE EDA WORKFLOWS

So far, this discussion has focused on RF system-level simulation needs. 6G design will also need full-bandwidth, multi-domain, nonlinear simulation capabilities at the component and module levels. Consequently, RF EDA will transition from single-purpose, specialized tools sharing data sequentially to a more integrated, scalable suite



▲ Fig. 6 A conceptual model of a digital twin platform for NTN Doppler pre-compensation.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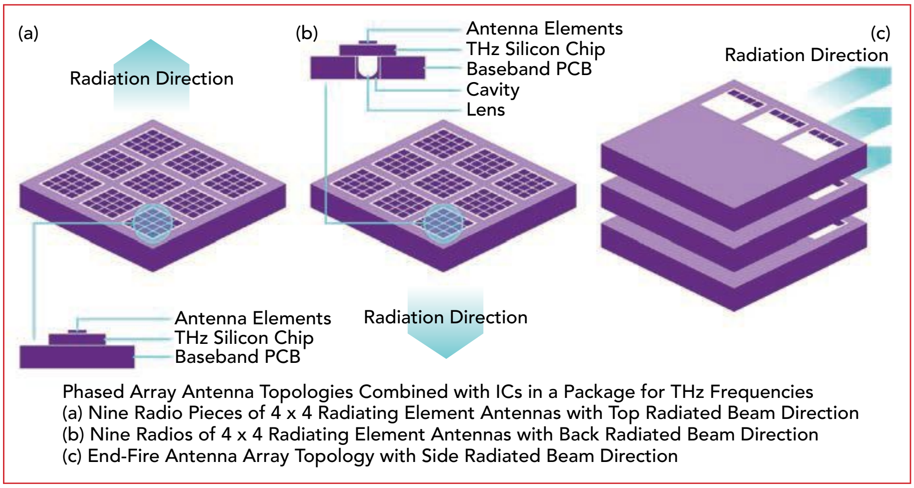

Fig. 7 **Top-fire, bottom-fire and end-fire 3D IC antenna array concepts (Courtesy of 6G Flagship/University of Oulu).**

of enterprise-class tools delivering a comprehensive design experience. Several factors will drive this shift and include:

- New semiconductor and material technologies will call for new RF design architectures.
- Shorter wavelengths and wider bandwidths will expose effects hidden at lower frequencies.
- Substantially increased packaging and integration density will concentrate problem spaces.
- Manufacturability will become a significant challenge at higher frequencies and integration levels.

Advanced III-V semiconductor materials are seeing adoption in RF and power electronics. While these materials and processes offer new possibilities, system-level challenges such as higher noise floors and lower output power levels will intensify. High peak-to-average power ratio (PAPR) signals squeeze into narrower operating windows at mmWave frequencies with further dynamic range degradation at sub-THz frequencies.

Another challenge involves effects stemming from the relative size of the signal wavelengths compared to the devices, packaging and their interconnects. mmWave frequencies push designs into a 3D guided-wave regime, introducing additional modeling complexity due to currents and components interacting in ways that can be ignored at lower frequencies. An example of this is new challenges presented by 3D current flow and ground references. Loss formulations, coupling, resonances and transmission modes all change, altering how ports must be set up, how ground references are made and how structures are designed to suppress unwanted interactions. In a 3D-stacked environment, power and ground distribution are linked to signal integrity and stability issues. Guided-wave port and excitation types require new calibrations, as do measurement and probing techniques and enclosures. Antenna elements can be directly designed into packaging like the monolithic mmWave IC concepts in ***Figure 7***. While this reduces the number of components and size, weight and power (SWaP), care must also be taken to prevent crosstalk, signal contamination, EMI/EMC and even security risks.

Another shift is the trend toward greater package and integration density. Silicon devices will be complemented with RF front-end modules in other technologies and integrated into heterogeneous packages. This modular approach improves yields, lowers fabrication costs and mitigates technology risks but it increases process and tool complexity, along with interconnect, density and system challenges.

Process design kits (PDKs) will play critical roles in overcoming these obstacles. Design tasks become more complex when components from different processes and vendors integrate into one module, requiring co-validation for EM, ther-

mal, stability and wideband modulated performance. Designs and PDKs must interoperate to address multiple effective stack-ups and dimensions within a single package.

Lastly, mmWave and sub-THz performance can vary significantly due to the tight tolerances associated with smaller wavelengths and material properties. ICs and packages become more sensitive to mechanical and material repeatability and thermal/environmental cycling. Measurement cabling, fixturing, probes and calibration standards also are vulnerable to these mechanical errors, leading to uncertainties. These complex environments have long, expensive fabrication timeframes and the modeling, validation and troubleshooting processes require more sophisticated skill levels and precise handling. All these factors increase design costs and hinder the pace of innovation. Monte Carlo simulation and design-for-manufacturing techniques can help, but some challenges are too difficult to address without computational assistance.

Scalable computation will be an essential element of next-generation EDA workflows. Cloud-based and high performance computing (HPC) platforms will become commonplace in many RF EDA workflows delivering simulation results with minimal wait times, keeping design team productivity high and shortening time-to-market. Digital twins with measurement-based simulation enhancements will represent complex RF components and subsystems before fabrication, enabling in-context RF system-level testing and troubleshooting impractical to execute in the real world.

AMPLE ROOM FOR AI TO HELP COMPLETE THE 6G DESIGN PICTURE

The complexity of the mmWave RF workflow is becoming unwieldy, necessitating a comprehensive digital transformation across the RF EDA workflow to prepare for the sub-THz era. EDA vendors and foundries are already striving for improved interoperability. A recent example of this trend is the innovation of an RFPro 3D EM-Circuit cockpit that interoperates between Cadence Virtuoso, Synopsys Custom Compiler, Keysight ADS and the just-approved 79 GHz TSMC 16 nm reference flow.

Managing models, scenarios, simulation data and result-driven optimization becomes a priority. AI techniques will take center stage and be applied in many ways. At the component level, AI will play a significant role in rapid model creation from datasheets or test data. This capability may manifest itself by scanning in a frequency response curve and automatically extracting S-parameters. Channel estimation and waveform design for 6G are also areas where AI is being explored. Sifting through simulation data and identifying mismatches against measurement data is also a task well-suited for AI. Ultimately, real-time, end-to-end 6G network optimization in response to the number of connected users and their traffic patterns at any given moment may only be possible using AI. Humans may be unable to describe the complex optimization for energy usage, capacity, latency and other network metrics in quantitative algorithm form. ■

RF EDA will play a pivotal role in firming up 6G specifications, creating sub-THz components and delivering advanced test and measurement equipment that enables complete 6G system design. For more insight on 6G requirements and innovation progress see:

RF Enabling 6G: Opportunities and Challenges from Technology to Spectrum
https://www.keysight.com/us/en/assets/7121-1085/article-reprints/RF-Enabling-6G-Opportunities-and-Challenges-from-Technology-to-Spectrum.pdf

6G Technology: Envision the Future of Wireless Communications
https://www.keysight.com/us/en/solutions/emerging-technologies/6g-technology.html

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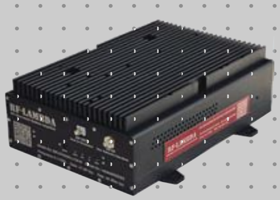

RAMP18G40GB-U 18-40G 20W

RAMP05M80GC 0.5-80GHZ

REMC02G06GE 2-6GHZ 500W

REMC08G11GE 8-11GHZ 400W

To Unleash Tomorrow's Open Radio Networks, Testing Must Evolve

Anil Kollipara
Spirent Communications

Walking the floor at Mobile World Congress last February, there could be no doubt that the age of Open Radio Access Networks (Open RAN) had officially arrived. Just six years since 3GPP first described a next-generation RAN architecture,[1] a sprawling Open RAN ecosystem has emerged. Stakeholders across the industry, from traditional network equipment providers and chipmakers to device manufacturers, new startups and independent software vendors were showing off groundbreaking Open RAN solutions. It was everything that advocates for open radio interfaces could have hoped for, except for one thing; real-world deployments.

The promise of Open RAN remains alluring as ever. By virtualizing and disaggregating the RAN and opening it up to new vendors and software-defined architectures, we should see a long list of benefits: increased competition, lower costs, innovative new service models and more. It's why every major communication service provider (CSP) is now conducting some sort of Open RAN trial. Almost all of these initiatives, however, remain stuck in proof-of-concept.

What's preventing Open RAN from progressing through the "peak of inflated expectations" in the Gartner Group's Hype Cycle, beyond the "trough of disillusionment" (where many CSPs find themselves today), to viable, productive solutions? In a word, complexity. Open RAN brings so many new architectural components, along with such radically different technical and operational requirements, there were always going to be open questions about how to proceed. Less appreciated, however, was just how much work would be needed to answer these questions. The only way to turn Open RAN hype into real-world deployments is with thorough, comprehensive testing. But technology as revolutionary as Open RAN demands a revolution in testing. Right now, CSPs and vendors are still grappling with what that transformation entails.

NAVIGATING THE NEW NORMAL

Open RAN will eventually take hold in production networks in some form; the rewards are too great to ignore. Beyond any benefits from vendor competition, Open

RAN introduces a degree of architectural and business flexibility that hasn't existed before. By breaking out base stations into independent components: radio unit, centralized unit, distributed unit and RAN intelligent controller potentially from different vendors, operators gain the freedom to architect access networks in new ways, a key enabler of 5G densification. At the same time, Open RAN lets CSPs position closed-loop control intelligence and even third-party applications right where devices connect, enabling new use cases and revenue models.

At this point, it's hard to imagine future telecom networks that don't provide this kind of flexibility. Before we get there, however, CSPs and vendors will need to overcome the many challenges that come with a disaggregated, software-driven RAN. Among the biggest of these challenges is integrating and testing all these newly independent components. The whole premise of an open, plug-and-play RAN is that you should be able to choose functions from different vendors and assemble them into a single, high performing system. That's a huge change from yesterday's RAN, where radio technologies came largely pretested and integrated from the vendor. If you're with a CSP lab team, it's now your job to patch together this collection of virtualized multivendor software functions into a production-ready infrastructure. That's a considerable effort. Among other challenges, you'll need to address:

Many more things to test and model: Open RAN involves many disparate parts and pieces, potentially from different vendors, all interworking seamlessly under high traffic loads in mission-critical enterprise customer environments. And by the way, many of these components and in some cases, vendors, are basically brand-new. It's now your responsibility to validate their interoperability, performance and conformance with standards. You'll need a broad range of new instruments and emulators and the ability to test each function in isolation, in tandem with adjacent components and as part of an end-to-end system.

Extreme performance requirements: The ability to support next-generation capabilities like ultra-low latencies will play a central role in enabling new 5G use cases and revenue models. But it also makes the RAN, already the most performance-sensitive part of the network, even more so. To deliver on next-generation services and service-level agreements (SLAs), you will need to assure that every element of every network function performs and interworks as expected, within much tighter latency windows, in a more dynamic and unpredictable environment, under real-world conditions.

Lack of mature tools: While CSPs already have an impressive array of Open RAN technology options, there remains a distinct lack of focused, integrated solutions to effectively test them. Even at the level of methodology, there is still no normalized, industry-wide approach. Test and emulation products that can provide all the necessary capabilities, much less in a way that makes testing simple, repeatable and scalable, don't yet exist. Instead, Open RAN deployments typically involve test companies dispatching engineers onsite to develop custom test bed solutions. This typically involves a great deal of manual setup, making the process expensive as well as fraught with errors. It's also only a temporary solution; as you update Open RAN software and hardware, those precisely tuned custom test beds won't be usable for long.

This is only a partial summary of what's needed to deploy a production Open RAN system and unfortunately, most existing testing tools can't help. Even in labs with sophisticated emulation and testing capabilities, most instruments were designed for previous 3GPP specifications. They don't account for the partitioning mandated by the Open RAN Alliance (O-RAN) specification, or the fact that it breaks traditional interfaces. So even if you limit such tools to piecemeal testing of individual functions, you can't trust that you are getting an accurate representation of how they will behave in the field.

ADOPTING MODERN SOFTWARE METHODOLOGIES — READY OR NOT

Beyond the need for new testing approaches, virtualizing and opening up the RAN brings far-reaching new operational requirements, particularly around software and change management. In a multivendor Open RAN, you can expect a constant flow of software updates and firmware upgrades at multiple layers, all released on different vendor timelines, far more frequently than in the past. Every time any vendor in the environment pushes out a new release, you'll need to repeat the whole testing effort of validating capacity, compliance and performance of the new function in isolation, as well as in adjacency testing and across the end-to-end system. Unfortunately, as more vendors enter the picture, the process only gets more complicated.

The only way to contend with so much complexity is with an automation-first approach. That implies a continuous integration/continuous delivery/continuous testing (CI/CD/CT) pipeline spanning the lab, preproduction and ultimately, production environments. CSPs have long discussed such methodologies in preparation for 5G core networks. For the kind of plug-and-play multivendor architecture that Open RAN envisions, however, a CI/CD/CT approach becomes mandatory. It's the only way to consume, test and deploy software updates in a reasonable time frame and at a manageable cost. Even more important, it's the only way to be confident that each new combination of functions and software versions in this constantly changing environment is safe to push into production.

DEVELOPING OPEN RAN-READY TESTING AND EMULATION

With so many challenges to overcome, we shouldn't be surprised that production Open RAN deployments continue to lag. In fact, those making the most progress today are often doing so in baby steps, starting with "partial" Open RAN solutions that use virtualized, Nxbeam™

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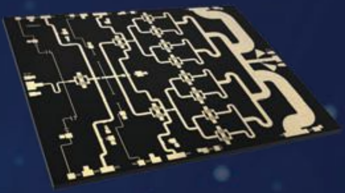
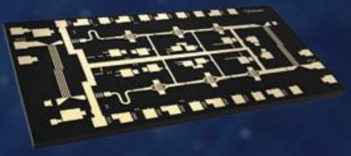
- NPA2002-DE | 27.0-30.0 GHz | 35 W
- NPA2003-DE | 27.5-31.0 GHz | 35 W
- NPA2004-DE | 25.0-28.5 GHz | 35 W*
- NPA2020-DE | 24.0-25.0 GHz | 10 W
- NPA2030-DE | 27.5-31.0 GHz | 20 W
- NPA2040-DE | 27.5-31.0 GHz | 10 W*



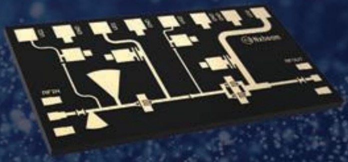
V

- NPA4000-DE | 47.0-52.0 GHz | 1.5 W
- NPA4010-DE | 47.0-52.0 GHz | 3.0 W



E

- NPA7000-DE | 65.0-76.0 GHz | 1 W
- NPA7010-DE | 71.0-76.0GHz | 4 W*



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standards-compliant components, but all provided by one vendor. For now, this model allows operators to move forward with Open RAN using more deployment-ready solutions, without having to take on a full multivendor integration effort and without having to transition to automated CI/CD/CT software methodologies, yet.

Most CSPs recognize, however, that they can't put off these changes forever. A viable Open RAN, really, a viable next-generation telecom network, will require continuous testing and integration, whether it's a plug-and-play architecture or not. Fortunately, we already know what a next-generation approach to testing should look like. Indeed, leading testing providers in this space can now deliver on many of its elements. Emerging Open RAN testing solutions will feature:

Advanced emulation: Lifelike, scalable emulation is essential for effective testing, especially in highly dynamic, disaggregated Open RAN architectures. The industry is developing a new generation of emulation tools designed specifically for these environments. These tools can emulate real-world network conditions for all Open RAN components in isolation, in adjacency testing and as part of end-to-end systems with stringent performance requirements. They can scale up emulated users, applications, data rates and other factors to model real-world network conditions, including unexpected impairments. Such capabilities will benefit vendors as well as CSPs. After all, you can't develop viable DU solutions, for example, if you can't emulate all the other pieces of an Open RAN system.

Ease of use: Configuring all the different test instruments and emulators necessary to validate an Open RAN system is not easy and each configuration must be precise and repeatable to avoid problems in regression testing. Trying to accomplish that by patching together point test instruments and disparate emulators is almost impossible. Emerging Open RAN testing solutions will expose a comprehensive set of Open RAN testing and emulation capabilities under a single, common UI.

Automation: Automation might have been aspirational in the past, but it's a basic requirement for many aspects of Open RAN operations, including testing. By starting with a common UI for all emulation and testing capabilities, new solutions make it possible to automate tasks across the testing lifecycle. They provide a framework to automatically configure instruments and emulators to their precise settings and accelerate time to results. To accommodate constant change in next-generation environments, these tools will also enable engineers to bring up any previously defined test, change parameters and run it again, in minutes instead of hours or days.

"Lab-to-live" scalability: Legacy testing models were designed with

the assumption that lab and production environments existed in largely separate worlds, managed by separate teams. In a software-driven network, however, they converge into a single continuum that demands continuous, comprehensive testing. Emerging solutions will be able to scale CI/CD/CT processes across the lab-to-live lifecycle, from test bed to preproduction and, ultimately, production. They will provide a framework where every change or update in the network triggers automatic testing to revalidate interoperability and performance.

Alignment with business requirements: Traditional testing tools tend to focus overwhelmingly on technical parameters. Such tooling will always be important, but too often, legacy test approaches seem largely isolated from business-level concerns. Emerging approaches promise more solution-oriented options, with test and measurement tools that tie directly to business outcomes. Ultimately, you will be able to thoroughly test your Open RAN, in the lab and at scale, at different performance intervals aligned to the specific SLAs and KPIs of your business.

LOOKING AHEAD

Clearly, much work remains to be done and many questions answered before we see mass deployments of Open RAN, whether in single-vendor implementations or full plug-and-play architectures. But we can already draw one important conclusion; RAN architectures can't evolve in isolation. Testing approaches must evolve right alongside them to make these new architectures and technologies field ready. If you are relying on test and emulation solutions designed for a legacy world, proceed with caution. It's only with comprehensive data derived from automated testing frameworks, ideally in the proof-of-concept phase, that you can accurately assess the performance and suitability of Open RAN for your business.

The good news is that a new generation of testing solutions is already emerging to help both CSPs and vendors advance Open RAN evolution, with fewer expensive missteps. As more organizations adopt such frameworks, we should expect to see Open RAN deployments accelerate. Operators will find they can transition to new RAN architectures and performance requirements more quickly and cost-effectively. Vendors will be able to promise repeatable results at scale and deliver them. And as an industry, we can all stop hearing about the potential of Open RAN and actually start monetizing it. ■

References

1. "NG-RAN; Architecture Description," 3GPP, Reference 38.401, Web: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3219.

