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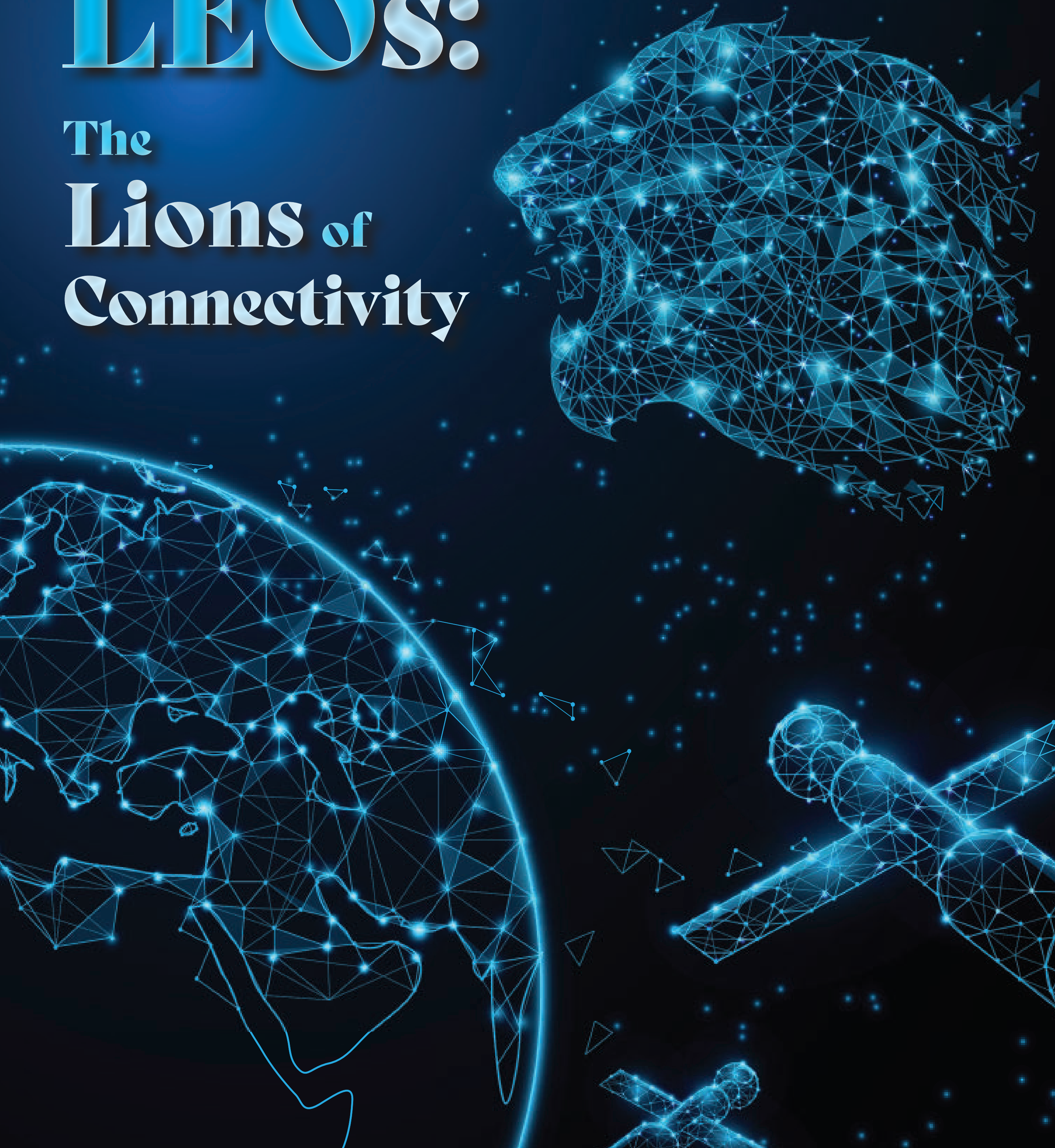
LEOs:

The Lions of Connectivity



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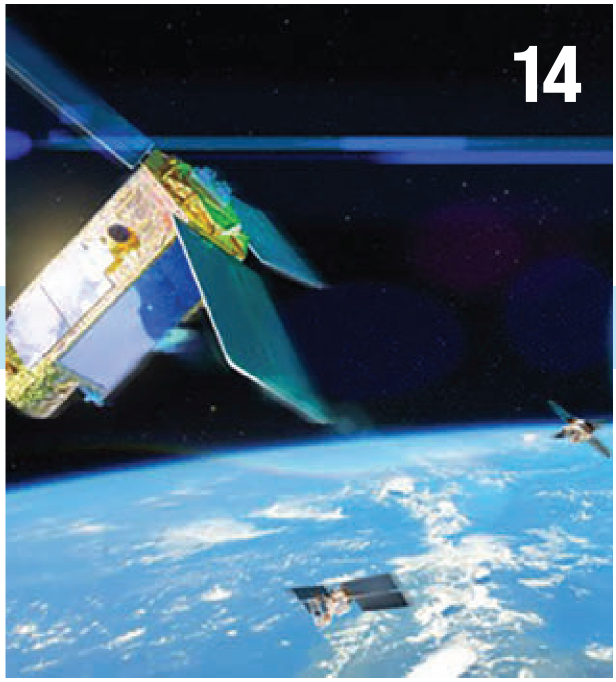

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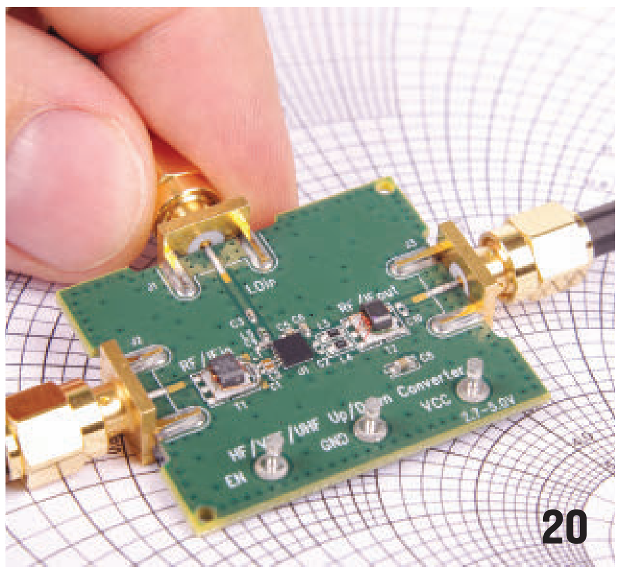

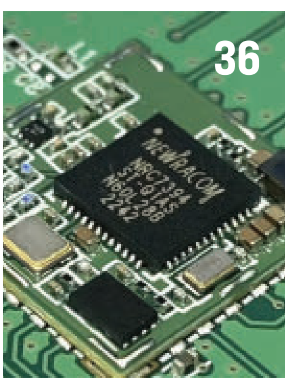

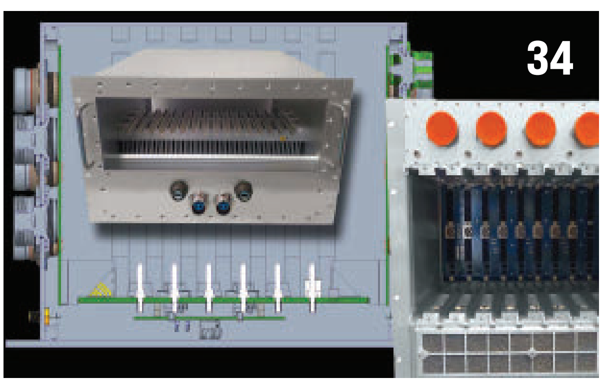

DAVID MALINIAK, Executive Editor

Orbital Space Junk is No Joke

The steady proliferation of space debris has led to concerns for the long-term health and well-being of active communications satellites.

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THE SPACE AGE KICKED OFF IN 1957 with the Soviet Union's launch of Sputnik 1, the world's first artificial satellite. Since then, according to the European Space Agency's (ESA) Space Environment Statistics, some 6,420 rocket launches have placed about 15,880 satellites into Earth orbit. About 10,590 of those are still in orbit and 8,900 of those are functioning today.

That's a lot of hardware sent into orbit. The ESA estimates the total mass of all objects in orbit to be over 11,000 tons. But satellites don't function forever. Some run out of fuel and die while others are decommissioned when the technology that they supported reaches obsolescence. More than 640 objects sent into orbit have broken up, exploded, or collided their way into fragmentation, resulting in clouds of debris.

The agency tracks about 35,530 debris objects, which have resulted from over 640 breakups, explosions, collisions, or other mishaps that caused fragmentation. However, many thousands of space debris objects up there are circling the Earth in all of the various orbital regimes from low-Earth orbit (LEO) to geostationary to high-altitude orbit.

Space debris ranges from items as small as flecks of paint to nuts, bolts, and tools, to large items like spent rocket stages and engines. Even the smallest of these objects, traveling at orbital speeds, can do significant damage to, say, a working satellite or the International Space Station. Aside from disruptions in services such as communication infrastructure, ISR coverage, navigation, or research, the proliferation of space debris can have a cascading effect if there's a catastrophic collision or explosion.

So, what are we doing about it? Knowing where these things are located is the first order of business. As mentioned above, agencies like the ESA and NASA diligently track the orbits and location of thousands of debris objects. At its Operations Centre in Darmstadt, Germany, the ESA takes action when it's alerted to a possible collision between an operating satellite and some chunk of metal. Often, an avoidance maneuver by the satellite can avert disaster, albeit at the expense of possibly shortening its lifespan through use of fuel.

An interesting effort mounted at Purdue University's College of Engineering aims to investigate how LEOs and geostationary satellites can be "parked" safely in orbit. With an ever-growing number of satellite constellations being established, it's bound to become more difficult to ensure the long-term survival of orbiting vehicles that are so critical to communications infrastructure. Purdue's team is looking into modified orbital patterns, predominantly in the cislunar region between Earth and the moon, as safe havens.

Hopefully, the ongoing efforts to either predict catastrophic events or prevent them altogether will produce a space environment that's conducive to orbital security for satellites of all varieties. ■

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Microwaves & RF Magazine ID Statement 2023:

Microwaves & RF, ISSN 2162-1411 online, is published 6 times a year (January/February, March/April, May/June, July/August, September/October, November/December) by Endeavor Business Media, LLC. 1233 Janesville Ave., Fort Atkinson, WI 53538.

POSTMASTER: Send address changes to Microwaves & RF, PO Box 3257, Northbrook, IL 60065-3257. **SUBSCRIPTIONS:** Publisher reserves the right to reject non-qualified subscriptions. Subscription prices: U.S. $68.75 per year; Canada/Mexico $81.25 per year; All other countries $93.75 per year. All subscriptions are payable in U.S. funds. Send subscription inquiries to Microwaves & RF, PO Box 3257, Northbrook, IL 60065-3257. Customer service can be reached toll-free at 877-382-9187 or at microwavesRF@omeda.com for magazine subscription assistance or questions.