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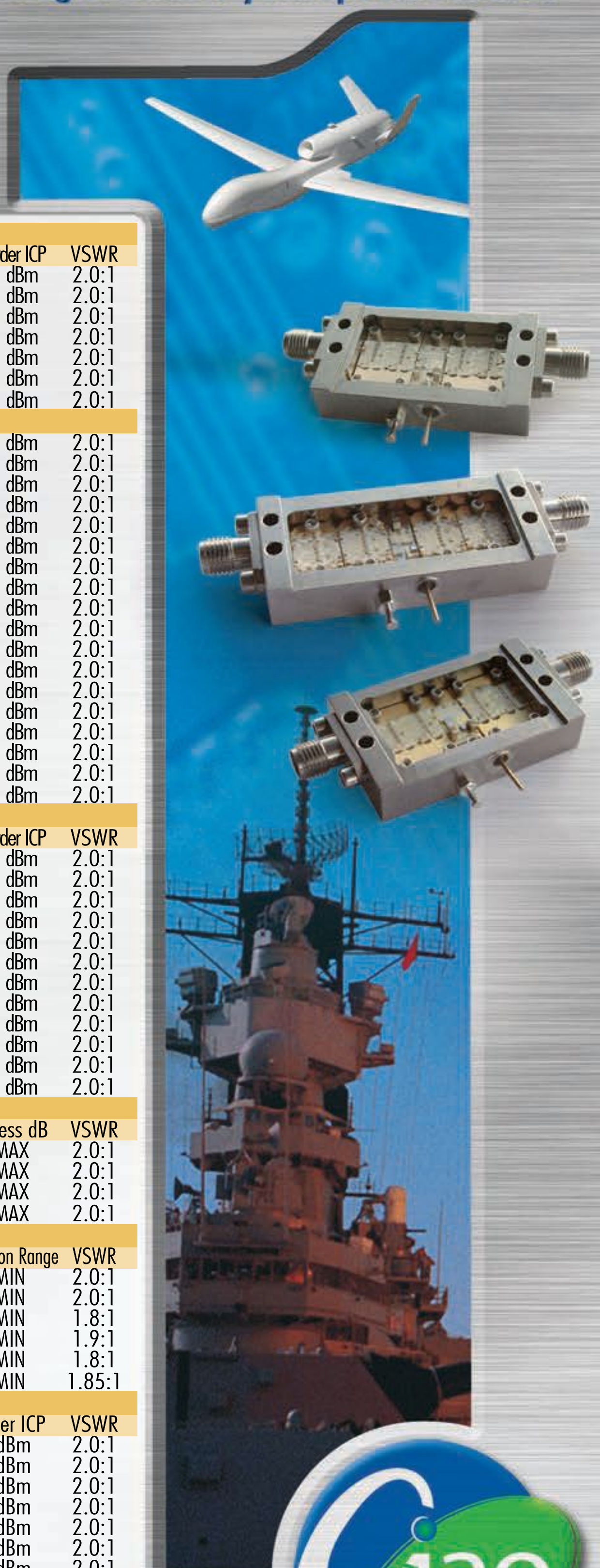

OCTAVE BAND LOW NOISE AMPLIFIERS

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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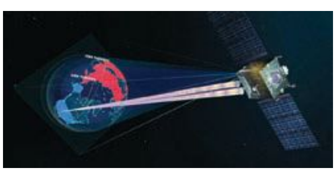
NGC On Track to Produce Early-Warning Missile Defense System

Northrop Grumman Corporation (NGC) recently completed a preliminary design review for the U.S. Space Force Space Systems Command's Next Generation Overhead Persistent Infrared Polar (NGP) program. The company is on track to begin production of the early-warning missile system in defense of the nation.

The design review establishes the company's technical approach for the full integration of the Eagle-3 spacecraft with the infrared sensor, auxiliary and high bandwidth communication payloads being developed by Northrop Grumman in Azusa, Calif.

"Northrop Grumman is on an accelerated path to delivering an early-warning missile system capable of surviving attacks from space, ground or cyber elements," said Alex Fax, vice president, NGP, Northrop Grumman. "NGP satellites will maintain a direct line of communication back to the continental U.S., limiting dependency on overseas ground station sites."

The two NGP satellites, operating in highly elliptical orbits, are designed to detect and track ballistic and hypersonic missiles over the Northern Hemisphere. Broad coverage over the polar region offers the highest probability of spotting potential missile launches.



NGP (Source: Northrop Grumman Corporation)

NGP can identify the infrared heat signatures of incoming threats and transmit this mission data to the ground. Based on the threat, decision-makers can then make responsive and informed decisions. This enhanced communication system also has resiliency features that reduce vulnerabilities to counter-space and cyberattacks.

BAE to Develop Autonomous Space-Based Surveillance Technology

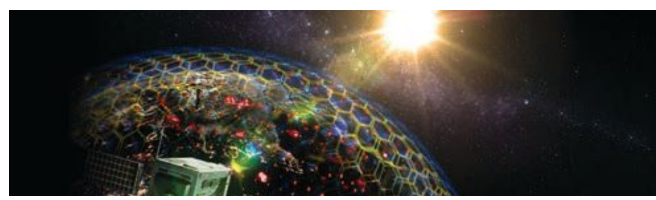
The Defense Advanced Research Projects Agency (DARPA) has awarded BAE Systems' FAST Labs™ research and development organization a $7 million contract for the Oversight Autonomous Space-Based Target Custody program.

Traditional space intelligence, surveillance and reconnaissance (ISR) collection can be siloed, labor intensive and unable to dynamically re-evaluate quickly enough to take advantage of new space systems. To address this, DARPA, the U.S. Space Force and the Space Development Agency are developing satellite constellations to improve the tactical relevance of U.S. space systems.

Proliferated low earth orbit satellite constellations are significantly expanding on-orbit ISR capabilities. The DARPA Oversight program will focus on creating an autonomous system that maintains constant "custody" of a large number of assets across new, diversified constellations. Under the terms of the program, the technology will be deployed to both tactical-edge satellites and ground stations.

"Rapidly advancing near-peer adversary capabilities are driving a need for additional long-range tracking at increased scale and timeliness," said Dr. John Grimes, director of small satellites at BAE Systems' FAST Labs. "To meet this requirement, our team includes technical expertise in autonomy, space processing, ISR systems, tactical-edge software development, system integration and architectures and mission focus."

Work on the program, which is part of BAE Systems' autonomous technologies portfolio, includes collaboration with subcontractors OmniTeq and AIMdyn, Inc.



Oversight (Source: BAE Systems)

Intelligence Takes Flight

Raytheon Technologies has developed a groundbreaking system called RAIVEN to address challenges in detection and identification. RAIVEN revolutionizes the way aircrews detect and identify threats, obstacles and targets in real-time. By combining artificial intelligence (AI), electro-optical imaging, hyperspectral imaging and light detection and ranging (LiDAR), RAIVEN provides an unprecedented intelligent-sensing capability like never before.

RAIVEN's hyperspectral technology can even detect the chemical signatures of human skin and hair. "You can imagine the value of such a capability when trying to find a downed aircrew member in a forest or sailor who has gone overboard at sea," said Jake Ullrich, surveillance and targeting systems engineering director at Raytheon Technologies. "RAIVEN informs aircrews, 'There's something here. Here's what I think it is or here's what I know it is.' It gives aircrews more time to make decisions," he said. "For aircrews on combat missions, it extends their range, provides a clearer battlespace picture, and offers an intelligent way to process that data. That's what RAIVEN brings to the table."

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With RAIVEN, pilots can see up to 5x farther and clearer than before, compared to traditional electro-optical imaging systems. This means aircrews can spot potential threats from a safe distance and keep their platforms out of harm's way. RAIVEN can automatically detect and identify threats, reducing the workload for operators and accelerating the decision-making process.

Inspired by the combat-proven Multi-Spectral Targeting System, which has been used for surveillance and targeting purposes for the past 20 years, the system's intriguing capability lies in its ability to analyze and identify chemical signatures of various materials including gases, metals, vegetation and more.

Its hyperspectral technology allows it to detect targets or objects that were previously invisible to the human eye or other conventional imaging technologies. By capturing the wavelengths of light emitted by materials and objects, RAIVEN's hyperspectral sensors can discern even the slightest changes in the chemical composition of the environment, providing an entirely new level of situational awareness.

RAIVEN turret's hyperspectral imaging system creates a unique "fingerprint" for different materials based on how they reflect and absorb light. This enables RAIVEN to detect and analyze the chemical composition of its surroundings. The onboard AI algorithms process this data in real-time "at the edge," providing immediate results to the aircrews.

RAIVEN (Source: Raytheon Intelligence and Space)

The integration of LiDAR into RAIVEN provides aircrews with an additional layer of safety during missions, reducing the risk of accidents or collisions. It helps in detecting and avoiding obstacles such as wires, buildings or trees, which is crucial during low-level flight or in complex terrains. By swiftly analyzing and processing LiDAR data, RAIVEN's AI algorithms identify potential threats and present them to the operator, reducing their workload and allowing them to focus on critical tasks.

RAIVEN, specifically the RT-1000 or RAIVEN Turret 1000, is designed for the U.S. Army's Future Vertical Lift variations of Future Long-Range Assault Aircraft and Future Attack Reconnaissance Aircraft, and it is scheduled for its first flight in 2024. However, the architecture of RAIVEN allows for scalability, making it adaptable to various platform installations and mission requirements.

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Cliff Drubin, Associate Technical Editor

The FCC Releases Report and Order for the Use of 12.2/12.7 GHz Bands

The FCC announced they are on the path toward expanding the beneficial use of up to 1050 MHz of midband spectrum by a diverse set of terrestrial (licensed and possibly unlicensed) and satellite communications systems, promoting technological innovation and bolstering the growth of the nation's economy. In this item, the FCC takes steps to ensure current and future satellite services are preserved and protected in the 12.2 to 12.7 GHz band (12.2 GHz band) while continuing to develop a pipeline of midband spectrum for mobile broadband or other expanded uses essential for connecting everyone, everywhere in the 12.7 to 13.25 GHz band (12.7 GHz band).

> **Substantial support for repurposing 12.7 GHz band for next-generation wireless technologies.**

In the 12.2 GHz band *Report and Order*, the FCC finds that authorizing two-way, high-powered terrestrial mobile service in the 12.2 GHz band would impose a significant risk of harmful interference to existing and emergent services in the band, including satellite services. Such interference could undermine investments made by incumbent licensees and jeopardize their potential to provide new services to underserved communities, including rural communities. Although the FFC declines to authorize two-way, high-powered terrestrial mobile use in these frequencies, in the 12.2 GHz band *Further Notice of Proposed Rulemaking* they further investigate the potential to expand terrestrial fixed use or to permit unlicensed use in the 500 MHz of midband spectrum.

To further their efforts to make spectrum available for terrestrial mobile service, in the 12.7 GHz band *Notice of Proposed Rulemaking*, the FCC proposes to repurpose some or all the 550 MHz of midband spectrum for mobile broadband or other expanded use. The record demonstrates substantial support for repurposing these midband frequencies for next-generation wireless technologies including 5G, 5G Advanced and 6G services that will depend on extremely high data rates, reliability, low latency and capacity that the 12.7 GHz band spectrum can provide. Accordingly, in this *Notice of Proposed Rulemaking*, the FCC seeks comment on various proposed means for transitioning some or all the 12.7 GHz band to mobile broadband and other expanded use, as well as on alternative changes to the Commission's rules that could promote use of the band on a shared basis. To improve the data on which to base their decisions regarding the future structure of the 12.7 GHz band, the FCC adopts a 12.7 GHz band Order directing fixed and mobile broadcast auxiliary services and cable television relay services licensees that use the 12.7 GHz band to certify the accuracy of the information reflected on their licenses.

The Primary Obstacle to 5G Core Deployment and Enterprise 5G Monetization

The 5G Core (5GC) market is expanding. To date, more than 35 5GC networks are operating in 5G standalone (SA) mode. 5GC is expected to lead to a growth in devices connected to the network and the traffic routed through it. ABI Research forecasts that 5G subscriptions will increase from 934 million in 2022 to 3.1 billion in 2027 at a compound annual growth rate (CAGR) of 27 percent. Further, 5G traffic is forecast to increase from 293 Exabytes (EB) in 2022 to 2,515 EB in 2027, at a CAGR of 54 percent.

"5GC holds potential for operators to monetize further existing cellular connectivity for traditional mobile broadband use cases but also offers scope for operators to expand cellular capabilities in new domains. Additionally, 5GC also offers innovation potential for committed telcos to establish new operating models for growth outside of the consumer domain," explained Don Alusha, senior analyst of 5G Core and edge networks at ABI Research.

With 3G and 4G, communications service providers' (CSPs) positioning in the global production frontier was anchored to hard-to-duplicate network assets that continue to yield profits in the consumer domain. But now, there is a realization in the industry that using existing infrastructure and Evolved Packet Core (EPC) may not be sufficient for new value chains. With 4G EPC, CSPs drive value with a centrally governed operating model. CSPs' growth strategy with EPC revolves around technical excellence and integration in cellular.

5GC presents CSPs with a fluid and dynamic landscape. In this landscape, there is no static offering (requirements constantly change), no uniform offering (one shoe does not fit all) and no singular endpoint (one terminal with multiple applications). 5GC guides the industry into edge deployments and topologies. CSPs step out of the four walls of either their virtual or physical data center to place network functionality and compute as close to their customers as possible. This constitutes decentralization, a horizontal spread of network assets and technology estate that calls for a 'spread' in the operating model.

The shift from a centralized business to a decentralized business stands to be a significant trend in the coming years for the telecoms industry. Against that backdrop, the market will demand that CSPs learn to

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drive value bottom-up. "What customers need" is the starting point for companies like AT&T, BT, Deutsche Telekom, Orange and Vodafone. Therefore, it is rational to conclude that a "bottom-up" approach may be required to deliver unique value and expand business scope. That said, CSPs may be better equipped to drive sustained value creation if they learn to build their value proposition, starting from enterprise and industrial edge and extending to core networks.

Broadband Operator Competition Driving Wi-Fi CPE Growth

The residential Wi-Fi market has been turbulent over the last few years, beset by erratic fluctuations in demand, protracted supply chain challenges, and escalating competition between internet service providers (ISPs). Disruption has been magnified by transformative innovations alongside the injection of government funding. With industry backlogs in decline since 3Q 2022 and demand generally becoming more predictable, the industry is now primed for these technical innovations, heightened market competition and government support to drive growth in the market.

ABI Research is forecasting that global Wi-Fi customer-premises equipment (CPE) shipments will rise from 266.9 million in 2022 to 397.4 million in 2028 at a CAGR of 6.9 percent. Much of this growth will be driven by new Wi-Fi CPE product types like Wi-Fi mesh and the latest Wi-Fi standards, although it is already clear that there will be some bumps down the road with Wi-Fi 7's introduction.

As competition intensifies between ISPs, differentiation through hardware alone is no longer sufficient, and software has emerged as a new front in the intense conflict. While in the past, ISP requests for proposal (RFPs) were typically combined requests for Wi-Fi CPE hardware and firmware, increasingly RFPs are being made solely for the hardware, with the ISP taking control of the firmware so that they can integrate advanced proprietary features.

Tier 1 service providers developing their own Wi-Fi CPE firmware in-house include AT&T, Comcast and Orange middleware platforms offering advanced value-added services like Wi-Fi management, parental controls and Wi-Fi sensing are also becoming vital for generating new revenue streams and raising the value proposition of broadband packages. Responding to this demand, a range of Wi-Fi CPE vendors, including Askey, CIG, Hitron, Sagemcom, Sercomm, Vantiva and ZyXel, have all chosen to pre-integrate their CPE with OpenSync for instant out-of-the-box access to Plume's smart home services platform.

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Maury Microwave Inc. announced that it entered into a definitive agreement to acquire **Wireless Telecom Group Inc. (WTT)** in a transaction that is expected to close in the third quarter of 2023, subject to the approval of WTT shareholders and the satisfaction of other customary closing conditions. Since its founding in 1985, WTT's test and measurement business — comprised of Boonton, Holzworth and Noisecom — has served as a trusted technology solutions partner to many leading manufacturers in the wireless technology chain. Across aerospace, defense, satellite communications, semiconductor, quantum and directed energy applications, WTT's technology portfolio enables its customers to push the boundary of RF and microwave technology.

Radientum Oy completed the acquisition of **al TreSolver Oy** stocks. For the time being, TreSolver continues as a subsidiary of Radientum in preparation for a merger estimated to happen later this year. The reason for the acquisition is to enable future development of EMC/EMI debugging services to meet the growing demand on the market. The acquisition does not affect the services provided by either company.

Renesas, a supplier of advanced semiconductor solutions, has announced its successful completion of the acquisition of **Panthronics**, a fabless semiconductor company specializing in high performance wireless products. The acquisition was completed as of June 1, 2023, following required regulatory approval. Renesas also announced 13 "Winning Combination" solution designs that combine Renesas' products with Panthronics' unique near-field communication (NFC) technology, showcasing the continued expansion of Renesas' portfolio, specifically in the connectivity space. NFC is now widely used and its market is expected to grow exponentially for both industrial and automotive use cases.

COLLABORATIONS

Anokiwave Inc., a provider of highly integrated silicon ICs for mmWave markets, and **Tidalloft Avionics Research LLC**, a company developing software-defined phased array radars, announced a collaboration to develop compact, lightweight X-Band radars for the aviation market. Phased array radar systems at X-Band are the perfect balance of range, target resolution and size. They enable capabilities to detect and monitor obstacles from significant distances, even amidst clutter. X-Band radar systems are lightweight and are self-contained for ease of integrating into most aviation systems.

Fujikura and **Avnet** have been collaborating to develop a 5G mmWave phased array antenna development kit. System architects can use the kit to prototype and optimize tuning parameters for 5G mmWave systems using AMD Xilinx's Zynq UltraScale+ RFSoC Gen3 and Fujikura's FutureAcess Phased Array Antenna Module (PAAM). **Rohde & Schwarz** has been working with Avnet to integrate remote controls for Rohde & Schwarz test instruments into the Avnet RFSoC Explorer software. The goal is to both control the entire signal chain from baseband to mmWave and to automate mmWave measurements with a single graphical user and application programming interface.

NEW STARTS

MACOM has completed the acquisition of the key manufacturing facilities, capabilities and technologies of **OMMIC**. Going forward, the facility, which is located near Paris in Limeil-Brévannes, France, will become the foundation for MACOM's newly established European Semiconductor Center. The center will enable MACOM to offer its customers higher frequency GaAs and GaN MMICs.

A leader in drone detection systems, **AARONIA AG**, is opening its subsidiary in Austria at Vienna-Vöslau Airport. Stephan Kraschansky, former officer and expert in drone defense in the Austrian Armed Forces, will lead the company as managing director. A live demo of the most successful anti-drone system AARTOS was presented to a group of international representatives at the start of the company's operations.

ACHIEVEMENTS

Triad RF Systems, a provider of high performance RF and microwave amplifiers, integrated radio systems and advanced RF product solutions, announced its 10-year anniversary in 2023. Over the past decade, the company has been committed to providing its customers with innovative RF solutions and exceptional service. From the very beginning, Triad set out to develop custom RF amplifiers and subsystems for various applications including wireless communications, range extension, unmanned systems and electronic warfare. The company further expanded their product line to include RF amplifiers and subsystems for CubeSat payloads.

2023 marks the twentieth year of trading for **Intelliconnect (Europe)**, a U.K.-based specialist manufacturer of RF, microwave, waterproof and cryogenic connectors and cable harnesses. The last few months have seen many changes to the way the company operates and is engaging with the future. Now a part of Trexon Global, a worldwide group of specialist companies providing unique connectivity solutions that withstand the toughest environments and the most exacting applications, Intelliconnect has access to even greater opportunities in a global marketplace.

Farmingdale State College (FSC) recently dedicated the **Murray Pasternack ('60) Lab for Radio Frequency and Microwave Technology**, unveiled during a ribbon-

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SDCHP-140	10 - 400	18.75	1	0.5 / 0.85	27 / 22	25
SBCHP-1100	10 - 1000	10	0.5	1.2 / 1.4	17 / 15	5
KBK-HP-1100	10 - 1000	10	0.5	1.2 / 1.4	17 / 15	5
KDK-HP-255	20 - 550	20	0.4	0.25 / 0.35	23 / 18	27.5
SDCHP-255	20 - 550	20	0.4	0.25 / 0.35	23 / 20	27.5
SDCHP-335	30 - 350	20.1	0.85	0.24 / 0.32	24 / 20	75
SDCHP-484	40 - 840	19.2	0.9	0.3 / 0.4	24 / 20	30
SCCHP-560	50 - 560	14.6	0.7	0.48 / 0.65	23 / 20	75
SCCHP-990	90 - 900	15.2	0.6	0.52 / 0.64	20 / 17	38.3
SBCHP-2080	200 - 800	12.3	0.7	0.64 / 0.80	24 / 18	48.3
SBCHP-2082	200 - 820	11.0	0.5	0.74 / 0.9	22 / 19	22.5
KDS-30-30-3	27 - 512	27.5	0.75	0.3 / 0.4	23 / 15	50
KDS-30-30	30 - 512	27.5	0.75	0.3 / 0.4	23 / 15	50
KBK-10-225	225 - 400	11	0.5	0.6 / 0.7	25 / 18	50
KBS-10-225	225 - 400	10.5	0.5	0.6 / 0.7	25 / 18	50
KDK-20-225	225 - 400	20	0.5	0.2 / 0.4	25 / 18	50
KDS-20-225	225 - 400	20	0.5	0.2 / 0.4	25 / 18	50
KEK-706H	500 - 2500	31.5	2.5	0.28 / 0.4	18 / 12	100
SCS-8012D	800 - 1200	20	0.6	0.22 / 0.25	22 / 18	100
KEK-704DH-2	850 - 1250	30	0.25	0.20 / 0.30	28 / 25	500
KEK-704H	850 - 960	30 5	0.25	0.08 / 0.20	38 / 30	500
SCS100800-10	1000 - 8000	10.5	2	1.2 / 1.8	8 / 5	25
SCS100800-16	1000 - 7800	16.8	2.8	0.7 / 1	14 / 5	25
SCS100800-20	1000 - 7800	20.5	2	0.4 / 0.75	12 / 5	25
SCS-1522B	1500 - 2200	10	--	0.65 / 0.75	23 / 18	100
SCS-1522D	1500 - 2200	20	--	0.32 / 0.38	23 / 20	100
SCS1701650-16	1500 - 15500	17	2.5	1 / 1.4	16 / 5	25
SCS1701650-20	1700 - 15000	21	2.5	0.9 / 1.3	10 / 7	25
SDC360440-10	3600 - 4400	8.6	0.25	0.7 / 1.4	18 / 10	10
SDC360440-20	3600 - 4400	19	0.25	0.7 / 1.2	16 / 10	10

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cutting ceremony to also celebrate his $1.4 million gift to FSC, which is also the largest gift made by an individual in the college's history. Previously, he provided two $500,000 gifts to support the launch of an honors program at the college. The lab will enable students to train using industry-leading equipment including vector network analyzers, spectrum analyzers, RF signal generators, noise sources, mixed domain oscilloscopes and more.

NTT Corporation (NTT) has successfully achieved the first orbital angular momentum multiplexing high capacity wireless transmission, at 1.44 Tbit/s, using an ultra-wide bandwidth of 32 GHz. They aim to implement terabit-class wireless transmission to support wireless demand in the 2030s. As an innovative wireless communication technology that uses the sub-THz band, this achievement will enable wireless access to vast amounts of information at a data transfer rate exceeding 1 Tbit/s. This achievement was realized using the sub-THz band within the range from 135 to 170 GHz and is a wireless communication technology that enables wireless access to a huge amount of information exceeding 1 Tbit/s.

CONTRACTS

Verus® Research, a New Mexico-based team of scientists and engineers specializing in advanced research and development, announced its largest contract to date. The company was awarded a $203 million ceiling increase on its current indefinite delivery indefinite quality contract with the **U.S. Army's Program Executive Office for Simulation, Training and Instrumentation**. The Test and Evaluation Non-Kinetic contract enables Verus Research to further improve the U.S. Department of Defense's ability to test the effectiveness of rapidly developing non-kinetic capabilities including directed energy, electronic warfare and nuclear systems.

The Defense Advanced Research Projects Agency (DARPA) has awarded **BAE Systems' FAST Labs** research and development organization a $7 million contract for the Oversight autonomous space-based target custody program. Traditional space intelligence, surveillance and reconnaissance collection can be siloed, labor intensive and unable to dynamically re-evaluate quickly enough to take advantage of new space systems. To address this, DARPA, the U.S. Space Force and the Space Development Agency are developing satellite constellations to improve the tactical relevance of U.S. space systems.

Elbit Systems UK has been awarded a contract from the **U.K. Ministry of Defence** to provide a series of ground-based surveillance radar (GBSR) systems, manufactured and developed in the U.K. and Europe, to the British Armed Forces to support front line threat detection for a range of end-users. Elbit Systems UK will deliver 90 GBSR systems throughout 2023 and 2024, with a follow-on option of an additional 40 systems. The GBSR system is easily portable and uses digital signal processing to detect, track and classify targets moving on or close to the ground.

L3Harris Technologies announced orders totaling $160 million from the **Marine Corps** for multi-channel handheld and vehicular radio systems, bringing total program orders to $336 million. The two new orders from the Marine Corps are under a 10-year, competitively awarded $750 million indefinite delivery, indefinite quantity contract for L3Harris Falcon IV manpack and handheld radios. The technology in these radios enables greater interoperability among U.S. and allied forces. By integrating voice and data communications, network routing and gateway functions, L3Harris' software-defined multi-channel AN/PRC-163 handheld radios provide real-time battlespace situational awareness to help warfighters make informed decisions.

PEOPLE

▲ *Arthur Gharakhanian*

Stellant Systems Inc. announced it has strengthened its executive leadership team with the appointment of **Arthur Gharakhanian** as chief financial officer (CFO). Gharakhanian brings over 10 years of executive level finance and accounting experience at private equity-backed companies in the aerospace and defense and medical device industries. Prior to joining Stellant, Gharakhanian was CFO of SaniSure, where he oversaw all finance and human resources operations in the U.S., E.U. and U.K.

▲ *Hinrich J. Woebcken*

CesiumAstro has teamed up with **Hinrich J. Woebcken**, general partner at Trousdale Ventures and former president and CEO of Volkswagen Group of America, Inc. Woebcken will serve a dual role, working with CesiumAstro to refine its vision for connected mobility and supporting the company's adoption of automotive mass manufacturing best practices. Woebcken's 30 years of industry experience contributing to the digitization and electrification of automobiles and profound understanding of automotive manufacturing efficiencies will benefit CesiumAstro as the company builds communications payloads for space, air and ground platforms.

▲ *Paul Blount*

Fabless semiconductor startup **mmTron Inc.** announced that **Paul Blount** has joined the company as a technology fellow. In this role, he will design MMIC products, focusing on low noise and high linearity amplifiers, and help mmTron's leadership team develop the operations infrastructure to accelerate growth. Blount started Custom MMIC in his basement in 2006. Over the next 15 years, he led the company to become a major supplier of MMICs for defense, satellite, instrumentation and commercial systems.

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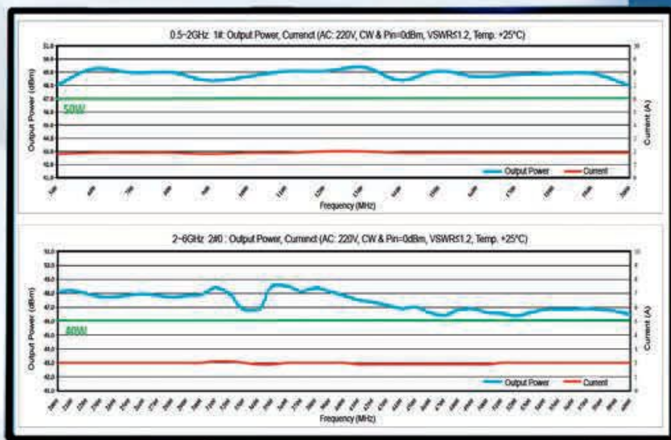

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MIcable announced the latest solid state high gain broadband power amplifier MPAR-005060P44 which covering 0.5~6GHz with output power 40W. It uses state-of-art GaN design technology and can reach higher saturated output power while keeping higher P1dB and better linearity.

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Around the **Circuit**

▲ *Leopold Pellon*

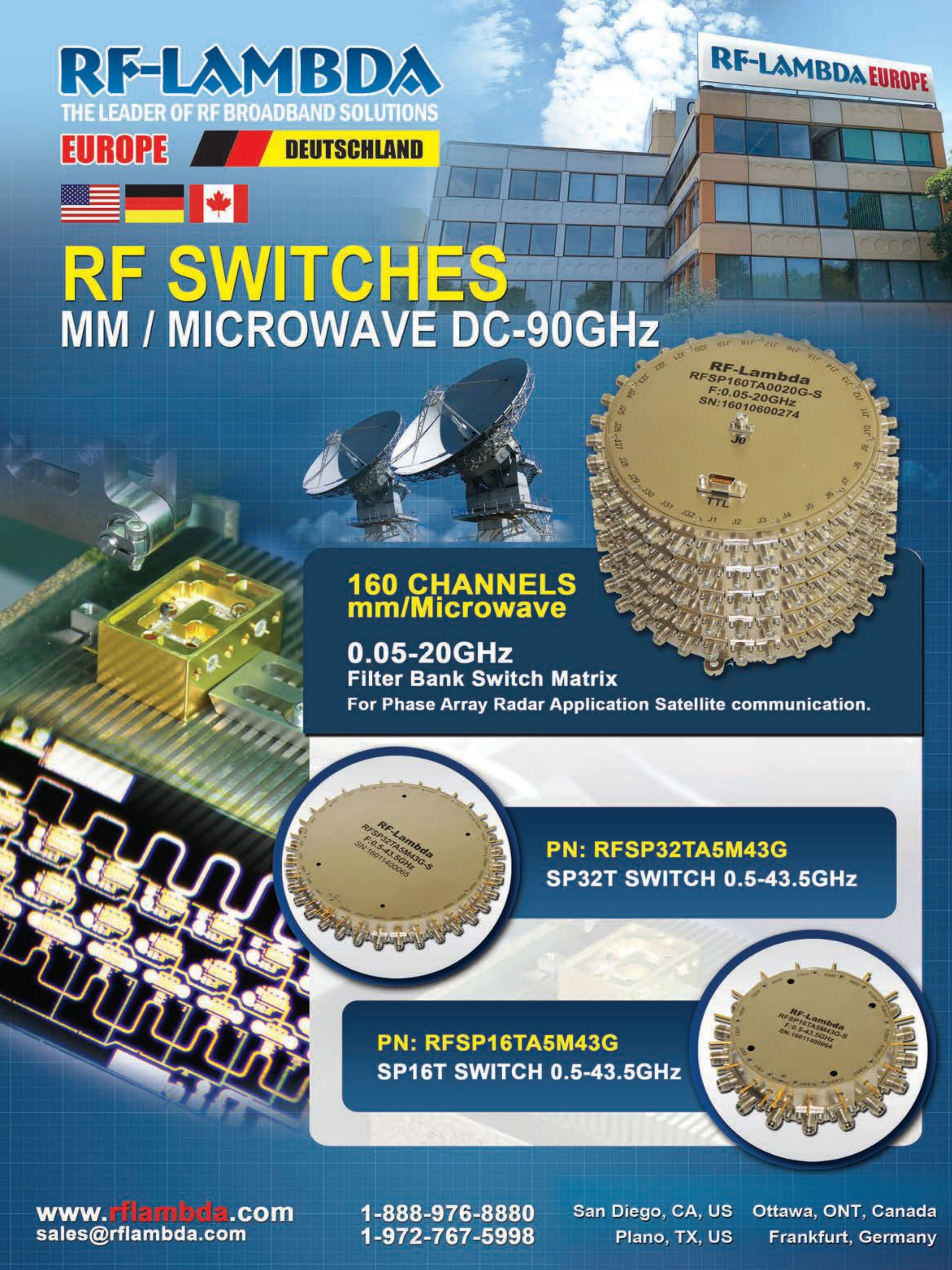
Leopold Pellon has been appointed to the **Defense Advanced Research Projects Agency (DARPA) Microelectronics Exploratory Council (MEC)**, a team composed of scientists and technologists in U.S. This will be a three-year team beginning this summer. The DARPA MEC group advises new areas of development in micro systems science and technology and recommends future possible research directions. Prior to Otava, Pellon worked 38 years at Lockheed Martin where he was a corporate senior fellow. He is a leading researcher in the field of RF sensor systems, advanced components and subsystems with an emphasis on innovative RF and mixed-signal microsystems.

REP APPOINTMENTS

Advanced Test Equipment Corporation (ATEC), a provider of electronic test and measurement equipment rentals, sales and calibration services, has been named an authorized rental partner for **Anritsu Company**, a provider of test and measurement solutions. Through this partnership, ATEC will be able to offer a wide range of Anritsu's advanced testing solutions to its customers, including signal generators, network analyzers and spectrum analyzers. With ATEC's comprehensive rental inventory and Anritsu's industry-leading instruments, customers will have access to a powerful and reliable testing solution for their critical applications. As an authorized rental partner, ATEC will receive training and support from Anritsu to ensure the highest level of customer service and technical expertise.

Electro Rent, a provider of test and measurement equipment rental services, announced a multi-year agreement with **L3Harris Technologies**. The agreement specifies Electro Rent as L3Harris' Tier 1 supplier for test and measurement rental requirements. As a result, Electro Rent is now L3Harris' preferred provider for these solutions and services.

Modelithics, a provider of RF/microwave simulation models, welcomed **Susumu** into the Modelithics Vendor Partner (MVP) Program at the Sponsoring level. Susumu is a manufacturer of precision thin film resistors and high frequency passive components. Susumu's product includes high frequency thin film chip resistors, high frequency chip attenuators, power splitters and high-power chip terminators, which are widely used in critical circuits of various industries such as telecommunications, automotive, medical and aerospace. As a Strategic MVP, Susumu and Modelithics are in collaboration to develop new models for Susumu's ATS1005-FD chip attenuator series and the RFD0603 50 Ω chip resistor devices to be included in the Modelithics COMPLETE Library ™.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INVITED PAPER

Wi-Fi Sensing – The Next Big Evolution of Wi-Fi

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Since the dawn of civilization, humans have relied on light, starting with fire, to see and comprehend the world. Our methods of illuminating our homes have evolved from igniting sticks in caves to using Wi-Fi. Light and Wi-Fi are related, both being on the electromagnetic (EM) spectrum, with light allowing us to see and Wi-Fi enabling digital communications. Today, Wi-Fi represents the second-largest volume opportunity in the EM spectrum after light. The average household had 22 Wi-Fi-enabled devices in 2022, accounting for shipments of nearly 3 billion Wi-Fi chips.[1] In comparison, households typically use an average of 40 light bulbs, with around 2.5 billion shipped annually.[2]

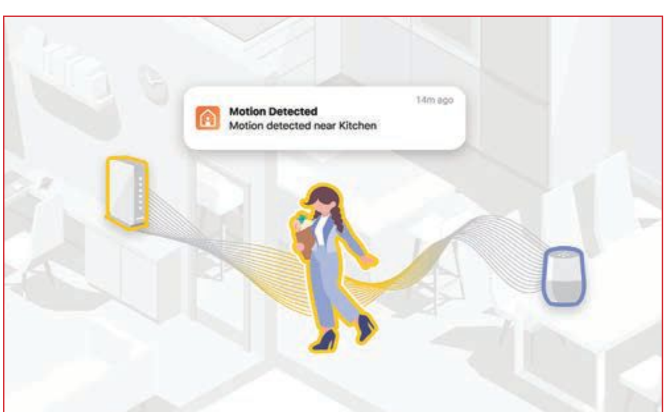

Fig. 1 **Illustration of Wi-Fi Sensing by the access point.**

Homes were dark in terms of Wi-Fi energy before the introduction of Wi-Fi technology in 2000. However, homes are now saturated with an abundance of Wi-Fi energy, illuminating the spaces within. As this Wi-Fi energy is transmitted around the home, it reflects off objects and becomes attenuated as it moves through space and objects. In a static environment, this energy distribution is somewhat stationary, not changing during the transmission of a Wi-Fi signal. However, as a person moves around in the environment, the spectrum of energy distribution changes. These changes indicate there is motion within the home. This idea is illustrated in ***Figure 1***. In the home shown in the diagram, the client devices illuminate the space with Wi-Fi energy and the access point (AP) observes the changes in the Wi-Fi spectrum due to human motion.

WHAT IS WI-FI SENSING AND HOW DOES IT WORK?