Video ▶ Four-Port Single-Sweep VNA Serves D- and G-Band Apps

Capable of measuring noise figures from 70 kHz to 125 GHz, Anritsu's VectorStar ME7838x4 broadband VNA is augmented by the company's MA25400A mmWave module, which implements Anritsu's Nonlinear Transmission line technology for measurements up to 220 GHz. A spectrum-analyzer option for the VNA performs spectrum-domain measurements of harmonics, spurs, distortion products, and general frequency content.
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Video ▶ Test Assemblies Enable SerDes Characterization Out to 90 GHz

With Samtec's Bulls Eye BE90A test assembly, users can characterize serial/deserializer (SerDes) interfaces found in extremely high-speed serial links with usable bandwidth out to 90 GHz. The solderless BE90A block mounts on boards directly adjacent to the SerDes link of interest. The back end of the cable assembly connects to instrumentation using 1.00-, 1.85-, 2.40-, or 2.992-mm interconnects.
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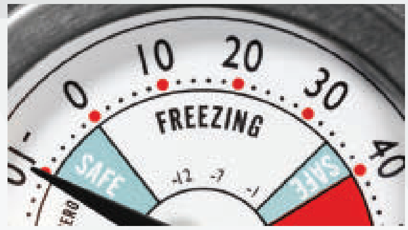

What Does LoRaWAN Have to Do with Your Next Cheeseburger?

Chances are you've never considered the link between LoRaWAN and your culinary proclivities, but there's a lot to be said about how low-power, long-range wireless technology can ensure that the food you eat is fresh.
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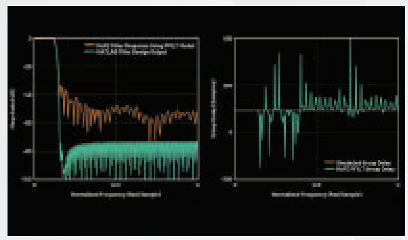

Easy Digital-Filter Applications for Not-So-Easy RF System Designs

Digital filters provide a meaningful way of controlling the input spectra of communication systems. This article demonstrates a quick and easy method for implementing these simple yet powerful filters for RF systems.
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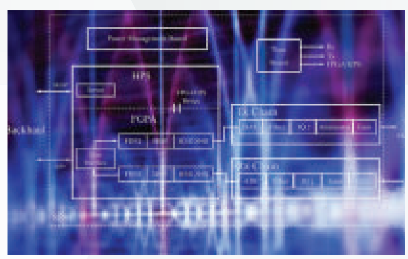

Monitor and Record More Data than Ever with SDRs

Software-defined radio can be used to increase the amount of data that's able to be monitored and recorded, with minimal effect on latency.
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R&D EFFORT Aims at V2X Comms Between Autonomous Vehicles

CEA-Leti hopes to eventually adapt wireless V2X technologies for use with drones and robots in factories.

THE FRENCH TECHNOLOGY research institute CEA-Leti is kicking off a new R&D initiative that hopes to result in a higher level of vehicle automation and cooperation. It will do so by exploiting recent developments in vehicular wireless communications that improve reaction time, pedestrian detection, and overall vehicle performance.

Building on its participation in three EU H2020 projects, CEA-Leti scientists have consolidated the institute's expertise in vehicle-to-everything (V2X) communication technologies and standards. CEA-Leti's efforts are aimed at evaluating and demonstrating connected and cooperative vehicular systems to improve automation.

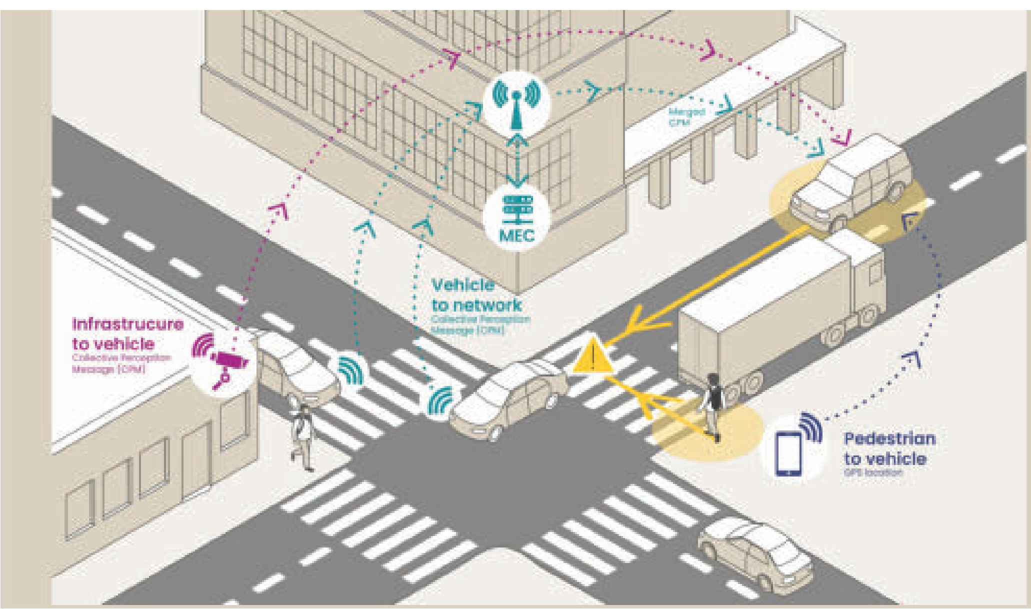
In turn, scientists hope to help ensure the safety of vulnerable road users, such as pedestrians, workers, and cyclists *(see figure)*. Further, the institute aims to help its partners in the automotive and related industries understand and adopt the benefits of V2X cooperative communications.

Those earlier H2020 studies included integrating a dedicated simulation flow for system-level evaluation of different short- and long-range radio technologies, such as IEEE 802.11.p/bd, C-V2X sidelink, or 5G NR. They also investigated different architecture and infrastructure options, including roadside units, 5G base stations, and MEC servers.

Another key H2020 accomplishment was the development of a simulation tool used to measure the actual impact of observed communication network performance in terms of latency, link reliability, coverage, and load on the critical vehicular applications. The measurements yielded insights into service availability and continuity, the allowed level of automation, time to collision, and other critical parameters.

V2X communication technologies and protocols were initially developed to improve road safety through cooperation between vehicles. However, with more autonomous fleets of collaborative robots and drones coming online, similar research questions and challenges have arisen in various complex mobile operating contexts. An approach like that being developed for V2X applications could also find uses for collision avoidance and cooperative maneuvers by autonomous robots in smart factories.

Looking ahead, CEA-Leti is exploring possible extensions of these H2020 studies in application fields for which standardization is still in its infancy, notably in connection with 6G. These may include cooperative robotics and digital twinning in factories of the future. ■



CEA-Leti scientists outlined their vision of how V2X technology might lead to a new era of cooperation between vehicles, making roads safer for all concerned. CEA-Leti

Finding Safe Spots **for Space Satellites**

A professor at Purdue University's College of Engineering is working with graduate students on finding safe orbits and locations for the growing numbers of satellites and satellite constellations.

FINDING SAFE LOCATIONS for the large number of low-Earth-orbit satellites (LEOS) predicted for launch in the next seven years has become a goal for Purdue University's College of Engineering. About 10X the number of satellites currently in orbit are expected to be launched by 2030, boosting concerns of collisions for these high-speed space vehicles that can travel faster than 4 miles/s.

David Arnas, an assistant professor of aeronautics and astronautics at Purdue and his graduate students are exploring ways to safely park LEOS and geosynchronous satellites safely in orbit, even with the numbers of vehicles increasing so dramatically over the next decade.

Arnas said, "With this density of satellites, something is going to fail and cause a collision. It is just a matter of probability. Satellite constellations are getting so big and numerous that it's becoming impossible to accurately track them all and ensure their long-term safety even through computational means."

But by exploring novel orbital patterns, Arnas *(see image above)* and his graduate students are hoping to find how modified orbits could create safer locations for orbiting satellites. One of the areas being investigated for a rapid growth of "parked" satellites is the cislunar region between the Earth and the moon.

Arnas and his satellite research teams hope to make outer space more equitable and reduce the likelihood of outer space becoming too cluttered with satellites for future space exploration missions to be conducted safely. He noted, "Space is a common resource of humanity, just like water and air. Even if it seems very vast, it is still limited. It is our responsibility to ensure that future generations will also have fair access to it."

Included in their research are ways to organize large satellite constellations to safely deal with space debris when the satellites are no longer operable. ■

Compact, Lightweight Module Encrypts Sensitive Data

A JDAR TYPE-1 encryption module that has provided security for classified and sensitive data on U.S. military platforms is now available for standalone military and government applications. The module, developed by Mercury Systems, first received National Security Agency (NSA) Type-1 encryption certification in 2022 and has been used for data-at-rest encryption and security in multiple U.S. military airborne systems. The module's encryption capabilities prevent unauthorized personnel from gaining access to inactive classified mission data.

The compact module *(see image)* is a good fit for manned and unmanned airborne and ground vehicles, measuring just 5.04 × 3.94 × 0.63 in. and weighing less than 1 lb. It consumes less than 7 W of power over a wide operating temperature range of –40 to +85°C, but enables operators to move sensitive data without risk or compromise in tactical mission strategies.

Mercury Systems' senior vice president for mission systems, Roya Montakhab, points out, "Mercury's JDAR Type-1 encryptor module introduces a new solution to the Department of Defense that is smaller, lighter, easier to integrate, and capable of operating in more extreme environments."

The rugged module has a rated mean time before failure (MTBF) of more than 30,000 hours and less than 12-second boot-up time, enabling JDAR encryption to be added to a wide range of systems. ■

Smart RF Accessories Provide Flexible, Scalable Test Solutions

FEATURED PRODUCT

The Overview

Siglent released a family of smart accessories to support multiport and multi-device test solutions. The company's SEM5000A series of electronic calibration (ECal) modules includes the SSU5000A series mechanical switch and the SSM5000A series switch matrix. They're designed and optimized for use with the SHA850A, SVA1000X, and SNA5000A series of vector network analyzers (VNAs) from Siglent. The devices offer a comprehensive, cost-effective solution for simple to complex RF measurement tasks on multiport systems and multiple devices.

SEM5000A series electronic calibrators include the 5002A, 5012A, 5022A, 5032A, 5004A, 5014A, 5024A, and 5034A, over frequency bands of 9 kHz to 4.5 GHz, 9 kHz to 9 GHz, 100 kHz to 13.5 GHz, and 100 kHz to 26.5 GHz. There's a USB interface for communication and power.

Suitable for calibration and error correction of the aforementioned VNA series, the SEM5000A series is simple, fast, efficient, accurate, and widely applicable, with SMA or 3.5-mm connections, or custom configurations.

Who Needs It & Why?

Developers of advanced mobile devices can use these solutions to contend with the rapid growth of cloud-oriented data traffic that's impacting frequency-spectrum sharing for mobile communications. Components used in modern communication devices such as mobile phones and tablet PC front-end modules must support more frequency bands and functions.

An important element of 5G development is that the number of ports in the front-end module has increased rapidly, including filters, amplifiers, and other components. Addressing this complexity requires advanced test and production solutions to accurately characterize the performance parameters of these systems.

When analyzing microwave networks, VNAs measure the network's scattering parameter (S-parameter) matrix, and the latest multiport and balancing devices often have more than the typical two or four ports found on a network analyzer, complicating characterization. This is made more difficult by repeated tests, multiple connection points, and repeat calibrations, which can slow test results and introduce additional errors. Test systems that combine RF switching, electronic calibration, and S-parameter measurements improve test speed and accuracy.

Siglent's multiport device test solutions offer increased speed, accuracy, and efficiency with cost-effective test expansion options. SEM5000A series electronic calibration modules perform calibration in one step and provide greater convenience for multiport and manufacturing tests by significantly reducing the number of connections made during the calibration process. This decreases the probability for operator error as well as the likelihood of connector wear and tear.

Under the Hood

SSU5000A series mechanical switches, which have a frequency range of up to 50 GHz, offer a compact design, excellent RF characteristics, low insertion loss, high impedance matching, and a fast switching time. The devices contain from one to four independent single-pole, double-throw (SPDT) mechanical switches with SMA or 2.4-mm connectors or one to two single-pole, six-throw (SP6T) mechanical switches.

For example, the SSU5264A comes in four varieties, and each is an independent SPDT with three connectors. Alternatively, the SSU5266A is divided into two types, and each group is an independent SP6T with seven connectors. Provided in a USB-connected enclosure, the switches can be configured using VISA and SCPI, or free standalone software.

The ECal module is connected to the VNA with the provided USB cable, and then the analyzer automatically identifies the calibration model, frequency range, and connector type. The SSM5000A series switch matrix can expand the number of test ports of network analyzers, signal sources, spectrum analyzers, and other equipment, with up to four input ports and up to 24 output ports. Able to support USB, LAN, and Direct Control communication modes, these switch-matrix systems simplify device connections as well as system topology with added flexibility.

A Direct Control interface makes it possible to further automate multiport calibration; the RF switch systems can be used with any RF test equipment for mixed system designs. Able to test transmission and reflection parameters across up to 24 ports in a single switch chassis, the SSM5000A can handle up to 20-dBm input power for a wide variety of applicable RF devices.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First SoC for 5G Small-Cell, Open RAN RUs Makes its Debut

Picocom

The Overview

Picocom's PC805 is touted as the industry's first system-on-chip (SoC) optimized for 5G small-cell Open RAN radio units (O-RUs). As a highly integrated, small-footprint, low-power SoC, the PC805 is expected facilitate implementation of 5G NR/LTE small-cell O-RUs in use cases including enterprise, industrial, neutral host, and private networks.

Who Needs It & Why?

Accelerated adoption of Open RAN technology, which is hoped to break the hegemony of large, integrated network-equipment vendors in the buildout of 5G infrastructure, depends in part on the availability of optimized and widely available silicon. SoCs like the PC805 are key to neutral-host and private network deployments as well as greater network density.

Many existing O-RU products are based on FPGA technology, necessitating redesign of hardware to address different use cases. The PC805 helps accommodate these changes with simple software changes. Moreover, spectrum aggregation is important to neutral-host network operators. The PC805 supports these use cases with a minimum of additional components, reducing both capital and operating costs.

Under the Hood

The PC805 SoC greatly simplifies the design of O-RUs, delivering a reduced bill of materials compared to current approaches. The SoC interfaces directly with Open RAN O-DUs via Open Fronthaul (split 7.2) and supports seamless connections to RFICs with a standardized JESD204B high-speed serial interface. PC805 is shipped with a fully integrated O-RAN-compliant Picocom 5G NR RU and M-plane software suite.

The device can aggregate four or more 4T4R carriers in a 200-MHz instantaneous bandwidth. A single PC805 can also support multiple bands, including time-division duplexing and frequency-division duplexing for both 5G NR and LTE, with a cascade of two SoCs doubling the supported bandwidth.

A complete software suite and a companion RU Demonstrator Board, the PC805RDB, were launched along with the SoC to ease and accelerate development efforts.

Digital-Radio Coprocessors Power Automotive Infotainment Systems

The Overview

A new family of automotive digital-radio coprocessors from Skyworks Solutions, the Si469xx family, brings high integration, flexibility, and low cost to future in-vehicle infotainment (IVI) systems. The Si469xx family of coprocessors is optimized to operate with Skyworks' Si479xx hybrid software-defined-radio (SDR) tuners to achieve a cost-effective digital radio receiver.

Who Needs It & Why?

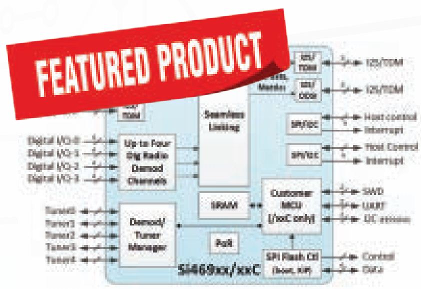
HD Radio is firmly entrenched in automakers' infotainment playbooks in the U.S., while DAB/DAB+ is the mode of choice in the European Union. Historically, automotive radios have been ensconced in the "head unit" or cockpit system in the middle of dashboards.

Now, though, car radios are increasingly being implemented in a separate module known as a remote tuner module (RTM). Implementation in this fashion brings the benefits of less cable weight and, perhaps more importantly for automakers, the ability to design and qualify the RTM for use in multiple car models.

Under the Hood

The Si469xx devices can demodulate and decode up to four digital-radio channels supporting HD Radio, DAB/DAB+, DRM (for AM and FM), and CDR, providing high performance and unmatched scalability. They also support maximal ratio combining (MRC) and seamless linking of digital radio, analog radio, and Internet Protocol content *(see figure)*.

Thanks to an integrated customer-programmable MCU, the Si469xx can significantly reduce bill-of-materials costs by eliminating the need for an external MCU and its support components. Software design is simplified through several improvements, including a Demod/Tuner



Skyworks Solutions

Manager that relieves system developers from having to program low-level radio control functions.

The cable weight reductions are a result of replacing RF coaxial cabling to the head unit with a much lighter twisted-pair cabling, typically accomplished with Analog Devices' A^2B technology. A^2B technology is optimized for automotive digital-audio applications, or Ethernet.

By leveraging separate tuner and coprocessor ICs, the Si469xx family offers an optimal balance between partitioning and integration.

LEOs Hold the Key to **Satellite Broadband Connectivity**

With several market drivers and enabling technologies coalescing, LEOs are filling the skies to bring broadband connectivity to the entire globe.

1. Mega-constellations of up to 12,000 LEO satellites are in the early stages of deployment. Images courtesy Analog Devices

By ***Joe Barry,*** *Vice President, Wireless Communications Business Unit, Analog Devices Inc.*

IMAGINE A MEGA-CONSTELLATION of thousands of tiny low-Earth-orbit (LEO) satellites blanketing the Earth and beaming broadband signals to populations in rural, remote, and underserved regions. From the mountains of Nepal to the plains of Africa, envision fast, reliable satellite broadband connectivity providing or improving digital access for millions of people.

Currently, the pricing structure of these networks is too expensive for most rural populations, and satellite broadband is limited to a few markets where terrestrial solutions don't work. Although many uncertainties remain, costs will continue to evolve with technological advances and economies of scale. If constellation providers can offer competitive pricing, consumer demand could soar, and LEOs could bring access to satellite broadband connectivity across the globe.

While cable, fiber optic, and 5G mobile fuel the next generation of digital infrastructure on Earth, LEO satellite constellations are projected, in the long run, to play a key role in supporting the global connectivity ecosystem when fully operational. LEOs are expected to stimulate economic growth, improve access to education and healthcare, and help close the digital divide.

LEOs will expand high-speed internet access to landlocked developing countries, developing states, and hard-to-reach remote and rural areas. Island nations can be given a pathway via satellite to broadband internet and circumvent the enormous cost of building a submarine cable system carrying international traffic. Satellites can also provide backbone connectivity to mobile 5G cellular networks while enabling critical communication access for those most in need.

The Economics of Fiber Cable vs. Satellite

Providing broadband internet to millions of customers in a heavily populated urban environment is a lucrative business. However, building and maintaining terrestrial expansion to more sparsely populated regions is expensive. Return on investment rarely offsets the cost. Thus, terrestrial build-out to rural and remote areas can lag for years, even decades.

One funder of such efforts puts it this way: "For geographies without direct access to fiber-optic cable infrastructure or at great distances from high-capacity bandwidth, satellite connectivity is the only option available."[1]

No matter the technology, there's an infrastructure cost to build and operate the core network, ongoing customer equipment costs, and recurring subscriber costs for the customer.

Local, state, and national funding programs can help cover some terrestrial-based infrastructure costs and service plans. The FCC's Affordable Connectivity Program, the USDA's ReConnect Rural Broadband Program, and the U.S. Bipartisan Infrastructure Bill provide billions of dollars to individual states, operators for infrastructure expansion, and subsidy programs to low-income families. But the size and scope of the terrestrial-based plans are limited. Another, more comprehensive solution is needed.

LEO Constellations

Today, LEO satellites are the focus of intense interest and capital investment. Mega-constellations of up to 12,000 LEO satellites are in the early stages of deployment *(Fig. 1)*. According to a 2020 analysis of the commercial space industry by McKinsey, current satellite internet proposals becoming a reality translates into about 50,000 active satellites orbiting overhead within 10 years.[2]

Recent statistics on satellites in operation:

- 90% of all satellites are LEOs
- 7,500 LEOs now circle Earth (as of September 2021)
- Orbit of 160 to 2,000 km (60X closer than geostationary equatorial orbits (GEOs))
- Orbit period of 88 to 127 minutes (depending on altitude)

Why So Many Satellites?

Low-Earth-orbit satellites pass overhead quickly, providing connectivity over a small geographic area for a brief time. The advantage of the LEO satellite's low orbit (2,000 km) vs. a geostationary Earth orbit (35,000 km) is lower latency and the subsequent reduction in the time it takes for a signal to travel round trip from ground to satellite and back down again.