Wi-Fi Sensing is the principle of measuring and classifying disturbances in the Wi-Fi spectrum over time due to a person's movement. The sensing machine learning software to measure these disturbances is typically contained within the Wi-Fi APs. The Wi-Fi clients radiate the EM waves for sensing in the form of standard Wi-Fi communication data frames. The clients transmit signals back to the AP at the sounding rate,

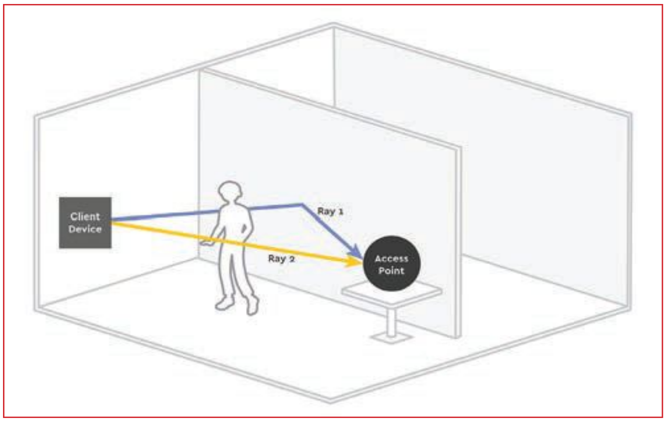

Fig. 2 **An example of signal propagation from a client device to the AP.**

which can be adjusted to be slower or faster. There are limits to this sounding rate adjustability, however. If the rate is too slow, some of the motion will be missed, while a rate that is too fast can impact the Wi-Fi throughput performance as the sensing software within the AP consumes more CPU. To achieve good sensing performance, an optimal sounding rate is around 10 Hz or 100 ms. A significantly higher sounding rate may negligibly improve motion detection latency but at the expense of degrading Wi-Fi network data communication performance, making that an inadvisable trade-off.

Taking a simple case where a Wi-Fi client sends a sounding packet to the AP; some of the radiated spectra will reflect off a wall as Ray 2 and another portion goes directly to the AP as Ray 1 shown in ***Figure 2***. For simplicity, this analysis only considers a very small part of the Wi-Fi spectrum at frequency ω, typically a single orthogonal frequency-division multiplexing (OFDM) subcarrier. The frequency spectrum received by the AP (S_{AP}) as a function of time can be written as:

$$S_{AP}(t) = A(t)e^{-i\omega t} = \left[a_1(t) + a_2(t)e^{-i\omega\Delta t}\right]e^{-i\omega t} \qquad (1)$$

where:

$a_1(t)$ = the amplitude received by the AP due to Ray 1

$a_2(t)$ = the amplitude received by the AP due to Ray 2

Δt = the time delay for Ray 2 compared to Ray 1 since it will take longer to get to the AP

t = time.

S_{AP} may also be expressed as a complex exponential with a magnitude A(t) as defined by equation 1. When there is no motion and all objects are static, the data sent to the AP remains the same, resulting in $\Delta A = 0$ from one sounding packet to the next. However, if the person is moving, ΔA would not be zero. The change in both the $a_1(t)$ and $a_2(t)$ terms stems from the shift in the individual's position within the environment, leading to changes in the overall level of reflection and absorption. Therefore, motion can be detected by looking at ΔA. Wi-Fi is a wideband signal, but the same principle can be applied if the spectrum is broken down into small frequency slices using the Fourier series. Utilizing larger bandwidths enhances the sensitivity to changes resulting from the movement of an individual. It is worth noting that typical Wi-Fi bandwidths range from 20 MHz, 40 MHz, 80 MHz to 160 MHz.

Assuming a bandwidth of 20 MHz, the spectrum undergoes modifications as a person moves. For instance, the initial spectrum resembles the traces shown in ***Figure 3a***, but as the person moves, it transforms into the trace shown in ***Figure 3b***. The disparity between the two traces is illustrated in ***Figure 3c***. Additionally, in Wi-Fi 5, both 2.4 GHz and 5.8 GHz can be employed. However, with the advent of Wi-Fi 6, the 6 GHz band was introduced, further enhancing sensitivity. To filter out unwanted environmental phenomena that do not represent human motion, like ceiling fans, Wi-Fi interference and pets, requires an understanding of how the patterns present in ΔA to be able to remove them accordingly. The use of multiple client devices sounding the AP forms a Wi-Fi Sensing network, which allows motion localization through triangulation. For example, if a person is walking close to a Wi-Fi smart speaker, the motion is localized to where the Wi-Fi smart speaker is located.

Features to enhance Wi-Fi Sensing have been under discussion by the 802.11 group since late 2019. A task group responsible for defining an amendment to the 802.11 standards was formed in late 2020 and a first draft was completed in early 2023. These motion standards will align with both Wi-Fi 6 and Wi-Fi 7 standards. This amendment defines components that will benefit sensing applications on both the AP and client sides. However, since the primary usage of Wi-Fi is digital communications, a sensing application will need to share the same spectrum. This constraint will ultimately limit the maximum rate at which measurement exchanges can be scheduled.

The integration of mmWaves into standards will necessitate alternative techniques for motion detection. These are likely to be similar to those employed in standard radar systems. These techniques possess the capability to detect and track motion effectively.

APPLICATIONS OF WI-FI SENSING

Since Wi-Fi Sensing detects motion and locates its source, the obvious application is home security. Wi-Fi Sensing may be the most cost-effective solution for home security

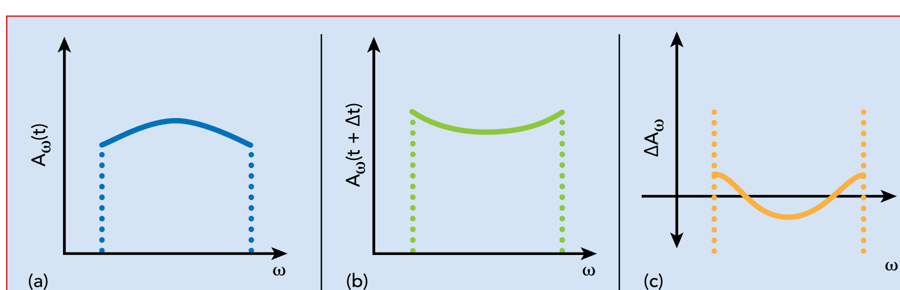

Fig. 3 **(a) $A_\omega(t)$ vs ω at time t, (b) $A_\omega(t+\Delta t)$ vs ω at time t+Δt, (c) ΔA_ω vs ω.**

since it can be provided to customers via an over-the-air software update to their Wi-Fi AP. Once the Wi-Fi Sensing software is installed on the AP, it turns the client's Wi-Fi-connected devices into motion sensors. This forms a motion network that localizes the motion to the closest device's location. The incidence of false detections is minimized by not relying on a singular data point, such as the presence of movement at one point of entry. Rather, the system is designed to track motion as it traverses through different devices within the home.

Beyond home security, Wi-Fi Sensing also provides insights into what is happening at home. For example, it can tell when your children come home from school or when the dog walker arrives at your home when you are on vacation. With Wi-Fi Sensing, there is a natural level of privacy since the information collected has less context than a camera. Unlike cameras, which capture a lot of context and can be intrusive, Wi-Fi Sensing only focuses on motion, which is less invasive and provides fewer details.

Wi-Fi Sensing also presents significant opportunities in the elder care market, which is growing as more seniors choose to age independently rather than move to care homes. Globally, there are over 650 million people aged 65 or older, with the value of the market opportunity widely reported at more than $80 billion. This technology can help families monitor their loved ones by providing valuable insights on:

- Activity levels
- Sleep patterns
- Number of times someone wakes up during the night
- Proof of life
- Pattern analysis.

Other applications for Wi-Fi Sensing, such as energy management and home automation, rely on detecting motion or lack thereof. Wi-Fi Sensing networks can be used to adjust heating or cooling systems or turn devices, like lights, on and off as necessary.

WI-FI SENSING DEPLOYMENTS

As the number of households equipped with Wi-Fi continues to climb, broadband customers increasingly expect more than just fast internet. They seek greater accessibility, cost savings and increased value. Communication was only the first use of Wi-Fi and now Wi-Fi Sensing offers internet service providers (ISPs) an innovative motion detection system that delivers convenience, privacy and peace of mind for a wide variety of applications. As of today, more than eight million homes have Wi-Fi Sensing and up to 30 million Wi-Fi clients can be motion sensors. With the success of this deployed base, the number of Wi-Fi Sensing-enabled devices is rapidly increasing. With Wi-Fi Sensing, consumers receive tangible benefits beyond their standard internet connection. Once integrated into an ISP's AP, Wi-Fi Sensing opens doors to future services and expansion into new verticals.

Cognitive Systems' Wi-Fi Sensing solution, WiFi Motion™, serves as a low-risk way for ISPs to enter new markets, such as home security, eldercare, energy management, network health and more, by leveraging their existing infrastructure. As a software-only solution, WiFi Motion does not require any additional hardware costs upon deployment and ISPs can continuously roll out new motion-based services at no additional expense. Consequently, WiFi Motion is highly scalable, making it an appealing long-term strategic roadmap priority for ISPs worldwide. As Wi-Fi technology improves, standards evolve and the Wi-Fi Sensing market expands, WiFi Motion will become a standard feature of homes of the future. While the world changes rapidly, one constant is that people desire innovative and useful technology. ■

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INVITED PAPER

The Impact of Topology and Parasitics on SMT Bandpass Filters

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DGS Associates, Boulder, Colo.

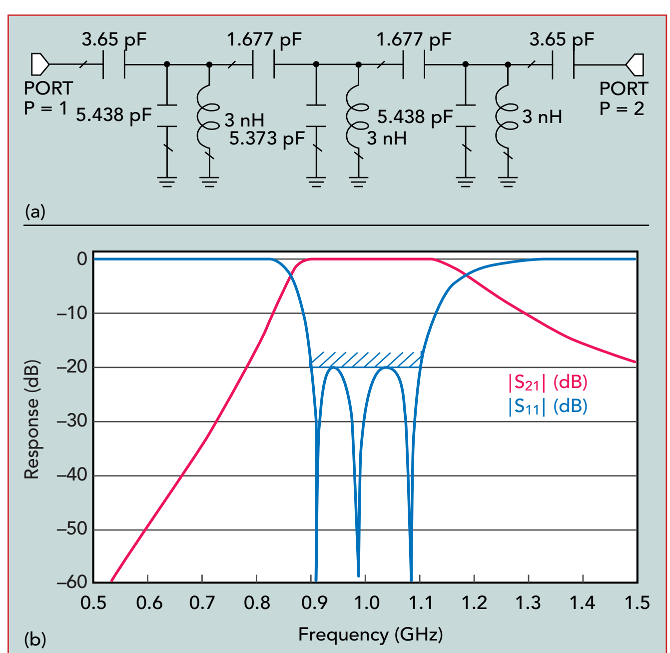
There are some catalog surface-mount technology (SMT) filters available for high volume applications, mostly in the industrial, scientific and medical, cellphone and Wi-Fi bands. Most of these filters use proprietary LTCC, SAW and BAW technologies. For other applications, there is a need for quick, custom filter designs that can be realized using standard SMT capacitors and inductors. However, there are some interesting choices to be made regarding filter topology that can have a significant impact on filter performance. The Modelithics CLR Library[1] and Cadence AWR Microwave Office software[2] are the right tools to explore these issues and achieve successful designs. The DGS Associates equal ripple filter optimizer, EQR_OPT_MWO, is also a key tool in our design flows.[3]

CONVENTIONAL TOP-COUPLED TOPOLOGY

To design a lumped element bandpass filter, it is tempting to start with the conventional top-coupled shunt resonator topology that is found in many textbooks. This topology is shown in ***Figure 1 (a)***. The top coupling in this approach can be inductive or capacitive. In higher-order filters, a mixture of the two couplings can be found that results in fairly symmetric stopbands. For physically symmetric filters, the DGS Associates optimizer will find an equal ripple response with or without loss. The simulated frequency response of this topology is shown in ***Figure 1 (b)***.

The schematic of Figure 1 (a) is translated into 0402 SMT components as shown in ***Figure 2***. The first conclusion is that the element values have shifted significantly compared to the ideal prototype. This analysis ignores microstrip junctions and vias for now but it includes pad stacks. ***Figure 3*** shows the simulated results of the filter topology from Figure 2 and there is a significant spurious response in the upper stopband that we assumed was caused by the inductors.

The Sim_mode feature in the Modelithics library allows users to do some simple experiments by temporarily making the inductors and capacitors ideal. Setting Sim_mode=1 for the inductors makes



▲ **Fig. 1** **(a) Top C-coupled bandpass filter schematic. (b) Top C-coupled bandpass filter frequency response.**

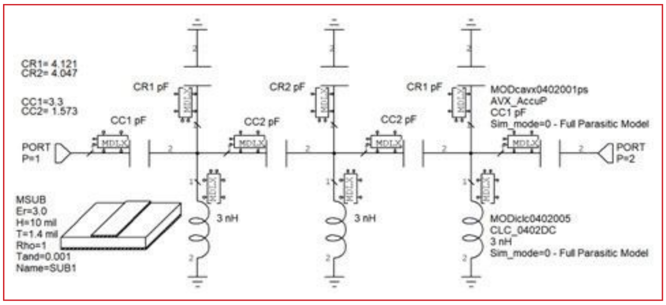


Fig. 2 Top C-coupled bandpass realized with SMT components.

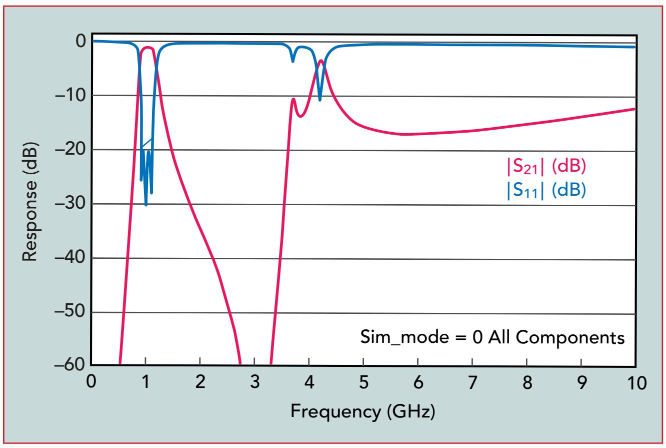


Fig. 3 Filter simulation including all parasitics with Sim_mode = 0.

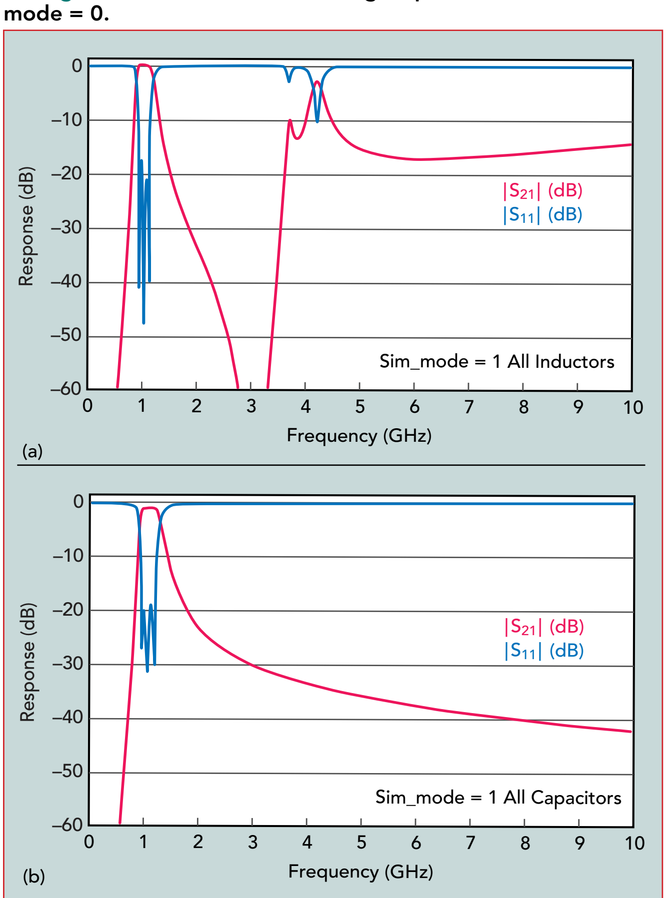


Fig. 4 (a) Frequency response with all inductors ideal. (b) Frequency response with all capacitors ideal.

them ideal and the spurious response hardly changes, as shown in ***Figure 4 (a)***, making only the capacitors ideal results in the close-in spurs disappearing as shown in ***Figure 4 (b)***. Further testing indicates it is primarily the shunt capacitors that are the problem.

It appears that this is a packaging issue with multilayer SMT capacitors that is not widely understood. It is largely independent of capacitor value, but does improve some as package size shrinks. Even the Accu-P capacitors[4] used here, which have a radically different internal structure, have spurious response issues.

MINIMUM-C TOPOLOGY

The so-called Minimum-C topology converts two of the parallel shunt resonators to series resonators and puts them at the input and output of the filter as shown in ***Figure 5***. The spurious response is improved compared to the top C-coupled filter as shown in ***Figure 6***. Because this network lacks the symmetry of the top-coupled topology, the optimization strategy is slightly different. In this case, the Expert Mode in the Modelithics models is used to set equivalent series resistance (ESR) equal to zero. Running the optimizer results in an equal ripple response in the passband. When the converged results are satisfactory, the user can change the ESR setting back to the default.

CAUER-CHEBYSHEV ELLIPTIC FUNCTION TOPOLOGY

Adding two more elements results in the N = 3 Cauer-Chebyshev elliptic function topology which is quite efficient for moderate filtering requirements in a

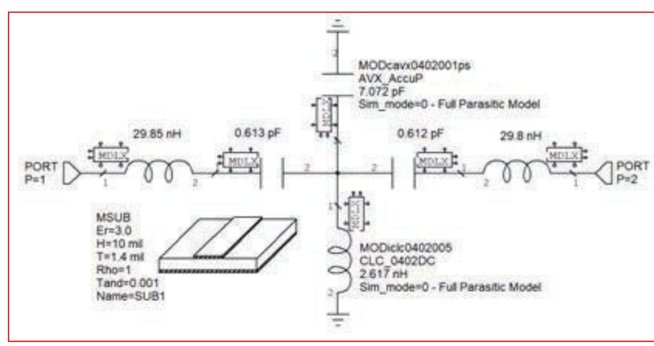


Fig. 5 N = 3 Minimum-C topology bandpass filter.

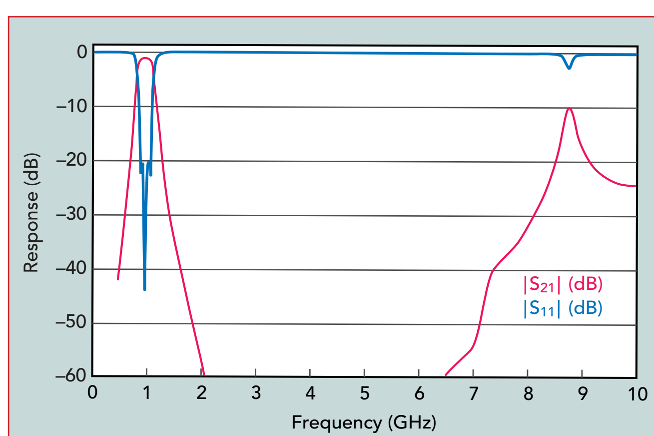


Fig. 6 Frequency response with SMT components.