A lower latency reduces lag and permits faster response times for communications. However, the current generation of satellite broadband will not support the 3GPP low-latency spec requirements needed for immersive gaming, video calls, streaming video, or much touted innovations such as remote robotic surgery and autonomous driving.

2. LEO constellations require an extensive network of hundreds or thousands of satellites to attain robust global coverage.

LEO constellations require an extensive network of hundreds or thousands of satellites to attain robust global coverage *(Fig. 2)*. Rural and remote communities, the areas most targeted by the constellations, are often the least able to afford the cost of the satellite dish equipment and data plans. This necessitates government programs and subsidies as well as new business models that require deeper collaboration and standards, and interoperable, open architecture among all of the players.

Space Business in Transition

Today's commercial space business is moving away from yesteryear's low-volume, government-funded, one-off programs to large-scale commercial ventures employing reusable rockets and smaller, cheaper LEOs. The industry seeks adaptable and flexible solutions that are cost-effective and capable of meeting accelerated demand. New players, applications, business models, and government programs make possible a dynamic competitive commercial space ecosystem.

The commercial space satellite business is being driven by several market drivers and enabling technologies. Among the former are:

- Global coverage for rural, remote, and urban areas
- A drive to close the digital divide
- Lower launch and ground-station costs
- Smaller, lighter, and less-costly satellites

Enabling technologies that are in play include:

- Modern IC technology
- Advanced phased-array functionality
- Development of large mega-constellations

McKinsey's analysis portends that "new satellite constellations are on the cusp of deployment, but their long-term success hinges on substantial cost reductions."[2]

Advances in design, manufacturing, and standardization have had the most significant effect on the satellite industry, enabling faster and more flexible deployment. Whether costs ultimately

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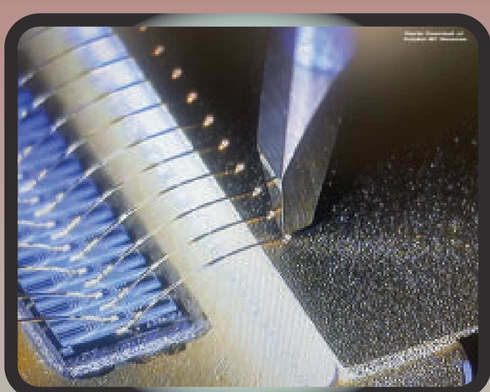

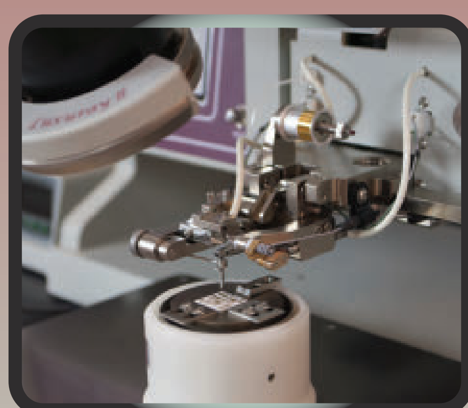

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come down enough to make satellite broadband connectivity affordable is still unclear.

Reusable Rockets and Smaller Satellites

LEO satellite launches are rapidly ramping up while costs continue to shrink. The decreased launch cost results from a vertically integrated launch vehicle production line that is more reliable, adaptable, and efficient. With the combined savings from ridesharing, booster reuse, and lower orbit satellite placement, the price per satellite for launch is now as little as $1 million *(Fig. 3)*.

3. SpaceX reuses the first stage of its Falcon 9 booster and launches up to 60 LEO satellites at a time.

Tailoring Reliability and Rad-Hardening

High-reliability, radiation-tolerant semiconductors were initially required to survive for decades in the extreme conditions of space aboard NASA missions to the planets and high-Earth-orbit GEO satellites. But LEO satellite markets have relaxed requirements, with durations of only a few years and lower earth orbits with reduced levels of radiation exposure.

"Today's high-volume commercial space market cannot afford, nor do they often require, the more costly 'classic' components," said Chris Chipman, Product Line Director, Aerospace, Defense and RF Products, ADI. "They can realize cost savings with ADI's commercial-off-the-shelf (COTS) components."

Benefits include access to advanced technologies; higher levels of integration and performance; and superior size, weight, and power (SWaP). Commercial space low (CSL) grading offers testing and screening suitable for constellations orbiting in lower-radiation environments for those requiring more protection.

Reducing Ground-Station Costs

Ground stations form the core of global networks, and a satellite dish must be within 500 miles of a ground station to access the internet. Thus, an extensive network of internet-connected ground stations is required. Cutting the cost or the number of ground stations needed is critical for an industry on a mission to bring connectivity to underserved populations in rural and remote areas.

LEOs with laser links or optical intersatellite lasers (OISLs) can reduce the number of ground stations needed for global connectivity. Laser links distribute communication traffic and route it around a constellation—between satellites—rather than pinging back and forth between ground stations and space. The routed signal is sent directly to a home antenna.

Increasing Bandwidth and Opportunity

According to the 2021 Asian Development Bank report, "LEOs are forecasted to significantly increase the available internet bandwidth in remote and rural geographies not currently served by fiber-optic cables."[1] The increased bandwidth could increase economic and social development opportunities in those regions, provided that the private sector companies investing in LEO constellations have identified market opportunities that unlock long-term value to extend service to these regions.

Satellite Broadband Access Now and in the Future

Satellite networks can potentially extend the internet's reach to places that conventional fixed and mobile networks can't be or where terrestrial-based technologies aren't economically viable.

Satellite broadband offers the promise of ubiquitous connectivity and new ways of working and living untethered from cable and fiber connections. Urban students, rural farmers, and people working in remote offshore mining rigs and ships at sea all stand to benefit. Service levels may eventually rival fiber-optic cable speed and latency, enabling new applications that are yet to be envisioned.

More than a dozen startups now plan to use small satellites (LEOs) to connect with the Internet of Things (IoT).[3] GSMA Intelligence forecasts that IoT connections, both consumer and those used in industry, will reach almost 25 billion globally by 2025.[4]

What's Needed and What to Expect

Space-based communications networks must integrate seamlessly with terrestrial networks to maximize their effectiveness. Significant investment is required in space communications technology and terrestrial wireline infrastructure between satellite ground stations, service providers, and data centers.

Given satellites' power to transform the communications landscape and bridge the digital divide, internet providers, manufacturers, and companies from all walks of industry should consider how to prepare for the future today. They should also investigate how to best tap into opportunities presented by the new communications frontier.

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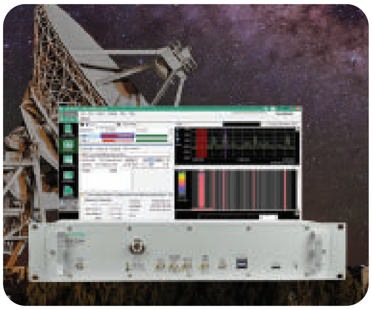

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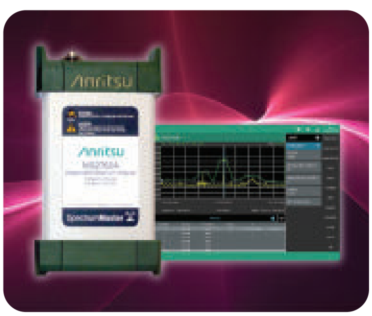

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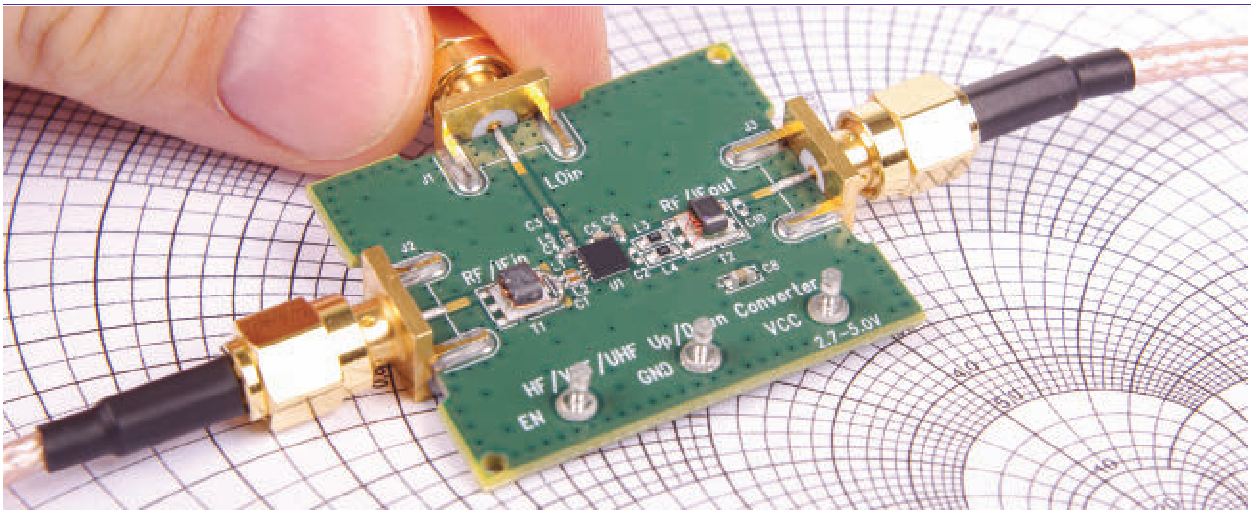

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An Introduction to **S-Parameter Network Flow Diagrams**

This article introduces S-parameter network flow diagrams and how they may be manipulated to solve real-world problems. Knowledge of network flow diagrams is a prerequisite to interpret the 12-term VNA error-term model, as it relates to calibration.

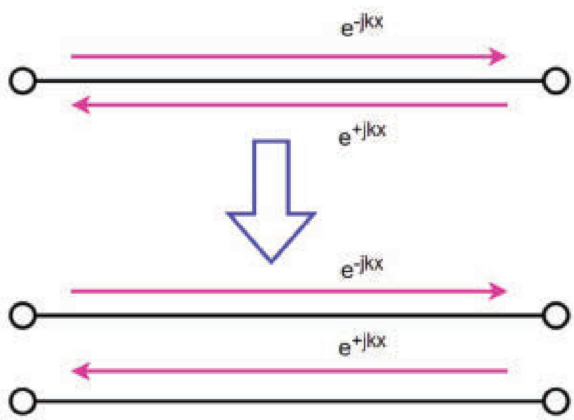
By Brian Walker, *Senior RF Engineer SME, Copper Mountain Technologies*

This is the second in a multi-part series of articles on vector network analysis. Part 1 introduced the VNA, how such instruments work, and some of their applications in the lab.

ENGINEERS SHOULD BE FAMILIAR with the solution of Telegrapher's equation for RF signals on a transmission line. That is:

$$V(x) = V_1 e^{-jkx} + V_2 e^{+jkx}$$

where the transmission line is oriented along the x axis. It shows that a transmission line will support RF propagation in both directions simultaneously. The first term represents a wave moving in the positive "x" direction, and the second represents a wave moving in the "-x" direction. Because these two waves can be separated and measured by a vector network analyzer (VNA), they may be considered separately. S-parameter network flow diagrams do just that.



1. This diagram, which depicts the forward and reverse signal flow, represents the first step in the graphical transformation. Images courtesy Copper Mountain Technologies

What Makes Up an S-Parameter Network Diagram?

The first step in the graphical transformation is shown in *Figure 1*. Signals flowing in each direction are shown in separate paths, with signals moving from left to right on the top and those moving from right to left on the bottom.

Next, we account for reflections by adding arrows, which allow for a portion of a signal moving in one direction to be channeled to the other direction, transferring from the bottom of the diagram to the top or from the top to the bottom. These are the vertical arrows shown in *Figure 2*.

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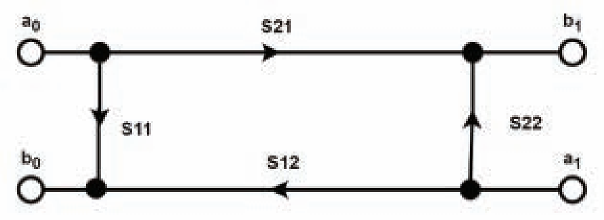


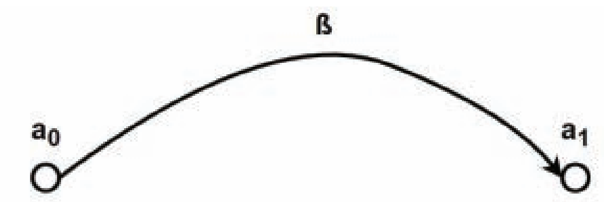
2. Adding arrows to an S-parameter network diagram accounts for reflections, which enable a portion of a signal moving in one direction to be channeled to the other direction, transferring from the bottom of the diagram to the top or from the top to the bottom.

The actual voltages have also been replaced with S-parameters, which represent the relative amplitude and phase of the voltages with respect to the incoming stimulus signal. The nodes where reflections occur have been labeled with "a" and "b" designations. The "a" nodes may have signals entering them from outside the network, and the "b" nodes have signals exiting the network. This is a convention, but it needn't always be the case.

Note that although the diagram of *Figure 2* looks like a ladder network with two ports on each side, it's nothing of the sort. There's only one actual RF port on each side, each one with two contrived nodes—one for the forward wave and the second for the reverse wave. Network flow diagrams are discussed in some detail in References 2 and 3.

How Can the Diagram be Manipulated?

The network diagram shows signals traveling in only one direction. The mathematics of network analysis must take this into account. *Figure 3* depicts a single flow connection. Here, it can be said that a_1=β*a0.



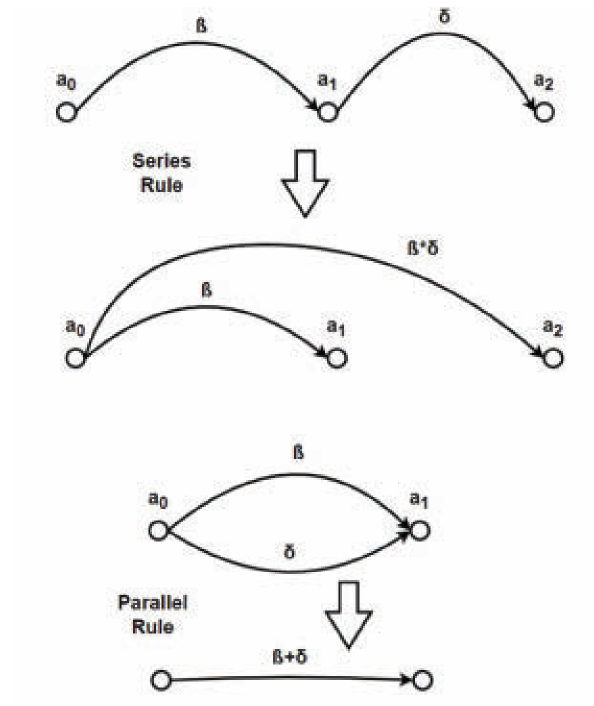
3. Shown here is a single-direction signal flow.

The math works only in the direction of the arrow, so:

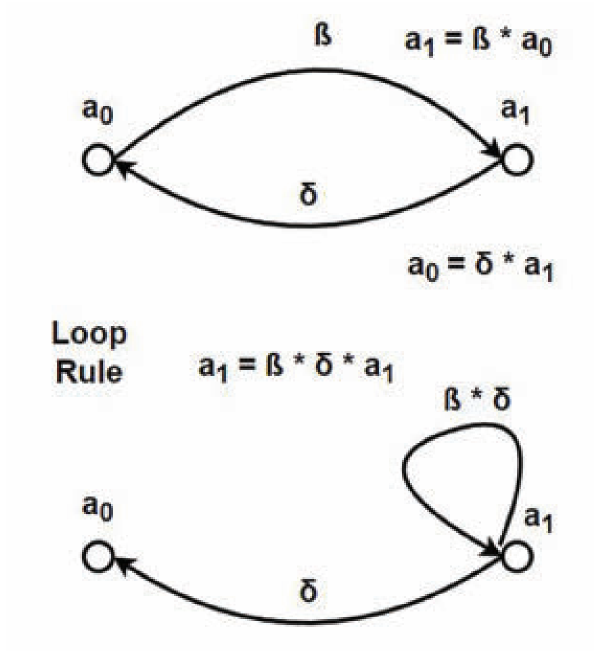
$$a_0 \neq \frac{1}{\beta} * a_1$$

With this simple rule in mind, one may derive all other rules of diagram manipulation. The first two, series and parallel rules, are as shown in *Figure 4*.

For two signal paths connected in parallel but with opposing directions, the parallel rule doesn't apply. Thus, one must consider the two equations represented by the arrows. *Figure 5* shows this condition.

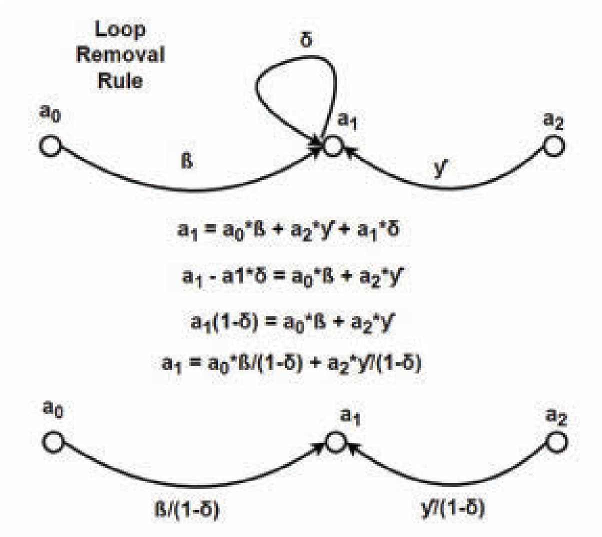


4. Building on the single-direction rule, one may derive all other rules of diagram manipulation. Shown here are the first two: series and parallel rules.

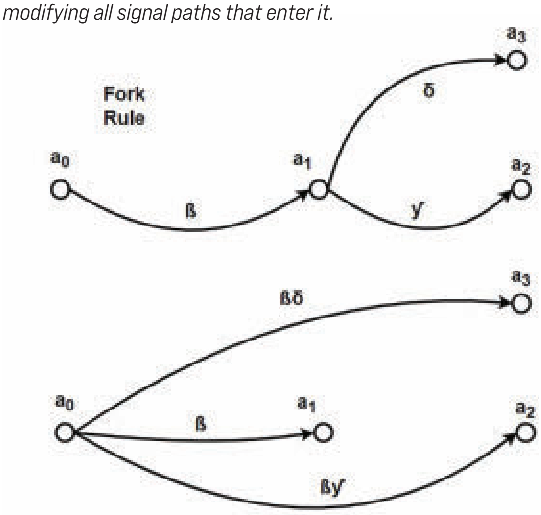


5. When two signal paths are connected in parallel but with opposing directions, the parallel rule doesn't apply. Thus, one must consider the two equations represented by the arrows. As shown here, one of the signal paths is replaced with a "loop."

One of the signal paths is replaced with a "loop." Resorting to another simple calculation, a loop may be removed by modifying all signal paths that enter it *(Fig. 6)*. A loop will always have at least one signal path entering it and signal paths leaving a loop aren't altered.



6. Through another simple calculation, a loop may be removed by modifying all signal paths that enter it.



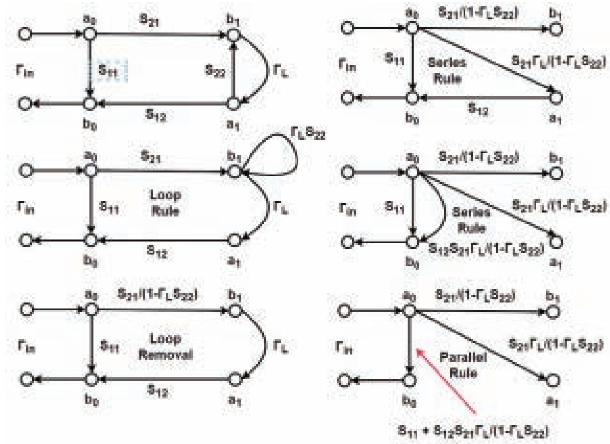
7. The fork rule solution uses the series rule twice.

Finally, consider the case of forking signal paths. The simplification uses the series rule twice, as shown in *Figure 7*.

The point of all of these transformations is to arrive at a diagram where every node is a function of a single independent input node, or the driven node a_0, in these diagrams.

A Practical Example

We can look at the simple example of a device with known S-parameters loaded with an arbitrary load Γ_L as in *Figure 8*.



8. Here's a simple example of a device with known S-parameters loaded with an arbitrary load Γ_L.

We want to simplify the network such that every node is a function of a_0 alone.

After this is achieved by applying the rules given earlier, the input reflection coefficient of an S-parameter network loaded by Γ_L has the familiar result:

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L} \quad \text{(Mason's rule) [1]}$$

This result makes intuitive sense. If the isolation S_{12} is small, the load will have little effect on the input of the network, and one will measure S_{11}. If the load is 50 Ω, then Γ_L is zero and again one measures S_{11} at the input.

Much longer networks may also be collapsed into this more deterministic form. There isn't much need to manipulate S-parameter networks in this way. But being able to do so provides an intuitive understanding of their function, which will be helpful for understanding the 12-term VNA error model. This model and a few others are essential parts of the calibration repertoire.