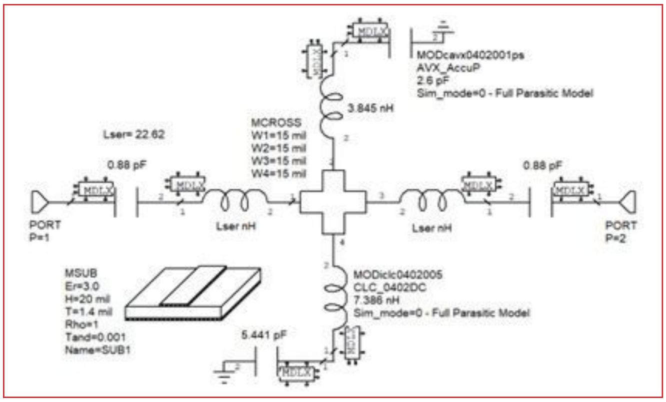


Fig. 7 N = 3 Cauer-Chebyshev elliptic function filter with all inductors at the common junction.

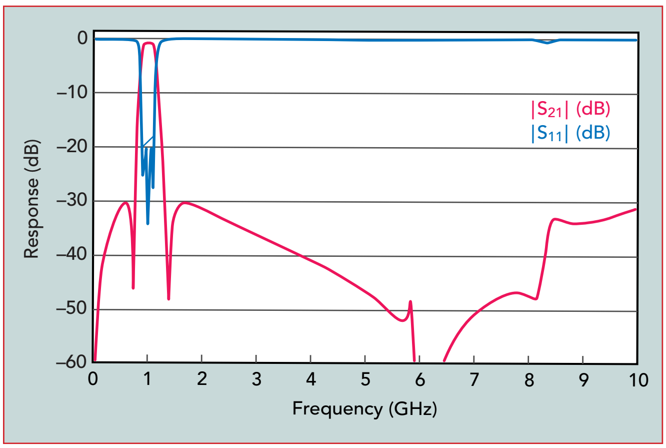


Fig. 8 Frequency response of the Figure 7 topology.

very small footprint. This topology is shown in ***Figure 7***. When compared to the Minimum-C topology, the Cauer-Chebyshev elliptic topology has lower insertion loss and steeper rejection in the stopbands, as shown in ***Figure 8***. Considering insertion loss and practical element values, a bandwidth of 15 to 20 percent and minimum rejection of -30 dB in the stopbands seems to be a sweet spot for this topology. These filters have been built with center frequencies from 900 MHz to 6 GHz. This topology can be synthesized using Cadence AWR iFilter as described in Appendix A. Lookup tables can be found in Reference 5.

When optimizing this topology, either the series capacitors or the series inductors at the input and output are held constant, which sets the filter return loss level. In the shunt arms, one element is held constant in each to set the transmission zero locations. After the optimization converges, each of these fixed elements can be modified to fine-tune the return loss and the zero locations. Because the optimization is so fast and repeatable, this adjustment process goes quite quickly.

Having settled on the Cauer-Chebyshev topology, a question arises as to the importance of the order of the elements in the series resonators. If the elements are ideal L's and C's, it clearly should not matter. However, considering the parasitics of all the SMT components and the particular problem with SMT capacitors, it is quite possible that the order of elements may have a significant effect.

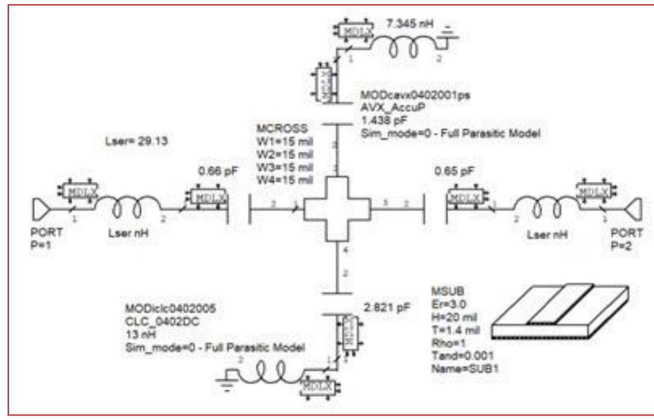


Fig. 9 N = 3 Cauer-Chebyshev elliptic function filter with all capacitors at the common junction.

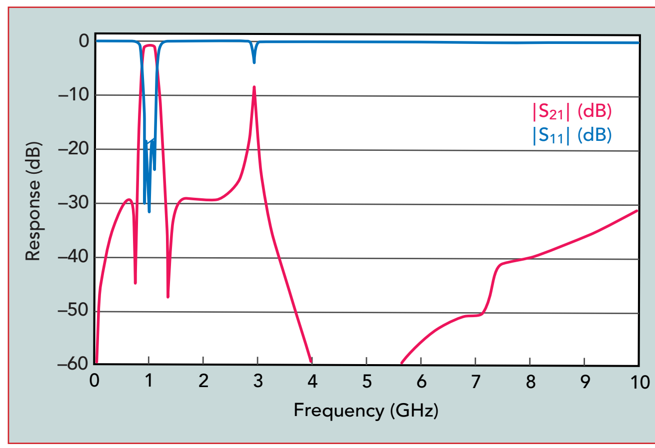


Fig. 10 Frequency response of the Figure 9 topology.

TABLE 1

FINAL ELEMENT VALUES

	Lumped Proto	Inductors at Center	Capacitors at Center
Cser (pF)	0.814	0.88	0.66
Lser (nH)	31.56	22.62	29.13
Cshu1 (pF)	2.488	2.6	1.438
Lshu1 (nH)	5.194	3.845	7.345
Cshu2 (pF)	4.216	5.441	2.821
Lshu2 (nH)	11.27	7.386	13.0

Experiments were run to determine the effects. In one experiment, the capacitors were placed at the common junction in the center as shown in ***Figure 9***. The result, shown in ***Figure 10***, is a spurious response much closer to the passband edge. This was the result of one experiment and several other layout options can be investigated.

It is also interesting to look at the final element values for these two options and compare them to the ideal lumped prototype. This has been done in ***Table 1***. In the preferred case with the inductors at the common junction, the inductors are smaller and the capacitors are larger, which is generally easier to realize. With the capacitors at the common junction, it is just the opposite, the inductors are larger and the capacitors are

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Low VSWR / Low Insertion Loss / High Isolation

P / N	Structure	Freq. Range (GHz)	VSWR Max. (:1)	Insertion Loss* Max. (dB)	Amplitude Unbal. Max. (dB)	Amplitude Flatness Max. (dB)	Phase Accuracy Max. (Deg.)	Isolation Min. (dB)
SA-07-4B006050	4x4	0.617~0.821	1.4	8.2	±1.1	±0.8	±10	16
		0.832~0.96	1.4	8.2	±1.1	±0.7	± 9	16
		1.427~1.71	1.5	8.3	±0.9	±0.7	± 9	15
		1.71~2.2	1.5	8.5	±0.9	±0.8	±10	14
		2.496~2.69	1.5	8.7	±0.9	±0.7	± 9	13
		3.3~4.2	1.6	8.9	±1.0	±0.7	±12	13
		4.4~5	1.6	9.2	±1.0	±0.8	±12	13
SA-07-4B020080	4x4	2.4~2.5	1.4	7.3	±0.5	±0.3	± 4	14
		5.18~5.83	1.5	7.7	±0.6	±0.4	± 5	13
		5.9~7.25	1.5	7.8	±0.7	±0.5	± 6	13
SA-07-8B020080	8x8	2.4~2.5	1.5	11.2	±0.6	±0.4	± 8	13
		5.18~5.83	1.5	11.6	±0.8	±0.5	±10	12
		5.9~7.25	1.55	11.8	±0.9	±0.7	±12	12
SA-07-4B240430	4x4	24~43	2.0	12.4	±1.2	±2.0	±15	10

*Theoretical 6dB Included

Note: The connected components are available from MIcable which include the phase matched assemblies & low loss high isolation phase matched switches.

Typical Test Curve**

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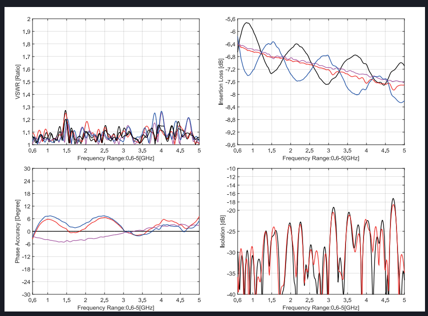

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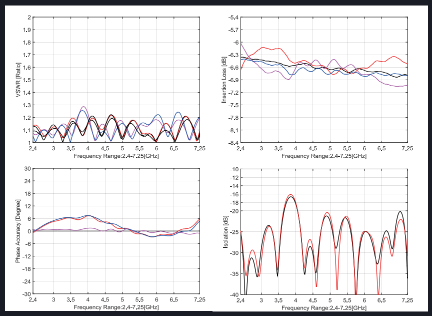

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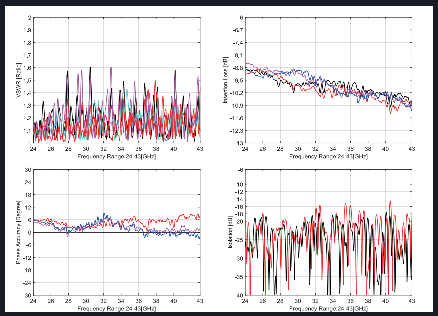

**Corresponding Channels: A1B1、A1B2、A1B3、A1B4

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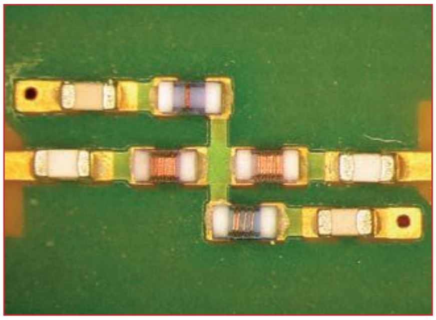


Fig. 11 Layout of the filter for Channel 1 of the preselector switched filter bank.

smaller when compared to the ideal prototype.

APPLICATIONS

The original motivation for this work was a preselector switched filter bank for an advanced handheld transceiver. The filter bank covered 0.9 to 6 GHz with eight equal percentage bandwidth filters. To save space, the shunt arms were folded next to the input/output resonators, which adds a little uncertainty to the measured versus modeled results. Some EM modeling of the right-angle connection to the shunt inductors was implemented. Future SMT 3D FEM models may be able to account for spurious coupling between components.

The filter layout for the lowest frequency channel of the switched filter bank is shown in ***Figure 11***. The analysis to this point has allowed the SMT element values to be continuous. In the final optimization, these values have been set to the closest standard values and the final optimization has been performed on the width and length of the microstrip lines between components. Because of the realities of the design process, a certain amount of skepticism is warranted for any software that claims it can automatically pick standard values and find an equal ripple response in the passband.

Channels 1 and 2 of the preselector switched filter bank had acceptable turn-on performance without tuning. The transmission and reflection characteristics for Channel 1 are shown in ***Figure 12***. The response shows that the stopband spurious prediction is quite good. Starting with Channel 3, small corrections were made to element values on the bench. Channels 7 and 8 necessitated a design spin that moved the inductors farther apart and re-

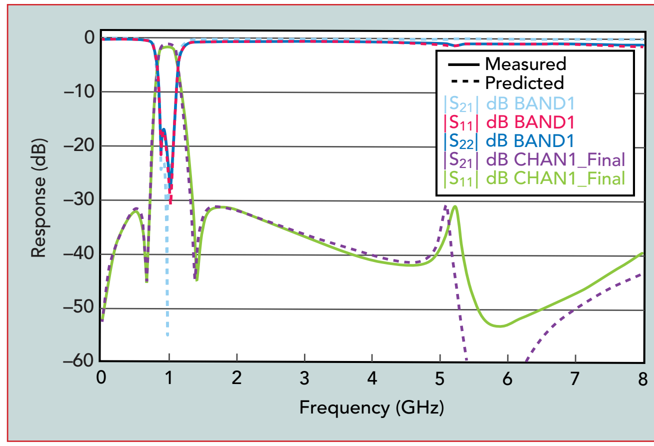


Fig. 12 Predicted versus measured response of the Channel 1 filters.

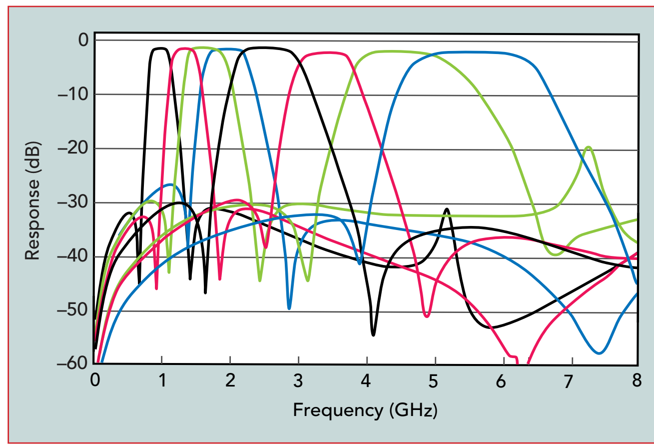


Fig. 13 Performance of the switched filter bank after tuning and one layout spin.

placed some of the small-value SMT inductors with printed transmission lines. The performance for the complete set of filters in the eight-channel preselector switched filter bank after tuning and one layout spin is shown in ***Figure 13***.

Another interesting example is a triplexer designed for Abside Networks[6] that covers small segments of the L-, S- and C-Bands. The application is a custom, low-power LTE base station. This design also used the Cauer-Chebyshev filter as the basic building block. The equal ripple optimizer can handle this case just as easily as a single filter and all three channels can be optimized simultaneously during development. The layout for the triplexer is shown in ***Figure 14***. In this design, the shunt inductors for the S-Band and C-Band filters are realized with printed lines and the via inductance.

The simulated performance for the SMT triplexer design is shown in ***Figure 15*** and the measured performance for the circuit is shown in ***Figure 16***. As with the previous example, a small amount of bench tuning was needed to achieve these results. However, a layout spin was not required.

PCB ETCHED DISTRIBUTED FILTERS

In a multilayer printed circuit board with through vias, the top layer metal is typically about 0.002 in. thick and the tolerance on via placement is no better than +/- 0.003 in. These conditions make it difficult to realize any kind of distributed filter with high accuracy and the filter will also be quite large at lower frequencies. ***Figure 17 (a)*** shows the layout for a 3.5 GHz interdigital filter and ***Figure 17 (b)*** shows the layout for a 5.8 GHz interdigital filter. Both of these microstrip interdigital filters are fabricated on 0.012 in. thick Rogers 4003 material. The relative size of the filters can be gauged based on the SMA connector footprint. Included in the design and fabrication are photoetched metal covers over each filter.

The microstrip interdigital filter design is very sensitive to the absolute placement of the resonator

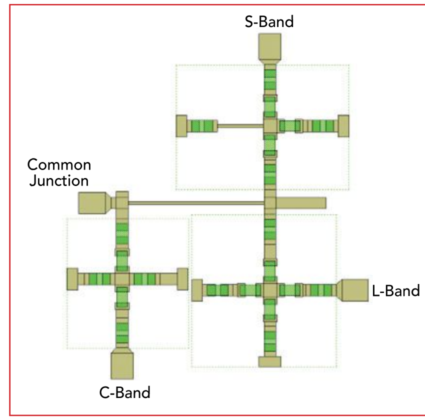


Fig. 14 **SMT triplexer layout.**

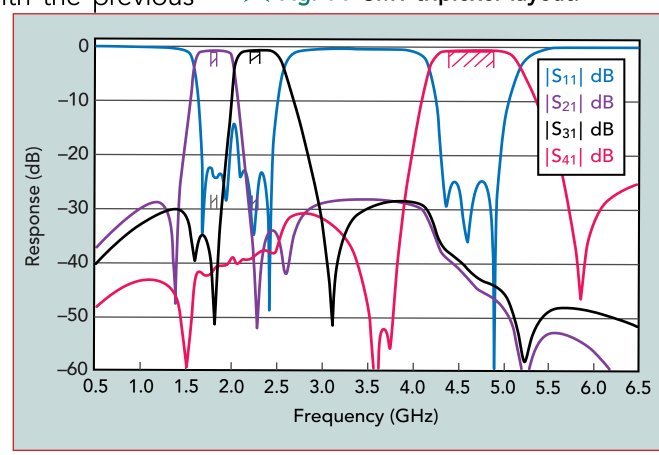


Fig. 15 **SMT triplexer simulated results.**

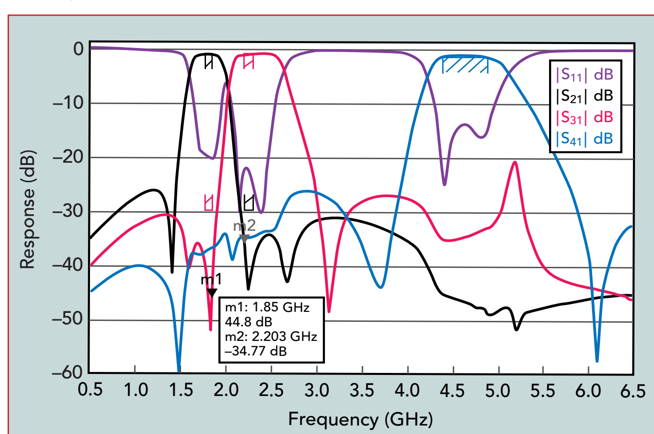


Fig. 16 **SMT triplexer measured results after bench tuning.**

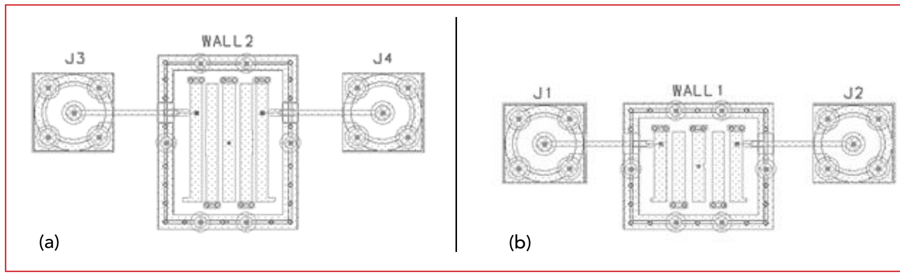


Fig. 17 (a) 3.5 GHz interdigital filter. (b) 5.8 GHz interdigital filter.

grounding vias and the alignment of the metal pattern to the vias. It is easy to imagine a somewhat random distribution of resonant frequencies in the etched filter. Measured data for the 3.5 GHz filter can be found in ***Figure 18 (a)***, along with the simulation results, while the same data for the 5.8 GHz filter can be found in ***Figure 18 (b)***. Any post-fabrication tuning of these filters is very difficult.