Conclusion

Network flow diagrams are a useful tool to analyze systems and devices characterized by S-parameter matrices. The diagrams promote an intuitive understanding of the interaction of the voltage waves moving in each direction. In the next article of this series, we will introduce 8- and 12-term vector-network-analysis error models expressed as a network flow diagram, which are helpful to interpret where the errors occur and what they mean to the measured result. ■

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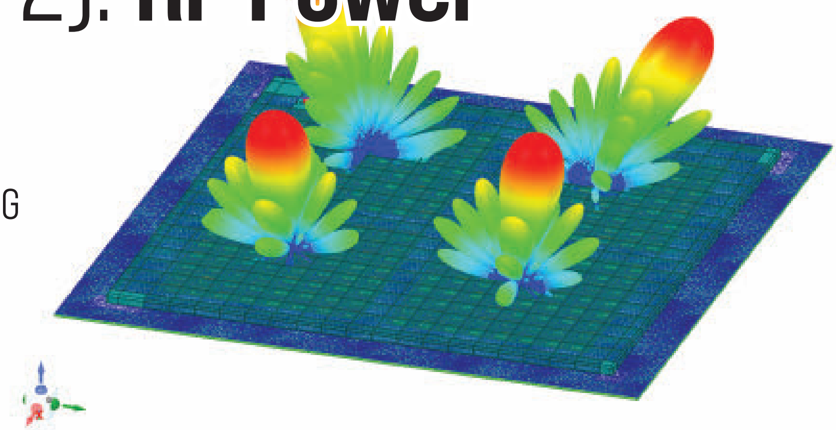
The 7 Pillars of 5G/6G RF System Design (Part 2): **RF Power**



How does power consumption create a set of complex, interrelated conundrums for 5G system design engineers?

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

AS DISCUSSED IN PART 1 of this series, customer service providers (CSPs) manage telecommunication systems as a business that yields profitable activity. The determining factor upon which they focus is the total cost of ownership (TCO). TCO is a numerical value driven by direct and indirect components.

The direct elements include:

- **Number of base stations** to serve a given region. Does the carrier choose fewer base stations with more power, or more base stations with lower power to cover a service area?
- **The electric bill.** What are the power costs to a base-station operator, and how can they be managed? What power profiles are expected at peak traffic and low traffic periods?
- **Reliability.** How long will the equipment operate before maintenance schedules dictate replacement of modules or subsystems? How do we minimize costly "truck rolls" for on-site repair, adjustments, or service? How is reliability influenced by power consumption?
- **Equipment and technology.** What does the equipment cost? Does the carrier use cutting-edge or more conventional technology? Does the local base station have edge-processing capabilities, requiring more hardware and support systems (cooling, power conditioning, monitoring, diagnostics, etc.?)
- **Installation.** Municipality permits and licenses for tower or antenna head installations aren't cheap. Some locations may be more costly than others. Tower structures may need to be erected in some cases, where in other cases buildings or other existing infrastructure could be used to elevate antenna systems.

Indirect factors consist of:

- **Customer satisfaction.** This is related to network performance (including key performance metrics such as call drop rate, sustained data rate, or effective coverage area). When network performance degrades or otherwise proves unsatisfactory, customers vote with their wallets and jump to different carriers.
- **"Second Order" costs.** These stem from training, software updates, management, documentation, insurance, and other ongoing support and administrative functions.

The Power Bill is the Elephant in the Room

Paying the local electrical utility is the major driver for TCO and the number one sustainability issue for 5G base stations. Energy consumption accounts for about half of all telco network operations costs. Electric power demands for 5G base stations are expected to be dramatically higher than previous-generation 4G systems.

5G base stations consume much more energy than 4G base stations: MTN Consulting, from April 2020, notes that the typical 5G site requires over 11.5 kW, which is nearly 70% higher than a previous-generation base station supporting a mix of 2G, 3G, and 4G radios *(Fig. 1)*.

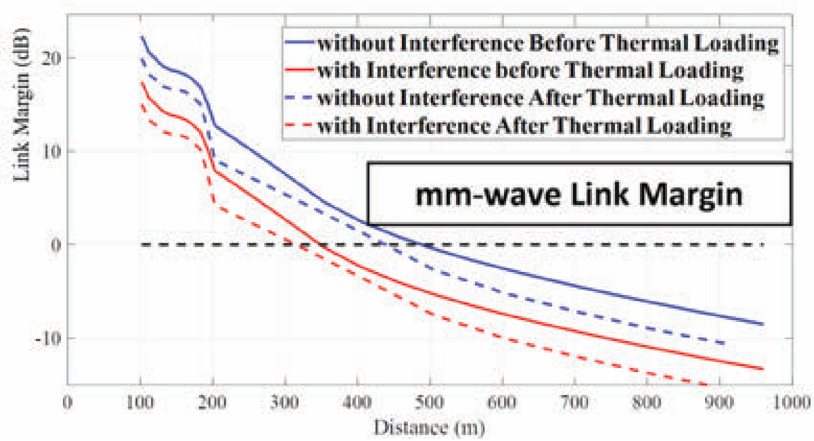
This increases the demand on the local power grid, as well as on the requirements for backup power systems that must keep base stations running in the event of a supply power outage. Consequently, sustainability is pushed unfavorably away from realizable self-power options intended to support environmental initiatives (i.e., local solar, wind, or water power.)

Losses are higher when it comes to the simple delivery of power to these base stations, requiring that the distance from supply to base station be limited where possible. Finally, power draw is further exacerbated by the deployment of co-located edge-computing resources to support local IoT deployments and low-latency network applications—things that weren't available in 4G networks.

What, then, are the major drivers for electric power costs for a base station, and how can they be optimized to reach the best TCO?

From this Nokia treatise, we can see that a typical base station consumes power in the following manner:

- 10% of power is lost in the transmission from power plant to base station. (This is a cost factor in the sustainability equation.)
- 80% of the resulting power in the base station is spent in the radio access system. The rest is spent in transport, core, and operational support systems (OSS.)
- An estimated 30% of the power delivered to the BTS is actually used in direct revenue generation; the rest is used in auxiliary passive components like air and power conditioning, fans, and power supplies.



1. The link margin between a 5G base station and a mobile device degrades by at least 50 m due to increases in antenna temperature. Ansys

Base-station technology developers are responding to these electrical cost challenges by turning to a number of solutions to conserve power, reduce the TCO, and deliver more sustainable solutions with reduced carbon footprints:

AI-based solutions for managing energy use in peak and off-peak periods

During off-peak demand periods, unused active and passive systems can be put into a standby "sleep mode" or even powered down entirely. Optimization of area coverage is also being optimized through the use of AI/ML-based azimuth and elevation angle adjustment for beamsteering. In addition, ML algorithms are being employed to monitor power draw and identify anomalies, failures, or leakages.

Trading antenna size for transmitter power

An engineering method that's been adopted directly ties the RF link budget to the effective isotropic radiated power (EIRP). The EIRP is a product of the total transmitted power and the effective size of the antenna system as determined by its radiation pattern directive gain. The larger the antenna system, the greater its directive gain. Larger arrays can achieve the same EIRP as a smaller array by using less power per radiating element.

Larger arrays enable lower-power transmit chains to achieve the same EIRP if RF transmitter amplification is performed at the element (or sub-array) level. This makes transmit functions less complex, cooler (heat generation is spread out across more elements), and less costly to design and maintain (though in the end you will need more of them). Another potential benefit with larger arrays is they make more multiple-input, multiple-output (MIMO) channels available, which is a consideration in the total service capability as well.

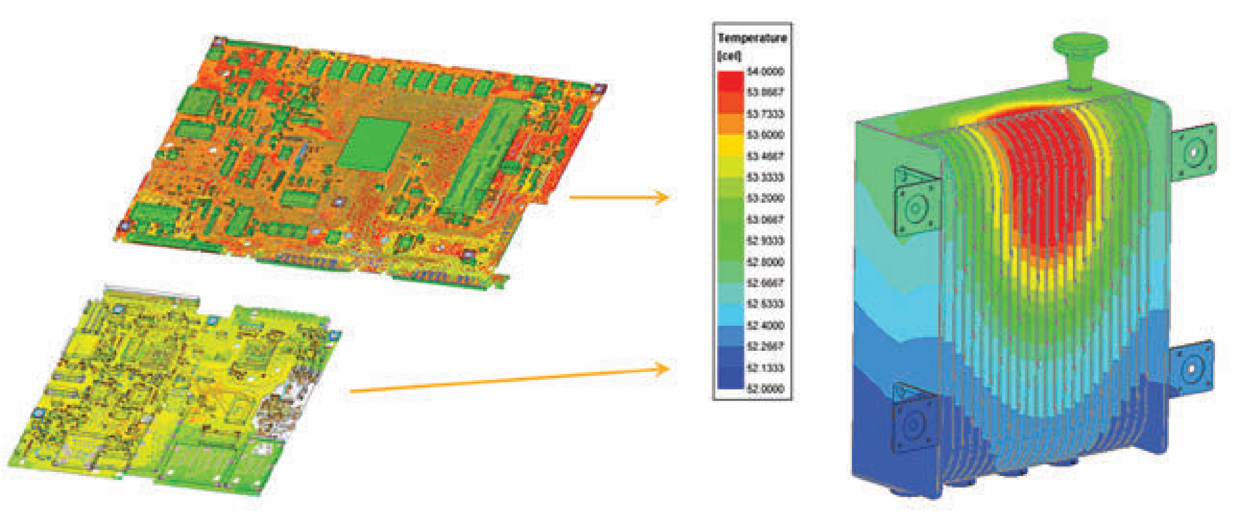
Naturally, deploying larger arrays has its downsides. In addition to increasing size, weight, and thermal challenges, they require more transmit channels or more analog signal beamforming, with an impact on potential RF power loss.

Trading transmitter and receiver amplification processes

Another emerging system engineering approach involves larger arrays with lower power per channel, which in turn enables lower-cost semiconductor alternatives. More specifically, lower power consumption makes it possible to use silicon-based processes, such as silicon germanium (SiGe) or CMOS. Higher transistor power usually requires the inclusion of costly III-V compound semiconductors like gallium arsenide (GaAs), gallium nitride (GaN), or even more exotic combinations.

Down at the VLSI design level, transistor chains require high linearity to avoid channel crosstalk from modulation impurities generated in the amplification processes. Power efficiencies in these amplifiers range from 30% to 45%, which represents power loss and thermal generation. The higher the power in the channel, the more acute the challenges.

Low-noise amplifiers (LNAs) at the receiver front-end require matching for optimal noise. LNAs can consume appreciable power in the overall system power budget. This is critical for maximizing the receiver's sensitivity. But optimal noise match often comes at the expense of power efficiency. Trading power efficiency for noise match is seen as a necessary performance-driven tradeoff to make.



2. This power and thermal integrity simulation was performed using Ansys SIwave and Icepak on a BSU PCB, showing the consequent heatsink thermal effects. Ansys

Another component that drives power consumption at the VLSI level is the high-speed sampler in the analog-to-digital (A/D) components used in the receiver baseband stage, and the digital-to-analog (D/A) parts in the transmitter exciter and modulator. In general, the higher the sampling speed and the greater the number of bits used in the A/D and D/A components, the more power they consume.

The trend toward gaining spatial diversity through MIMO methods is clearly on the rise. However, more MIMO channels require more receiver channels, which leads to the need for more LNAs in the system design. Similar to transmitter power amplifiers, tradeoffs at the semiconductor level must be scrutinized to optimize the implementation. Tradeoffs also extend to power requirements versus thermal considerations—a conundrum that can be aggravated by the fact that best noise match is often achieved at high bias current points.

How Computational Multiphysics Simulation Can Help

From the above discussion, it can be safely concluded that optimizing power draw and costs for a base-station implementation is a complex multiphysics optimization. To fully understand the cost of both radio head and auxiliary systems, it becomes necessary to develop and size thermal mitigation approaches at the chip, package, and board level, experiment with the size of fans, compare against the impact on air-conditioning requirements, and more.

Heat causes mechanical and structural challenges in boards, chips, antennae, and chassis through material expansion and warping. Power consumption itself is an electromagnetic phenomenon *(Fig. 2)*. These directly interdependent and interactive factors are driven by communication-system data loading (traffic) and RF drive levels. They all affect component and system reliability, which translates into operational, maintenance, repair, and replacement costs.

TCO is thus ultimately a computational multiphysics problem. Tools for capturing the electromagnetic fields associated with an antenna and its supporting electronics, as well as the thermal effects their operations generate, are needed to ensure signal, thermal, and power integrity at both the component and system level. The structural impact of heat requires another simulator that models and simulates mechanical effects.

Converging on a solution for such a dynamic, multivariant problem can be something of a Gordian Knot for mere mortals. It calls for an appropriate optimization platform that takes advantage of the nonlinear capabilities of ML algorithms to accelerate its resolution. Workflows/methodologies and robust interfaces between all of these tools allow not only the proper data interactions and file sharing, but also facilitate scaling the problem from micro to macro while preserving accuracy in modeling and simulation results.

Finally, a tool for model-based system engineering (MBSE) ties it all together. It helps a design team drive the computational, multiphysics-based, virtual-prototyping effort from the perspective of meeting specifications and KPIs while experimenting freely to develop a holistically optimized end product that maximizes operational profit for the customer service provider.

But it must not be forgotten that power is simply one of the seven pillars that must be completed for 5G system design. The next installment in this series will examine the second pillar: antenna sizing. ■

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Self-Governing Wireless Networks Can Empower Smart Buildings

When it comes to smart buildings, conventional low-tech facilities can also benefit from smart technology.

*By **Thomas Steen Halkier**, CEO, NeoCortec*

THE MOVE TO SMART BUILDINGS AND facilities will significantly impact the marketplace. According to *FortuneBusinessInsights.com*, the smart-building market is projected to grow from $80.62 billion in 2022 to $328.62 billion by 2029, at a CAGR of 22.2% in the forecast period from 2022-2029 *(Fig. 1)*.

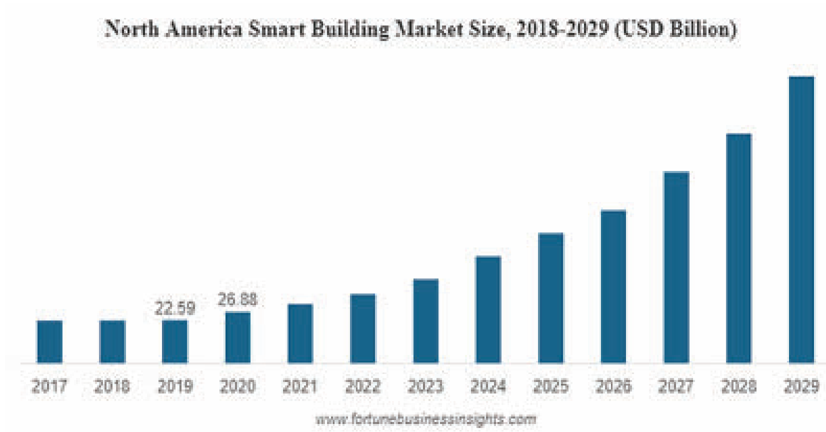
Making buildings and facilities smarter isn't just a fad—it delivers real-world operational and financial benefits. Intelligent sensors provide data that gives useful information, for example, to achieve reduced heating costs, optimize ventilation and HVAC, manage lighting, and improve the overall energy efficiency of the building. A smarter building is more sustainable, with reduced maintenance costs. It also optimizes use of its spaces, making occupants of the building more comfortable, which often leads to better productivity.

The cost barrier to adoption of such systems is real but often overblown. Still, facilities managers are sometimes hesitant to introduce intelligent systems in older buildings because of the cost of cabling to connect to the sensors and subsystems.

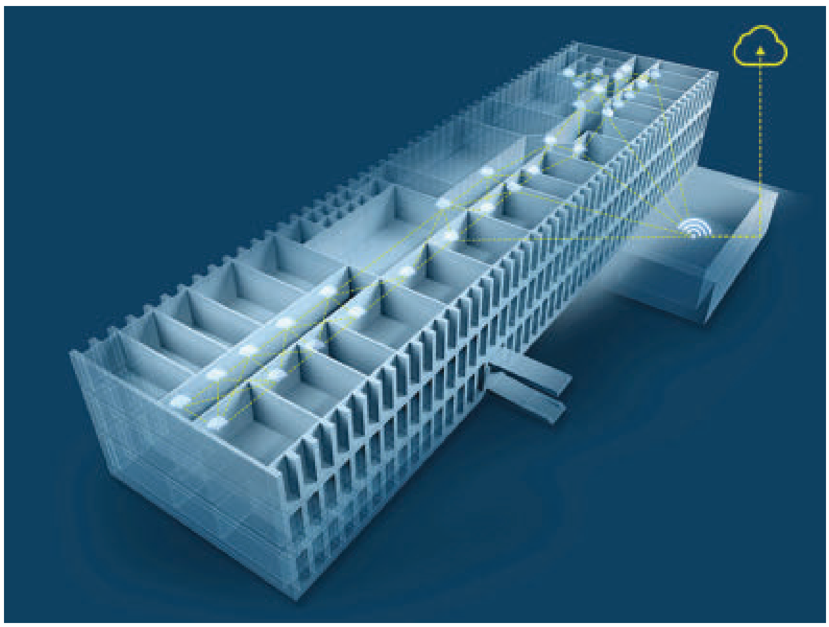
However, wireless IoT and cloud technology has reached the point where you can manage a smart building without cables. Data can easily be sent wirelessly to the cloud or building management systems, bypassing the need to re-cable the building. The challenge is nonetheless complex—it's not possible to simply visit a hardware store and buy a do-it-yourself hardware kit. Therefore, facilities managers will need the advice of a consultant to select the most appropriate solution for their sites.

A good example of such a wireless smart-building implementation can be found in the upgrades made to a Copenhagen office building. Nrlyze, a company that focuses on optimizing energy systems to reduce energy waste in the real-estate sector, implemented the self-governing and flexible NeoMesh network technology from NeoCortec.

The wireless network enabled the company to quickly roll out a large and capable sensor infrastructure in a cost-effective manner. It sets itself up and automatically establishes connectivity between the sensors, easing integration efforts and reducing the need for complex cable installations *(Fig. 2)*.



1. According to the FortuneBusinessInsights.com "North America Smart Buildings Market Size (2018-2029)" report, the market is expected to soar to $328.62 billion by 2029. FortuneBusinessInsights.com



2. Diagram of the Nannasgade deployment: Sensors connect in a mesh to other sensors on the same floor as well as other floors, with those at the lowest levels meshed with the gateway in the basement. NeoCortec

Wireless Solutions Ease "Final Meter" Pressure

Creating a smart building with wireless mesh technology is the most cost-effective way to implement an intelligent facility infrastructure, especially when it comes to pre-existing buildings. In such older structures, getting from the wiring behind the wainscotting to the intelligent systems inside the rooms presents a significant "final meter" problem to connect the cables behind the walls to the intelligent sensors and devices.

Often, these buildings don't even have wires (except mains power) at all. Therefore, the challenge is both to power devices and get data in/out of the devices.

Wireless solutions come in different types, based on how the network is managed. This will impact the final implementation's ability to operate and respond to challenges.

A flat and distributed node-based mesh topology has significant advantages when compared to star-type hierarchical networks with a central processing hub. Many mesh technologies are still star-based in nature. However, truly decentralized mesh wireless solutions, such as NeoMesh, offer robustness, self-healing, and the ability to get around obstacles in a way that's not possible with a star-based network.

If a node in a star-based solution has a poor or even a broken link to the gateway, for example, there's no redundant link that can be leveraged. In a decentralized structure where all nodes can act as routers of data on behalf of each other, there's no single point of failure, and if an individual node goes down, the system re-routes through an alternative pathway.

Of course, there still needs to be a gateway from the mesh to the building's systems. An advantage of a mesh solution like the flexible NeoMesh network technology from NeoCortec is that you only need one central gateway to collect all of the sensor data and transmit it to the cloud. There's no need for repeaters or additional gateways to connect different parts of the network. Embedding the

NeoMesh protocol in Nrlyze's platform addressed the need for network size, scalability, installation flexibility, and optimal performance of all nodes in the network.

NeoMesh Network Technology

The advantage of NeoMesh network technology over legacy mesh networks such as Zigbee, Thread, Wi-Fi, and Bluetooth is that it addresses issues like power consumption, network size, network management, and high reliability in transporting data. For example, it synchronizes the nodes to each other timing-wise, for ultra-low power consumption in all parts of the network. Decentralized network management significantly reduces vulnerability by preventing any single point of failure from impacting the network.

NeoCortec developed its second-generation mesh technology to directly address the world of wireless, low-power sensor networks for smart-building and other IoT applications. NeoMesh leverages self-governing nodes to form networks autonomously, allowing for extreme scalability, node mobility, and optimum performance. Each node in the network is asleep most of the time and only wakes up when necessary.

Consequently, all nodes are equally power-efficient, while maintaining full routing capabilities. The result is that the entire network can be low power and thus run on batteries for many years.

Here, it's also vital that other mesh networks are able to claim that nodes consume very little power and, therefore, run off batteries. However, they also require hubs or repeaters that are much more power-hungry. As previously mentioned, with NeoMesh, each node is equal, so there's no need for hubs or repeaters, and the entire system can be battery-powered.