CONCLUSION

For RF and microwave frequencies below 6 GHz, this lumped element approach to filter realization has significant advantages. For moderate to broad bandwidths, these techniques can produce useful results with an SMT approach, especially if the designer is aware of the impact of parasitics and filter topology have on design choices. At lower frequencies, the SMT filter is smaller than its distributed equivalent, has broad stopbands and is easier to tune, if

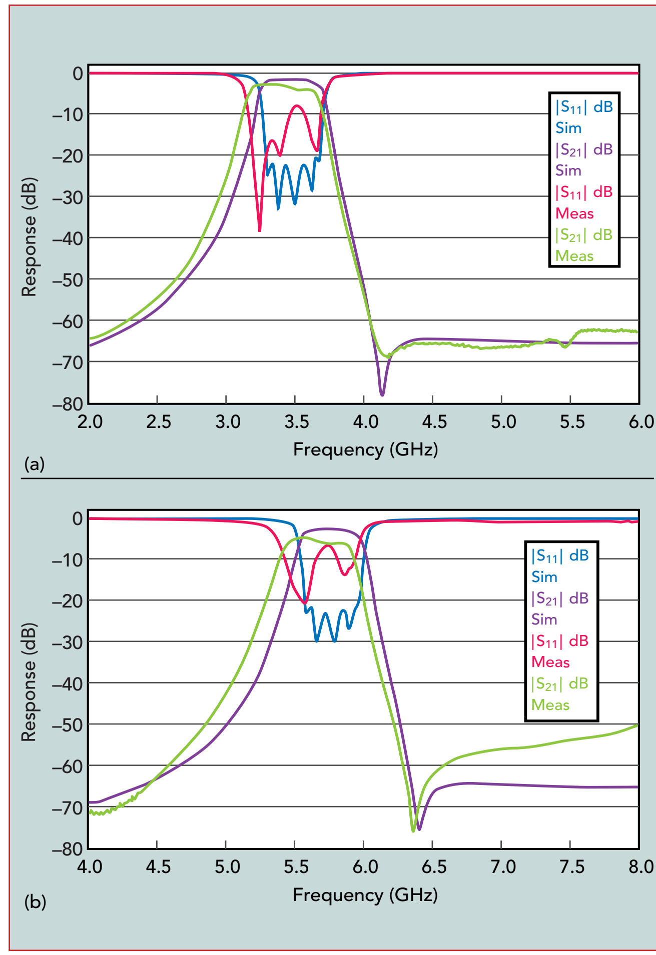


Fig. 18 (a) 3.5 GHz measured and simulated results (simulation is in red). (b) 5.8 GHz measured and simulated results (simulation is in red).

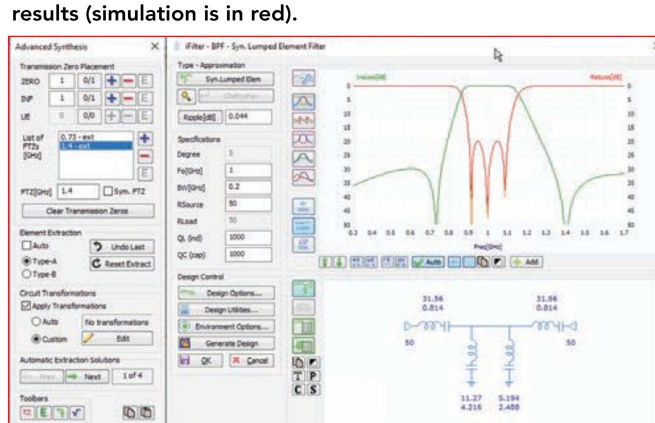
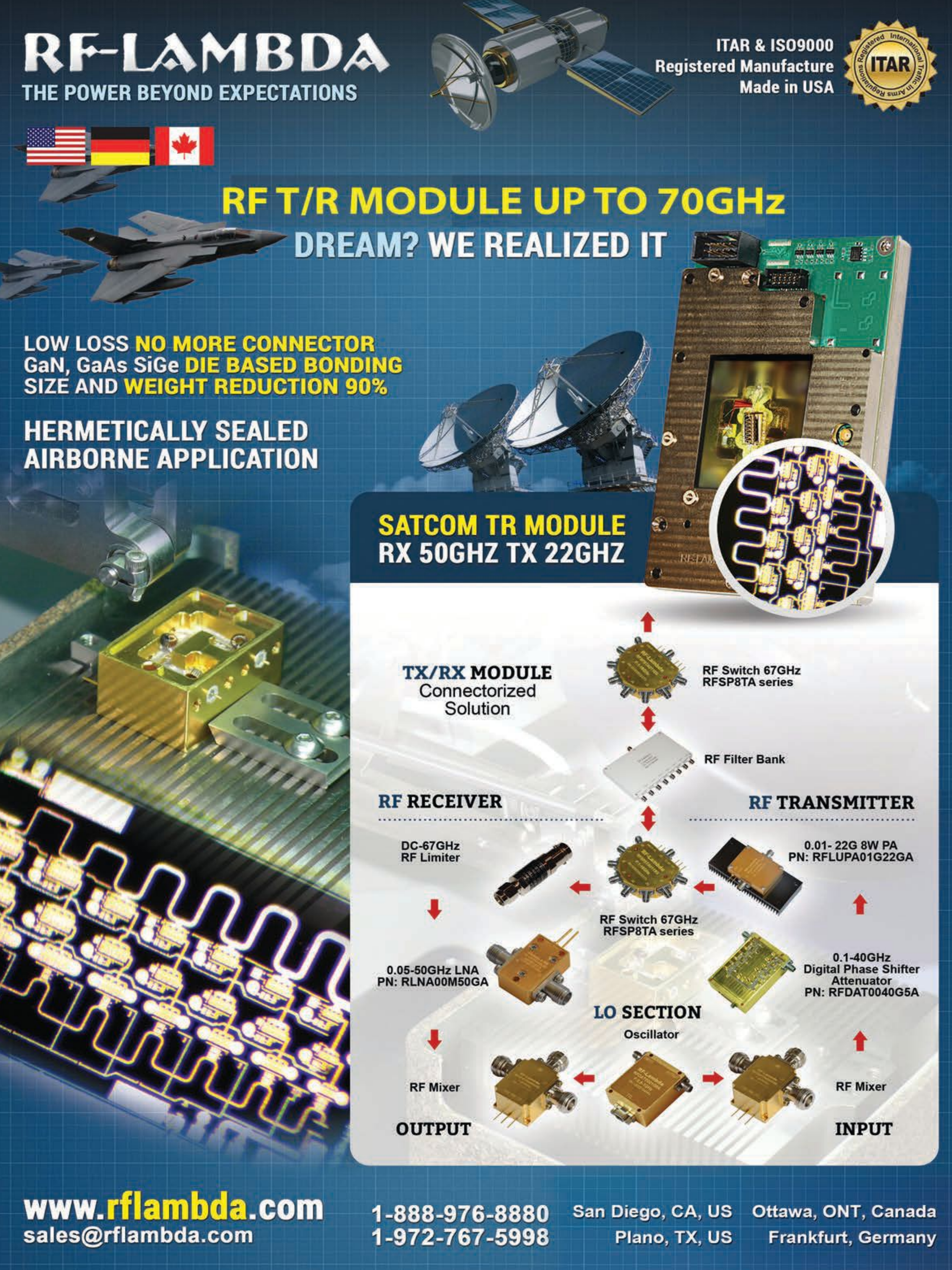


Fig. 19 Cadence AWR iFilter display.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APPENDIX A

Starting with V18, the Cauer-Chebyshev elliptic filter can be synthesized using Cadence AWR iFilter, with a representative display shown in ***Figure 19***.

Enter the filter specifications in the Main Dialog: Fo = 1 GHz, BW = 0.2 GHz, Ripple = 0.044 dB.

In the Advanced Synthesis Dialog, Transmission Placement Group:

- Click Clear Transmission Zeros
- Click + on the first row to set ZERO=1
- Click + on the second row to set INF=1
- Click + next to the FTZ list and add a finite TZ (FTZ) at 0.73 GHz
- Click + next to the FTZ list and add a finite TZ (FTZ) at 1.4 GHz

In the Element Extraction group:

- Uncheck Auto
- Check Type-A

In the Circuit Transformations group:

- Uncheck Apply Transformations
- Now do the element extraction:
  - While 1.4 GHz is selected in the FTZ list, Click E next to the FTZ list
  - While 0.73 GHz is selected in the FTZ list, Click E next to the FTZ list
  - Click E next on the ZERO row
  - Click E next on the INF row

*Observe the schematic in the Main Dialog.

INDser/SLCsht/CAPser/SLCsht is a specific quad topology that we will convert.

In the Circuit Transformations group:

- Check Apply Transformations
- Check Custom
- Click Edit

In the Circuit Transformations dialog:

- The top list is the existing macro
- Click Clear List if there is anything in that list
- Select 'Replace 4-LC by 4-LC (Inv Geffe)' from the available transformation list (fourth from the end)
- Click Add
- Select 'Simplify Circuit' from the list at the bottom left (fifth from the top)
- Click Add
- Click Close to close the dialog

*Now we have a macro that will replace all quad sections with an Inverse Geffe section (SLCser/SLCsht/SLCsht/SLCser). Geffe/InvGeffe are specific topologies arrived at by applying successive Norton transformations.

By checking/unchecking Apply Transformations, the effect of the macro can be seen.

Note the "Replace 4-LC by 4-LC (Inv Geffe)" transformation is new in V18 of Cadence AWR iFilter.

Note if an FTZ is selected and tuned by the mouse wheel, the whole extraction-transformation sequence will automatically update after every change.

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Thursday 21st September 2023	09:00 - 16:30

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- European Microwave Conference (EuMC) 19th - 21st September 2023
- European Radar Conference (EuRAD) 20th - 22nd September 2023
- Plus Workshops and Short Courses (From 17th September 2023)
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- Friday 22nd September 2023 (08:00 - 10.00)

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CONFERENCES REGISTRATION	ADVANCE DISCOUNTED RATE (FROM NOW UP TO & INCLUDING 25th August 2023)				STANDARD RATE (FROM 26th August 2023 & ONSITE)			
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EuMC	€ 560	€ 160	€ 790	€ 220	€ 790	€ 220	€ 1,110	€ 310
EuMIC	€ 430	€ 140	€ 600	€ 200	€ 600	€ 200	€ 850	€ 280
EuRAD	€ 380	€ 130	€ 540	€ 180	€ 540	€ 180	€ 750	€ 260
2 Conferences	Standard	Student/Sr.	Standard	Student/Sr.	Standard	Student/Sr.	Standard	Student/Sr.
EuMC + EuMIC	€ 800	€ 300	€ 1,120	€ 420	€ 1,120	€ 420	€ 1,560	€ 590
EuMC + EuRAD	€ 760	€ 290	€ 1,060	€ 400	€ 1,060	€ 400	€ 1,490	€ 570
EuMIC + EuRAD	€ 650	€ 280	€ 910	€ 390	€ 910	€ 390	€ 1,280	€ 540
3 Conferences	Standard	Student/Sr.	Standard	Student/Sr.	Standard	Student/Sr.	Standard	Student/Sr.
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	Date	Delegates*	All Others**	Delegates*	All Others**
Automotive Forum	18th September 2023	€ 300	€ 420	€ 380	€ 490
Defence, Security & Space Forum	20th September 2023	€ 40	€ 70	€ 40	€ 70
5G to 6G Forum	21st September 2023	€ 70	€ 100	€ 90	€ 110
13th Tom Brazil Doctoral School of Microwaves: From Microwaves to Machine Learning	17th September 2023	€ 40	€ 40	€ 40	€ 40
7th European Microwave Student School: Microwave Measurement Techniques	17th/18th September 2023	€ 40	€ 40	€ 40	€ 40

* those registered for EuMC, EuMIC or EuRAD ** those not registered for a conference

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Despite the organiser's best efforts to ensure the availability of all listed workshops and short courses, the list below may be subject to change. Also workshop numbering is subject to change. Please refer to www.eumweek.com at the time of registration for final workshop availability and numbering.

Sunday 17th September 2023			
SC1	EuMIC	Full Day	Fundamentals of Microwave PA Design
SC2	EuMC/EuMIC/ EuRAD	Half Day	Wideband Microwave measurements of Multi-Port Devices on VNA-type Measurement Systems
WS1	EuMC/EuMIC	Full Day	Broadband and microwave signal processing using electronic-photonic integration
WS2	EuMIC	Full Day	Terahertz Device, Circuit and System fundamentals and applications
WS3	EuMC	Half Day	Highly-Integrated mm-Wave Circuits and Systems for Emerging Radar Applications
WS4	EuMC/EuRAD	Half Day	Joint Communications and Sensing
WS5	EuMIC/EuMC	Half Day	Heterogeneous integration for next generation of communication and sensing
WS6	EuMIC/EuRAD	Half Day	mm-Wave Integrated Radar Circuit Design and SoC Integration in Silicon Technologies
WS7	EuMC/EuMIC	Half Day	Design, Linearization, and Optimization Techniques for Multiple-Input Power Amplifiers
WS8	EuMC	Half Day	Polarization surfaces for next-generation communications systems

Monday 18th September 2023			
WM1	EuMC	Full Day	Millimeter-wave on-wafer measurement and material measurement for future communications and automotive radar sensors
WM2	EuMC	Full Day	Measurement methods for passive intermodulation and environmental testing of electronic circuits
WM3	EuMC	Half Day	mMIMO Active Antenna System Calibration for 5G/6G
WM4	EuMC	Half Day	Technology for RF/MW and pulsed power bioelectromagnetics
WM5	EuMC	Half Day	SiGe BiCMOS technologies as enabler for D-band applications and beyond
WM6	EuMC	Half Day	REAL base station and related device techniques for 5G and beyond 5G mm-wave systems
WM7	EuMC	Half Day	Multi-tone power amplifier characterization as enabler of higher efficiencies and better linearity under wideband modulation
WM8	EuMC	Half Day	Additive Manufacturing
WM9	EuMIC	Full Day	Integrated Antenna Systems: Technologies and Innovations for high-density antennas and phased arrays

Friday 22nd September			
WF1	EURAD	Full Day	Virtual Validation of ADAS with Automotive Sensors
WF2	EUMIC	Full Day	Unlocking the Potential of Radar by Compressed-Sensing, Machine-Learning, and High-Resolution Data Processing
WF3	EURAD	Half Day	Characterization of sub-THz Channels for Communication and Sensing
WF4	EURAD	Half Day	Radar Target Simulation
WF5	EURAD	Half Day	Applications for advanced passive radar systems
WF6	EURAD	Half Day	Industrial Radar

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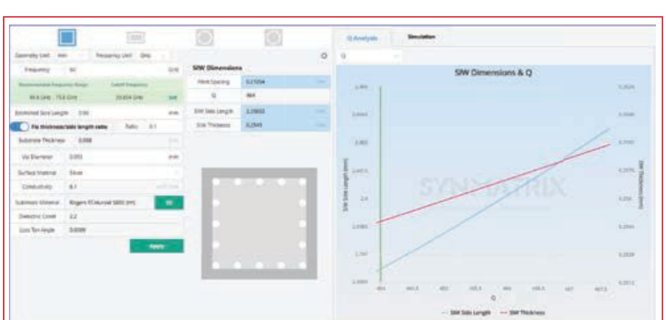
Half Day	€ 110	€ 90	€ 150	€ 110	€ 150	€ 110	€ 200	€ 150
Full Day	€ 160	€ 120	€ 220	€ 160	€ 220	€ 160	€ 290	€ 220

3D Geometry Workflows for Substrate-Integrated Waveguide Filters

SynMatrix Technologies Inc.
Toronto, Canada

SynMatrix recently upgraded capabilities in existing functions to help reduce the barriers to engineering new RF filter designs. Building on the success of last year's release, SynMatrix is announcing automatic 3D geometry workflows for substrate-integrated waveguide (SIW) filters. The current Monte Carlo analysis function has also been upgraded, expanding the current coupling matrix sensitivity analysis to yield analysis prediction for a 3D model simulation.

SIWs have recently gained popularity in RF filter design engineering. A combination of compact size, manufacturability and relatively low loss, coupled with good electromagnetic (EM) properties and performance make these filters excellent candidates for aerospace and automotive communication systems. The SynMatrix SIW design package is an exciting new solution now available for users. Like the capabilities and workflows for cavity and waveguide filters released last year, users can now build and optimize substrate-integrated waveguide filters starting from a single cavity. From there, users can select several coupling schemes that are ready for practical design, select several options for input and output schemes and complete a full 3D model geometry in Ansys HFSS using automatic workflows.



▲ Fig. 1 **SynMatrix SIW design package example.**

The SynMatrix SIW package offers a convenient guided workflow for users to follow. It also provides a library selection at each step to help users customize and realize their designs to meet specific requirements. Users can select several different SIW cavity shapes and then synthesize corresponding SIW side lengths and thicknesses. This allows users to see the impact of these selections on unloaded Q. Based on these dimensions, users can select pre-defined materials and customize them as needed. An example of this selection process and the result is shown in ***Figure 1***.

Users are also given convenient interfaces to choose their tuning vias. Based on pre-

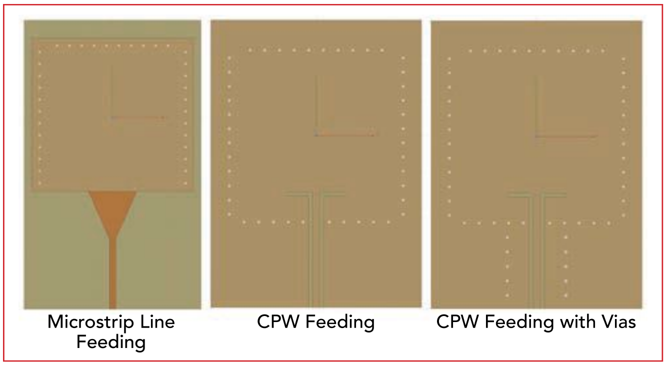


Fig. 2 **Examples of different feeds in the SynMatrix SIW design package.**

defined and pre-integrated design rules, users can consider manufacturability in the early stages of the design process. SynMatrix's SIW package also supports several different coupling schemes for a practical design that can be customized and analyzed using a parametric study. Users can select from two types of feed solutions for input and output structures and consider via spacing designs to avoid higher order modes and emissions. ***Figure 2*** shows an example of different feed schemes and via spacing.

SynMatrix's 3D workflow makes it easy for users to realize a full 3D design, like the workflow released last year with cavities; users can customize their topologies. These fully generated geometries easily transition into EM simulations and an integrated optimization workflow in Ansys HFSS. ***Figure 3*** shows representative results from this process.

The Monte Carlo analysis function currently offers users the ability to analyze the sensitivity of the coupling matrix. The newly released Yield Analysis function expands the scope of the Monte Carlo analysis. This enables users to apply sensitivity analysis against a full 3D simulation. ***Figure 4*** shows an example of Yield Analysis in SynMatrix.

Users can apply the analysis using absolute dimension variation or percentage change variation. By editing and analyzing the physical variables, users can analyze the sensitivity of their designed model, see how RF performance changes and make accurate yield predictions for production volumes. Application scenarios include mmWave components, non-tunable filter structures, planar/coplanar structures and 3D printing structures.

SynMatrix continues to expand the portfolio of structures supported by automatic 3D geometry generation in Ansys HFSS. With the complexity of requirements and variation of applications for filter design engineering, designers will need a vast array of different structures, options and better tools to meet their needs. Manufacturability is also a major factor when considering design options. Design tools must consider the practicality of design choices before fabricating prototypes and considering volume production. SynMatrix users can expect more product upgrades as the company expands its portfolio of capabilities to support additional filter structures and additional workflow functions to help designers get to market faster, more accurately and with better RF performance outcomes.

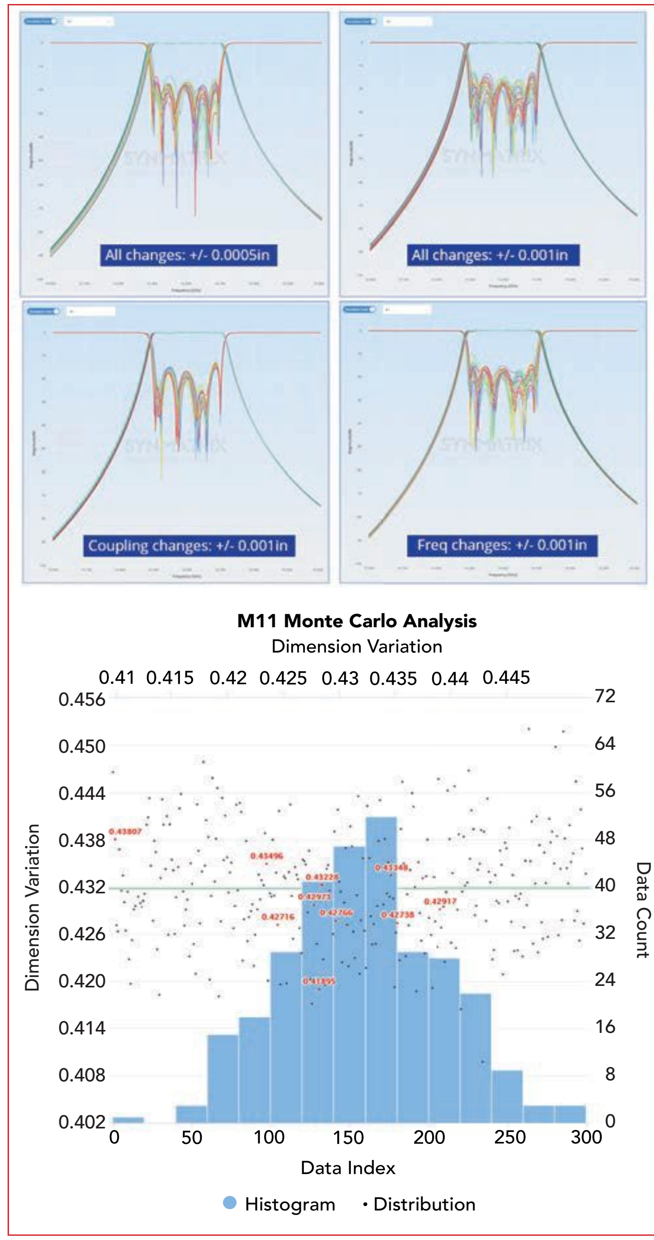


Fig. 4 **SynMatrix Yield Analysis display.**

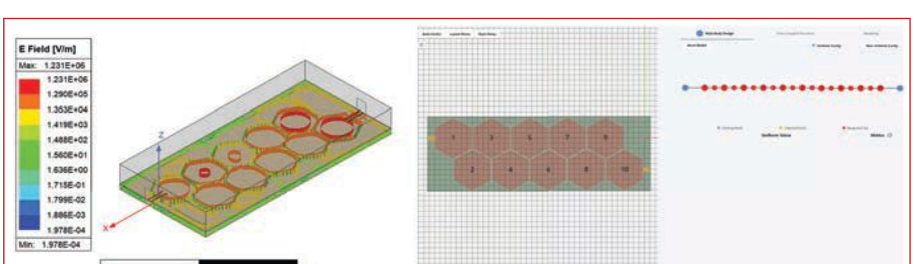


Fig. 3 **EM results for a customized 3D topology.**

SynMatrix Technologies Inc.
Toronto, Canada
www.synmatrixtech.com

VITA 67 Multi-Port Connector Blocks Enhance Reliability

Fairview Microwave, an Infinite Electronics brand and a leading provider of on-demand RF, microwave and mmWave components, has announced the release of their VITA 67 multi-port connector blocks. VITA 67 is a standard for blind mate coax connectors that defines how RF connections are made between a backplane and plug-in modules. The VITA 67 multi-port connector blocks are designed to provide high density RF connections in challenging environments while minimizing space requirements, weight and cost.

The VITA 67 multi-port connector blocks are engineered for side-by-side implementation with VITA 46 hardware and they are compatible with 0.086-in. and smaller diameter coaxial cables. These features make these multi-port connector blocks ideal for use in aerospace and defense applications. The unique SV connector retention mechanism of the VITA 67 multi-port connector blocks increases the ease of assembly and disassembly of the daughter card module versus competitive designs. In addition, these connectors can withstand numerous flexures directly behind the connectors without weakening or deteriorating. The connector blocks also utilize existing and proven SMPM interfaces, providing substantial advantages in compatibility, reliability and cost-effectiveness.

Constructed with an IP67 rating and superior shock and vibration resistance, these VITA 67 multi-port connector blocks ensure consistent operation in even the harshest environments. The VITA 67 multi-port connector blocks do not require any special adapters, streamlining the system and enhancing its performance and reliability. Fairview's new VITA 67 multi-port connector blocks are in-stock and available for same-day shipping with no minimum order quantities.

VENDORVIEW

Fairview Microwave
Lewisville, Texas
www.fairviewmicrowave.com/t-vita-67-multi-port-connector-blocks.aspx

Adjustable Control Components Address Multiple Applications

Pasternack, an Infinite Electronics brand and a leading provider of RF, microwave and mmWave products, has expanded their family of adjustable phase shifters and attenuators. Phase shifters change the phase angle of an RF signal with constant amplitude constant. Attenuators change the amplitude of an RF signal while keeping the phase constant. The new additions to the Pasternack portfolio target multiple applications, including test instrumentation along with cellular, wireless and satellite communications.

Pasternack's new additions to the continuously variable attenuators feature higher maximum power with ratings of 5 W and 10 W. They are available with operating frequency ranges up to 18 GHz and attenuation levels up to 50 dB. Members of the attenuator family come with waveguide or SMA RF connections.

The new variable phase shifters operate from DC to 2, 4 and 8 GHz. The devices handle 100 W of continuous power. These new variable phase shifters are available with adjustable phases rated at 60, 90 and 180 degrees per GHz.

The new additions to the step attenuator family are engineered for superior RF performance with frequency ranges of DC to 6, 8 and 18 GHz. They feature maximum attenuation levels of 10, 60, 70 and 99 dB. Minimum attenuation steps are 1 dB or 10 dB depending on the model. The attenuation states are controlled by push buttons or a dial on the unit.

A leader in RF products since 1972, Pasternack is an ISO 9001:2015-certified manufacturer and supplier. They offer the industry's largest selection of active and passive RF, microwave and mmWave products. Like other products in the portfolio, the new additions to Pasternack's family of variable attenuators and phase shifters are in stock and available for same-day shipping.

VENDORVIEW

Pasternack
Irvine, Calif.
www.pasternack.com/t-continuous-attenuators-step-attenuators-phase-shifters.aspx
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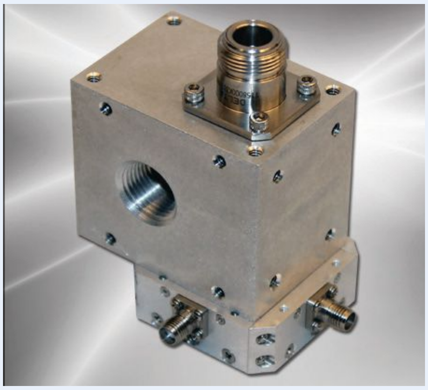

2-18 GHz Coaxial Combiner/Divider is Rated to 200 W CW

Werlatone®, a leading supplier of high-power, broadband passive RF components that include RF directional couplers, combiners and dividers, announces the Model D12628-12. This 4-way RF combiner/divider covers the full 2 to 18 GHz frequency band and it is rated at 200 W CW. The Model D12628-12 supports military and commercial applications and operates with less than 1.1 dB of insertion loss over the entire frequency range. The D12628-12 operates with better than 1.40:1 VSWR from 2 to 16 GHz and better than 1.60:1 from 16 to 18 GHz. The Model D12628-12 RF is supplied with an N-type connector at the sum port and SMA at the input ports while measuring just 1.7 x 1.7 x 2.5 in.

Werlatone also offers an accompanying, low loss, high directivity 2 to 18 GHz, 250 W CW 40 dB dual directional coupler which enables our customers to accurately monitor power levels across the entire band.

Werlatone directional couplers, combiners and dividers are designed to operate into high load VSWR conditions, for extended periods and our Mismatch Tolerant® RF directional couplers and combiners/dividers enable continuous operation into open or short conditions. When specified, high-power RF combiners tolerate input transmitter failure conditions to ensure a failsafe mode that enables the remaining transmitter(s) to operate until the system can be shut down properly. Werlatone designs also ensure adequate heat dissipation for non-coherent combining applications where two or more input signals may operate at different frequencies, power and/or phase signals on the ports.

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RF Connector Considerations for Millimeter Wave Designs

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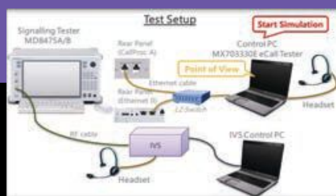
MAKING WAVES

Video Demo - NG112 LTE eCall

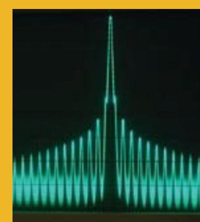
Watch this video for a brief demonstration of LTE-based eCall with the Anritsu MD8475B and the MX703330E eCall tester software.

Anritsu Company

bit.ly/3qfDusF



What is the Difference Between a VNA and a Spectrum Analyzer



There is sometimes confusion regarding the differences between a VNA and a spectrum analyzer. This app note from CMT highlights the distinct differences between the two measurement devices including a comparison of their block diagrams.

Copper Mountain Technologies

buff.ly/3IShue5

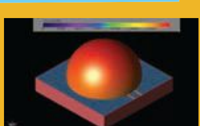
Rack-Mount 1 kW Amplifier with Built-In Power Source for 2.4 to 2.5 GHz

Mini-Circuits' RFS-2G42G51K0X+ is a solid-state power amplifier capable of delivering up to 1 kW CW output power for ISM RF/microwave energy applications in the 2.4 to 2.5 GHz band. This model incorporates a signal source, power supply, cooling and all control circuitry in a 19 in. 2U rack-mount chassis.

Mini Circuits

bit.ly/3OWcvN4

XFdtd Simulation of a mmWave On-Chip Cylindrical Dielectric Resonator Antenna for WPAN



This example demonstrates how XFdtd simulates a 60 GHz cylindrical dielectric resonator antenna that is constructed on a silicon base to emulate on-chip designs.

Remcom

bit.ly/43CoDqY

#ThinkSix - Phase Noise Characterization in the D-Band

This video introduces the topic of phase noise, demonstrates a test setup for investigating phase noise for the latest communication systems, and, with D-Band (110 to 170 GHz) frequencies, a hot tip for 6G research shows extensions to the setup to investigate the higher frequencies.

Rohde & Schwarz

www.youtube.com/watch?v=PmWKyomfV4M

New Location Alert

Skyworks is excited to welcome teammates to their new site in Bangalore. This IT center of excellence will be critical as they build a digital first resilient supply chain while leveraging data modernization and the cloud across business operations.

Skyworks

www.skyworksinc.com

NEW PRODUCTS

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FEATURING VENDORVIEW STOREFRONTS

DEVICES/ COMPONENTS/MODULES

Programmable Direct Reading Attenuator

VENDORVIEW

Model STA-60-06-S1 is a dual function, direct reading and programmable rotary vane attenuator for waveguide systems operating from 110 to 170 GHz. With an exceptionally flat frequency response, the attenuator is accurate to within 0.15 dB or 3.5 percent, whichever is larger, up to 40 dB. The maximum attenuation is 60 dB. Manual operation is enabled by large rotary dial and a digital LCD readout. Programmed control is achieved using an internal motor that quickly responds to attenuation commands received over a USB connection.

Eravant
www.eravant.com

Electromechanical Relay Switches

VENDORVIEW

Fairview Microwave, an Infinite Electronics brand and a leading provider of on-demand RF, microwave and mmWave components, has launched a new series of ruggedized electromechanical relay switches for reliable RF signal routing in critical applications across various market bands, from DC up to 40 GHz. The newly launched series includes 40 different switch models and configurations, all in stock and ready to ship with no minimum order quantities. They are suitable for multiple market bands, including L, S, C, X, Ku and K.

Fairview Microwave
www.fairviewmicrowave.com

Cryogenic Fixed Attenuator

VENDORVIEW

MIcable SMP cryogenic fixed attenuators have a frequency coverage of DC to 18 GHz and attenuation values of 1 to 40 dB. They have excellent attenuation accuracy and stability at temperatures as low as 4K, which make them the ideal choice for extending power range, controlling power level, decoupling components and other applications.

Fujian MIcable Electronic Technology Group Co., Ltd
www.micable.cn

Phase Shifter

Model P0P-83A-5 is a digitally controlled PIN diode 360-degree phase shifter operating from 30.0 to 40.0 GHz in 0.35 monotonic dB steps. Across the entire band, phase accuracy is ±15 degrees and amplitude balance is ±2.0 dB. The unit features an insertion loss of less than 15.0 dB and VSWR of less than 1.8:1 in 50 Ω. It can accommodate a Handling Power of +15 dBm CW or 1.0 W maximum. The operating temperature range is -10°C to +60°C with 10 BITs of TTL compatible binary logic and switches in less than 500 ηSec. The package size is 3.00 × 3.00 × 1.00 in. This model is also available in a 2.00 × 2.00 × 1.00 in. package.

G.T. Microwave Inc.
www.gtmicrowave.com

Isolators & Circulators

VENDORVIEW

JQL Technologies Corp. has launched space qualified surface-mount and microstrip isolators and circulators. These devices have gone through Group B qualification testing and screening per MIL-STD. Surface-mount isolators are available from L- to Ku-Band and microstrip isolators are available from C- to Ka-Band. JQL has built hundreds of these devices for LEO programs.

JQL Technologies Corp.
www.jqltechnologies.com

Broadband Capacitors

Passive Plus (PPI) has developed larger broadband capacitors in four larger case sizes: 0201BB, 0402BB, 0603BB and 0805BB. Values available are 10 nF (10,000 pF) and 100 nF (100,000 pF), depending on case size. These capacitors are intended primarily for coupling RF signals or, occasionally, for bypassing them to ground, while blocking DC. The applications for which they are intended require small, surface-mountable devices that provide low RF impedances, i.e., low insertion losses and reflections, across extremely large RF bandwidths and temperatures typically ranging from -55°C to +125°C.

Passive Plus
www.passiveplus.com

Dual Directional Coupler

The PCD-200-400-R5N40 is a 500 W, 40 dB dual directional coupler which operates from 200 to 400 MHz. It has an insertion loss of < 0.1 dB with a typical VSWR of < 1.1:1 on the primary thru line. This coupler also boasts a directivity of -27 dB with a coupling value of -40 dB ±1.5 on the forward and reflected ports. Connectors are Type "N" female on all ports with a unique feature of internal 50 Ω terminations. It is constructed using 6061,T6 aluminum with LASER Marked MIL-STD-130.

Preferred Power Products LLC
www.p3-rf.com

RF Multifunction Module in 6U or 3U Package

Using their expertise in RF filters, converters, switch filter banks and amplification, Q Microwave manufactures a wide range of multifunction modules that include VITA standard interfaces and FPGA digital controls using UHART or TCP/IP through RS-422 or RS-485.

Q Microwave
www.qmicrowave.com

Highpass Filter

VENDORVIEW

Quantic PMI Model No. HP3G55M18G-SMA is a highpass filter with a frequency range of 3.55 to 18.0 GHz. It has cutoff frequency of 3.145 GHz, an insertion loss of 0.56 dB, a rejection of 61 dB, a VSWR of 2.0:1 and a power handling of 10 W. This model has SMA female connectors in a housing measuring 1.26 × 0.71 × 0.39 in.

Quantic PMI
www.quanticpmi.com

RF Chip Attenuators

VENDORVIEW

Smiths Interconnect, a leading provider of technically differentiated electronic components, subsystems, microwave, optical and RF products, announces the launch of its new AT Series of RF chip attenuators from DC to 20 GHz. RF chip attenuators are components used in communication systems to reduce the strength of a signal passing through it. They play a crucial role in

protecting systems from receiving a signal with a power level that is too high to process.
Smiths Interconnect
www.smiths.com

CABLES & CONNECTORS

Multi-Port Connector Blocks

VENDORVIEW

Pasternack, an Infinite Electronics brand and a leading provider of RF, microwave and mmWave products, has announced the release of its new VITA 67 multi-port connector blocks that connect multiple antennas, transmitters or receivers in a limited space or demanding environment. They provide a reliable and efficient solution for military, aerospace and defense applications. The VITA 67 multi-port connector blocks feature a unique SV connector retention mechanism that, compared to similar designs, offers easier assembly and disassembly of the daughter card module.
Pasternack
www.pasternack.com

Connectors

The Rosenberger connectors provide reliable and high precision service in the spectrometer sub-mmWave instrument, which investigates the atmospheric composition of Jupiter and its moons, and in the particle spectrometer particle environment package, which measures neutral and charged particles in the Jupiter system. Rosenberger is certified by the European Space Agency (ESA) as manufacturer of SMP connectors for space applications. Further connector series from Rosenberger – SMA, RPC-2.92 and TNC – are also qualified by the ESA standard European Space Components Coordination ESCC 3402.
Rosenberger
www.rosenberger.com

AMPLIFIERS

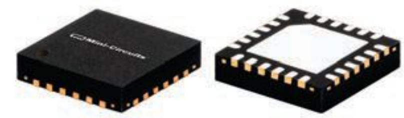
Solid-State L-/S-Band Amplifier

VENDORVIEW

Exodus Advanced Communications' AMP2074P-4KW pulse amplifier is designed for pulse/HIRF, EMC/EMI MIL-STD 461/464 and radar applications. Providing superb pulse fidelity 1.0 to 2.5 GHz, 5 KW typical and up to 100 µs pulse widths. Duty cycles to 6 percent with a minimum 66 dB gain. Available monitoring parameters for forward/reflected power in Watts and dBm, VSWR, voltage, current, temperature sensing for outstanding reliability and ruggedness in a compact 10U chassis.
Exodus Advanced Communications
www.exoduscomm.com

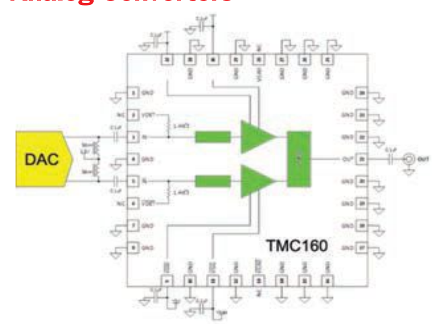
MMIC Amplifier

VENDORVIEW



Mini-Circuits' model AVA-183MP+ is a surface-mount technology 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
www.minicircuits.com

Interface for High Speed Digital-to-Analog Converters



Fabless semiconductor startup mmTron Inc. announced the release of the TMC160 digital-to-analog converter (DAC) interface IC. The IC amplifies and converts the differential output of a high speed DAC to a clean, low noise, single-ended signal to drive the RF chain of a transmitter. With 16 GHz bandwidth, the TMC160 integrates anti-alias lowpass filtering, low noise amplification and a balun that converts the differential DAC output to a single-ended 50 Ω output compatible with traditional RF signal chains. The differential architecture provides high common-mode rejection.
mmTron Inc.
www.mmtron.com

GaN MMIC Power Amplifiers and Transistor

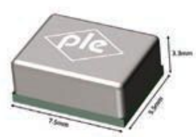
VENDORVIEW

Richardson RFPD Inc., an Arrow Electronics company, announced the availability and full design support capabilities for three GaN RF devices from Wolfspeed. The CMPA5259050S and CMPA5259080S are 50 W and 80 W, respectively, 5.0 to 5.9 GHz GaN MMIC power

amplifiers featuring a two-stage reactively matched amplifier design approach that enables high power and power-added efficiency to be achieved in a 5 mm × 5 mm surface-mount (QFN) package.
Richardson RFPD Inc.
www.richardsonrfpd.com

SOURCES

OCXO



Pletronics introduced the smallest (just 7.5 × 5.5 mm – OHA4) OCXO. It offers exceptional performance for the telecom industry like small cell base station applications. It boasts tight stability, superior phase noise and good holdover and aging performance, making it an ideal solution for demanding wireless networks. With its compact size and impressive specifications, this OCXO is the perfect choice for space-constrained designs that require high accuracy and stability.
Pletronics
www.pletronics.com

ANTENNAS

Permanent Vehicle Mounting Kits

Southwest Antennas' permanent vehicle mounting kits for radio systems allow deployment of omnidirectional antennas on most vehicles. Kits support a frequency range of DC to 8.0 GHz. Simple to install or retrofit. Drill a new 0.75 in. hole or remove your existing NMO antenna mounting kit and feed the RF cable through the hole and screw down the Valox™ nut. Ruggedized, IP-67, 17 in. LMR-195 cable included and includes your choice of five different connector options for antenna mounting. Type-N(f), TNC(f), RP-TNC(f), SMA (f) and RP-SMA.
Southwest Antennas
www.southwestantennas.com

TEST & MEASUREMENT

16-Channel Device Power Supply (DPS)

Marvin Test Solutions' GX3116e delivers industry-leading semiconductor DPS channel densities with 16 independent, fully programmable, isolated power supply channels in a compact 3U PXIe/hybrid form factor. Greatly exceeding the capabilities of commonly available DPS instrumentation, the ability to force voltage/measure current (FV/MI) and force current/measure voltage (FI/MV) on an individual channel basis provides exceptional flexibility. The GX3116e is the ideal solution for existing and emerging semiconductor test applications with demanding device power requirements.
Marvin Test Solutions
www.marvintest.com

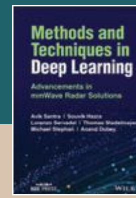
Vector Measurement System

Cassini's vector measurement system expands its frequency and application capabilities to 50 GHz with the RI8607 2-port Test Set. The instrument interfaces with up to three of the Cassini 25 GHz microwave sources and the new 25 GHz receiver to provide 2-port, vector error corrected S-parameters with enhanced dynamic range and resource switching capability. Additionally, each bilateral port can deliver two-tone signals for intermodulation testing as well as single insertion multi-functional tests.
Roos Instruments
www.roos.com

Low Profile Digital Storage Oscilloscope

The SDS6000L series oscilloscopes provide up to eight analog channels + 16 digital channels in a space-saving chassis size. This series is available in bandwidths of 2 GHz, 1 GHz and 500 MHz, features a maximum sample rate of 5 GSa/s (10 GSa/s ESR) for each channel and a record length up to 500 Mpts. It also employs an innovative digital trigger system with high sensitivity and low jitter.
Siglent
www.siglentna.com

MICRO-ADS



Bookend

Reviewed by: Brian Rautio

Methods and Techniques in Deep Learning: Advancements in mmWave Radar Solutions

By Avik Santra, Souvik Hazra, Lorenzo Servadei, Thomas Stadelmayer, Michael Stephan and Anand Dubey

I remember freshman year physics reading Halliday, Resnick and Walker and laughing at the intro to the infamous problem No. 85:

"You are kidnapped by political science majors (who are upset because you told them political science is not a real science)…"

It's approachable and engaging, and while the book is serious, it's not too serious. It's the Star Wars of textbooks.

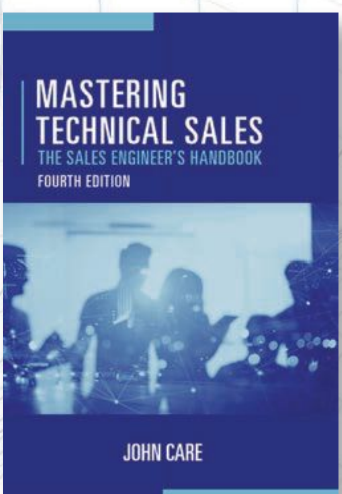
Conversely, I just finished reading *Methods and Techniques in Deep Learning*. If Dr. Halladay and friends are George Lucas, then Dr. Santra and the crew that wrote this are Neal Stephenson. This book is dense, it's heavy and you would argue with its veracity at your peril. The last book I would say that about had a red cover with the name Harrington embossed on it. So, this crew is in good company, but that also means their book is not for the faint of heart.

Read it through and it will give you impressive detail about radar and the various types of deep learning — a technology some will term AI, although I agree with the authors' decision not to explicitly call it such — that are applicable. As frequencies go up and radar gets more precise, it's easy to surpass human ability to parse large, fast, multi-dimensional datasets. Deep learning, on the other hand, is a fantastic way to see through noise, recognize patterns and boil that data to what we're concerned with.

With all the detail, this is still a concise book; I found myself re-reading passages to make sure I unpacked what I wanted to. The authors have clearly spent considerable time wrestling various problems in the field and have documented it so you won't have to repeat those efforts. With that said, it is likely useful for many things beyond what you will personally use it for, so I would recommend studying the table of contents and recognizing what your interests will be as opposed to reading it linearly.

Also, this is more of a reference than a primer, someone brand new to radar or deep learning will probably prefer something lighter to read first. It could be used as a supplement for a graduate school class involving mostly laboratory experimentation, but I generally wouldn't outline a classroom course with it. Rather, I think the ideal case is to be in the library of researchers and engineers working on these types of problems, ready to catch them if they stumble. If you work in radar, deep learning or even machine learning, you owe it to yourself to have a copy of this book. The next time you stumble on a technical problem, or need a citation in a paper, you'll be glad it's there.

ISBN 13: 978-1-119-91065-7
Pages: 336
To order this book, contact:
Wiley-IEEE Press (December 2022)
www.wiley.com



AdvertisingIndex

Advertiser	Page No.
3H Communication Systems	27
Amplical	8
AnaPico AG	24
Anritsu Company	28
AR RF/Microwave Instrumentation	23
Artech House	86
B&Z Technologies, LLC	25
Berkeley Nucleonics Corp.	24
Cadence Design Systems, Inc.	11
Cernex, Inc.	68
Ciao Wireless, Inc.	40
Coilcraft	26, 62
COMSOL, Inc.	15
EDI CON Online 2023	COV 3
ERAVANT	18-19
ES Microwave, LLC	85
EuMW 2023	69-72, 77
Exceed Microwave	52
Fairview Microwave	13
Frontlynk Technologies Inc.	29
Fujian MIcable Electronic Technology Group Co., Ltd.	51, 61
G.T. Microwave Inc.	38
Herotek, Inc.	64
IEEE MTT-S International Microwave Symposium 2024	65, 75
iNRCORE	37
Intelliconnect Ltd.	78
JQL Electronics Inc.	3
KR Electronics, Inc.	85
KYOCERA AVX	COV 2
LadyBug Technologies LLC	30
Marki Microwave, Inc.	33
MiCIAN GmbH	36
Microwave Journal	52, 79, 80, 81, 87
Mini-Circuits	4-5, 16, 44, 89
Nxbeam	35
Pasternack	56, 57
Pulsar Microwave Corporation	46
QML Inc.	47
Quantic PMI	9
Reactel, Incorporated	43
Remcom	39
RF-Lambda	6, 31, 53, 67
Rosenberger	21
Special Hermetic Products, Inc.	76
Spectrum Control	7
Swift Bridge Technologies	42
Synergy Microwave Corporation	49, 63
Tecdia, Inc.	66
TTE Filters, LLC	37
Weinschel Associates	84
Wenteq Microwave Corporation	85
Werlatone, Inc.	COV 4

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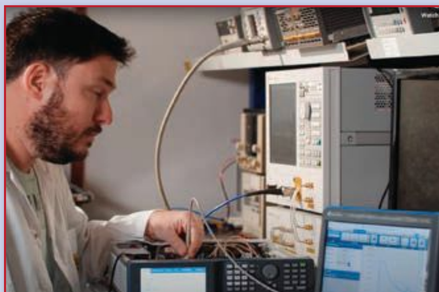
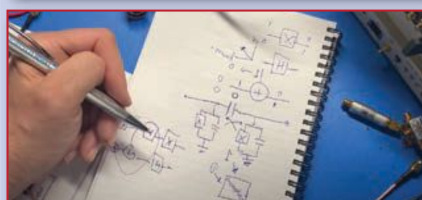
FABS and LABS

Tabor Electronics: Simulate, Stimulate, Test





Tabor Electronics was established in 1971 as a spin-off of Elron Corporation, considered the first Israeli start-up company. Zvi Glazer founded Tabor Electronics to develop and market Glazer's innovative invention of the world's first automatic counter. Over time, the product line gradually expanded to digital multimeters, digitizers and generators. During the last two decades, the company evolved to specialize in the signal source market. Starting with low-frequency generators and moving to products with frequency ranges reaching 40 GHz, the company now focuses on core applications areas of quantum computing, wireless communications and radar/electronic warfare.

The company now operates in 46 countries. Tabor's headquarters and core hardware technology center are still located in Israel, but the company has expanded its footprint. There is a software center in India, a Quantum Characterization and Algorithm Development Center in the United States and a Communications/Radar Algorithm Development Center in Europe. The Israeli government remains a strong supporter with the Israeli Innovation Authority (IIA) awarding multiple grants to the company. These grants have helped fuel the development of key technologies in the measurement and characterization market space.

The core of Tabor Electronics technology has been arbitrary waveform generators, with a set of complementary signal amplifiers for customers requiring higher signal amplitudes. The introduction of the new Proteus arbitrary waveform generator brought two innovations to the market. The first was the ability to directly generate RF and microwave signals digitally at frequencies up to X-band, eliminating the need for local oscillators and IQ mixers. The second innovation added a direct RF digitizer with a user-programmable FPGA that made Proteus a closed-loop device with low latency, fast feedback and hardware-based control. The company feels that these innovations make Proteus the ideal generator for high-speed device characterization in quantum computing processors, radar target generators and closed-loop EW threat simulation.

In addition to the Arbitrary Waveform Division, the company has created the RF Signal Generator Division. This new division is responsible for the Lucid family of signal generators that currently operate at frequency ranges of 3 GHz, 6 GHz and 12 GHz. The division is set to expand this family with the introduction of the Lucid Series X mmWave generator operating to 40 GHz. They are also developing a quadrature modulator and a 2 GHz IQ arbitrary waveform generator that will serve as building blocks to support Tabor's investments into vector signal generators.

In 2016, Tabor Electronics named Ron Glazer as CEO of the company. The Glazer lineage is strong in the company as Ron, grandson of Tabor Electronics founder Zvi Glazer, succeeded his father, Moti Glazer, in the role of CEO. This year, Tabor Electronics celebrates 52 years in business. The company attributes its longevity to three factors; understanding the markets and applications that drive the requirements for product platform generation, finding the early partner/beta customers to validate their offerings and then quickly executing the release of new features in the market as requirements morph. Tabor Electronics counts as strengths their strong technology base, a global engineering footprint, loyal and enthusiastic customers and a strong roadmap of new technology innovation. They believe that these factors allow them to continuously innovate in the face of competition threatening to commoditize their products. Tabor Electronics feels that the steady hand of the Glazer family management, coupled with their innovations and a strategic evolution to higher sampling rates and frequency ranges is the recipe for continued success.

www.taborelec.com

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ENGINEERING EVOLVED

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Up to 1000:1 Bandwidth ✦ Low Insertion Loss ✦ *Mismatch Tolerant*® Designs

Model	Type	Frequency (MHz)	Power (W CW)	Coupling (dB)	Insertion Loss (dB)	Connectors	Size (inches)
C8730	Dual	0.009-250	500	40	0.40	N-Female	10.5 x 3.0 x 2.0
C8731	Dual	0.009-250	1000	40	0.40	N-Female	10.5 x 3.0 x 2.0
C11462	Dual	0.009-400	500	40	0.45	N-Female	6.7 x 2.28 x 1.69
C8510	Dual	0.009-1000	500	40	0.45	N-Female	6.7 x 2.28 x 1.69
C5047	Dual	0.01-100	4,000	50	0.15	7/16-Female	10.0 x 4.16 x 3.5
C1979	Dual	0.01-100	10,000	60	0.10	LC-Female	2.0 x 6.0 x 4.5
C5086	Dual	0.01-250	250	40	0.50	N-Female	5.2 x 2.67 x 1.69
C5100	Dual	0.01-250	500	40	0.40	N-Female	10.5 x 3.0 x 2.0
C5960	Dual	0.01-250	1,000	50	0.40	N-Female	10.5 x 3.0 x 2.0
C1460	Dual	0.01-250	2,000	50	0.15	N-Female	10.0 x 3.0 x 2.0
C4080	Dual	0.01-250	3,500	50	0.20	N-Female	10.0 x 4.6 x 3.5
C11026	Dual	0.01-220	5,000	60	0.10	LC-Female	12.0 x 6.0 x 4.5
C8390	Dual	0.01-250	10,000	60	0.10	LC-Female	12.0 x 6.0 x 4.5
C5339	Dual	0.01-400	200	40	0.50	N-Female	5.2 x 2.67 x 1.69
C6047	Dual	0.01-400	500	40	0.50	N-Female	5.2 x 2.67 x 1.69
C2630	Dual	0.01-1000	100	40	0.60	N-Female	5.0 x 2.0 x 1.51
C6021	Dual	0.01-1000	500	40	0.45	N-Female	6.7 x 2.28 x 1.69
C6277	Dual	0.01-1000	500	50	0.45	N-Female	6.7 x 2.28 x 1.69
C11146	Dual	0.01-1000	500	43	0.45	SC-Female	6.7 x 2.63 x 2.20
C11047	Dual	0.01-1000	1,000	43	0.45	SC-Female	6.7 x 2.63 x 2.20
C11161	Dual	0.01-1000	1,000	50	0.45	SC-Female	6.7 x 2.63 x 2.20
C1795	Dual	0.1-1000	100	40	0.50	N-Female	5.0 x 2.0 x 1.51
C5725	Dual	0.1-1000	500	40	0.50	N-Female	5.2 x 2.28 x 1.69
C11077	Dual	0.1-1000	1,000	43	0.45	SC-Female	6.7 x 2.28 x 1.69
C3910	Dual	80-1000	200	40	0.20	N-Female	3.0 x 3.0 x 1.09
C5982	Dual	80-1000	500	40	0.20	N-Female	3.0 x 3.0 x 1.09
C3908	Dual	80-1000	1,500	50	0.10	7/16-Female	3.0 x 3.0 x 1.59
C6796	Dual	80-1000	5,000	60	0.20	1 5/8" EIA	6.0" Line Section
C8060	Bi	200-6000	200	20	0.40	SMA-Female	1.8 x 1.0 x 0.56
C8000	Bi	600-6000	100	30	1.10	SMA-Female	4.8 x 0.88 x 0.50
C10117	Dual	700-6000	250	40	0.20	N-Female	2.0 x 2.0 x 1.06
C10364	Dual	700-6000	500	50	0.20	7/16-Female	2.15 x 2.0 x 1.36
C10996	Dual	700-6000	700	50	0.20	7/16-Female	2.15 x 2.0 x 1.36
C11555	Dual	700-6000	1,000	50	0.20	7/16-Female	2.15 x 2.0 x 1.36
C10695	Dual	700-6500	500	50	0.20	7/16-Female	2.15 x 2.0 x 1.36

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