NeoMesh network technology decentralizes network management, with the functional relationships between the nodes created and maintained locally, making it relatively simple to deploy from a few to a few thousand nodes in a network. The NeoMesh routing protocol creates a route for the data packages to travel through the network. It manages any data-transmission issues, with real-time routing of data over long distances through multiple hops, while still using very little energy.

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Network Robustness and Security

NeoMesh also meets the robustness and security standards demanded by building and facilities managers. The high level of security is ensured through ACK/NACK, AES-128 encryption, CRC32 handshake, and Challenge/Response authentication between source and destination. In addition, reliable radio communication is ensured through frequency hopping for more robust performance.

The network is also easy to deploy because it's self-forming—the system grows as you add new nodes, which automatically connect to the network. All you need are the communication nodes themselves (with batteries), antennas, and, of course, the appropriate sensors.

The second-generation mesh technology behind NeoMesh makes it a versatile and robust wireless network for connecting nodes, with true low-power connectivity, flexibility, and scalability, as well as no recurring licensing fees. Hundreds, even thousands, of devices can be included on the same network, so an entire building of any size can be covered. Installation creates no disruption—devices are stuck to a wall in minutes. Thus, employees can carry on working while the network is set up.

Incremental Network Setup

Another advantage to NeoMesh is that upgrading a building to a smart facility can be done incrementally, adding one aspect of functionality at a time rather than all of it at once. This means that there's a lower investment threshold for any given building owner, since they only have to install and pay for functionality that brings value, as required. The scalable nature of a NeoMesh network (up to 65k nodes) also means no additional gateways or repeaters are needed to cover very large areas, as long as there are enough nodes to provide sufficient density in the network.

In the case of the three-floor Copenhagen office building example, it only took a few hours to install all 93 temperature and humidity sensors, which automatically connected to each other due to the self-governing NeoMesh network protocol. Using battery-powered sensors meant no additional power cables were required, and after installation, the sensors started to transmit data to the cloud without any need to configure the network.

Conclusion

To improve operation and reduce inefficiencies, advanced analytics must be provided for building owners and facility managers, enabling them to fine-tune their building control systems. Exact and continuous measurements are essential in this optimization effort, and the flexible and scalable NeoMesh network technology can facilitate that smart-building functionality in an efficient, low-power, and cost-effective manner. ■

11 Myths About **Power Distribution**

Some misconceptions persist about power distribution while some old rules of thumb should be retired, particularly as they apply to interconnects. In truth, power distribution needn't be a mystery.

By Istvan Novak, *Principal Signal and Power Integrity Engineer, Samtec*

AS NEW DESIGNS COME ONLINE with their associated power requirements, designers face new power integrity challenges. Unfortunately, some misconceptions exist about power distribution and some old rules of thumb need retiring, particularly as they apply to interconnects. What follows are some of the most common myths about power distribution in connectors and PCBs. The bottom line, though, is that power distribution doesn't have to be a mystery—we need only to pay attention to the relevant details.

1. A connector's power rating is the same regardless of stack height.

For connectors, the limiting parameter is the self-heating due to the flow of current through it. If you take the current, square it, and multiply by the resistance, you get the power that's dissipated in the connector. Too much heat will slowly degrade or even destroy the connector. As a result, designers need to carefully consider how high that temperature will rise during operation.

So, does the same current rating apply to different stack heights? No. For each stack height, the resistance of the connector will be different. Therefore, power dissipation will also be different, and the connector will have a different rating. Moreover, heat from the middle of taller connectors can't escape so easily, further increasing the maximum temperature.

2. The connector's current rating is the same for vertical and right-angle styles.

This is sometimes true, but not always. If the total pin length is the same between right-angle and vertical, then the current rating will be comparable.

However, if the right-angle configuration has a different length compared to the baseline vertical, it will be different because a pin's resistance is approximately linearly proportional to its length (it would be exactly linearly proportional if the cross-section of the pin or blade was uniform throughout its entire length). In summary, dissipated power translates to temperature rise, and it can be hugely dependent on construction.

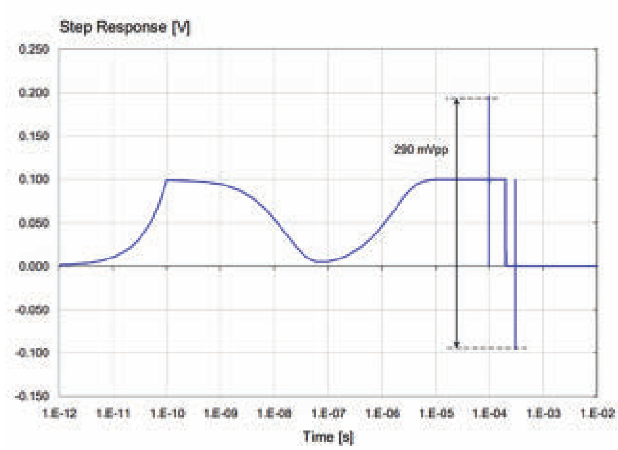
3. Current-carrying capacity testing can be AC or DC.

No, standard current-carrying capacity (CCC) testing is strictly DC. AC current (or a superposition of DC and AC currents) would heat up the connector. Then, we would have to consider the root-mean-square (rms) value of the current, which would depend on several parameters of the AC current, making it harder to specify a limit in simple terms. For more information, check out "Simplified Pulse Current Duty Cycle Guidelines."

4. DC penetrates the connector cross-section uniformly.

It's often thought that DC penetrates conductor cross-sections uniformly. But it doesn't necessarily, unless we enforce strict, often impractical, conditions. This misconception often comes from using a typical textbook calculation of resistance that assumes current penetrates a cross-section uniformly and doesn't change along the lengths.

That assumption breaks down when a conductor's aspect ratio isn't long and skinny, but rather it's thicker (like a power-connector blade). One can't assume that the current penetrates a cross-section uniformly, because it very much depends on the conductor geometry around the connector. The actual current distribution can't be answered without knowing the circuit characteristics.



1. Illustration of worst-case transient peak-to-peak noise of a PDN with flat impedance, but a notch driven into the impedance profile. Note the logarithmic horizontal scale. Images courtesy of Samtec

The good news is that if you perform a DC simulation with any of today's professional simulators, you will get the correct answer. There's a bigger risk if you do not.

5. Surface roughness is only a concern for high frequencies.

The impact of surface roughness is very hard to prove through measurements. But engineers have known the impact of surface roughness at high frequencies for decades, and the industry has come to a consensus on how to describe and capture its impact. It's hard to simulate at high frequencies, and such simulations must be done iteratively with detailed knowledge of the surface topology so that we can accurately set the parameters of the simulation.

You can't use these same simulations at low frequencies. It would require meshing of the exact surface topology, which isn't a practical task. This mostly applies to PCBs, but connector contacts aren't perfectly smooth either (it's easier to determine the surface topology of connectors pins or blades; a PCB's conductor layers are obscured). Moreover, even if you know the roughness of the copper sheet before it's laminated within the PCB, the processing steps change the roughness.

The bottom line: Surface roughness is a problem not only at high frequencies but is also a potential problem for DC. It's just much harder to put a number on it.

6. Lowering PDN impedance on the PCB will reduce noise.

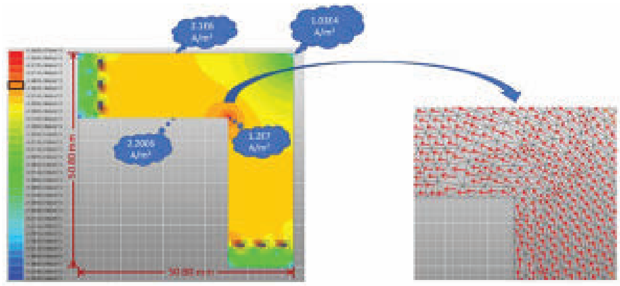
Since the early 1990s, a favored means of designing a power-distribution network (PDN) has been with reference to its impedance. The misconception: Lowering the impedance in any frequency range will lower the noise.

What really matters for worst-case transient noise is the impedance value together with flatness. Flatness (how much the frequency response fluctuates), for example, is a significant contributor to the worst-case transient noise *(Fig. 1)*.

7. Temperature limits are meant to protect the connector contact.

Temperature limits are determined by what fails first. In the case of connectors, it's widely believed that limiting the temperature they see is on behalf of the contact. Connector contacts are typically a composite layered material, often copper with nickel and gold plating. With such materials, it's important to understand that there's a temperature limit before some degradation occurs.

But the plastic used in connectors may have a limit as well, and it could be lower than the contact (especially if the connector is manufactured using low-cost nylon). If that limit is reached, the connector's plastic housing degrades and becomes soft, which in turn degrades the precision of the blade/pin position.



2. A right-angle turn at DC causes current discontinuity, which can result in overheating (right) blow out of small inner corner, showing up to 5X discontinuity at the right angle.

Typically, this isn't a concern if the connector's body is composed of a liquid crystal polymer (LCP). Then, the temperature limitations are usually set depending on the type of plating on the contact.

8. Inductors aren't good for PDNs.

An old maxim holds that "if I purposefully design in a component, such as a series inductor, that cannot be good for the PDN under any circumstances." In fact, situations arise where series filtering is very useful, such as using an inductor to filter out noise from noisy loads like a DC-DC converter.

9. X5R capacitors are worse than X7R for DC bias.

This was true 30 to 40 years ago, but in general, it's not the case today. Now, it really depends on the material and manufacturing process details of the multi-layer ceramic capacitor. Use a verified vendor's datasheet or measure it directly.

10. Small-value capacitors are better for high frequencies.

This is a very widely held misconception because decades ago it was true. As frequency goes up, inductive reactance goes up, too, so lower inductance helps. The physical size of the capacitor affects its inductance (with a smaller capacitor, we expect lower inductance).

In the past, a 1-nF capacitor was much smaller than a 100-nF part. However, dielectric materials and manufacturing processes have evolved to the point where we can get a very wide range of capacitance values in the same-size package. Of course, the inductance still depends on the size of the capacitor, but not necessarily on its capacitance value.

11. Right-angle turns hurt only high-frequency or high-speed signals.

The truth is that current crowds at sharp corners and, thus, resistance increases for all types of signals, whether at low or high frequency. The current density isn't uniform at the right-angle turn (almost 5X at the inner corner in *Figure 2)*, which can cause discontinuity and perhaps result in overheating. The better approach is to make an arc, just like at high frequencies. ■

SOSA-Aligned OpenVPX Chassis: Platform and Design Trends

SOSA ramps up heat dissipation with the latest OpenVPX chassis. This article looks at the latest trends in backplanes and chassis cooling.

By Justin Moll, *Vice President of Sales & Marketing, Pixus Technologies*

SENSOR OPEN SYSTEMS ARCHITECTURE (SOSA) consortium products continue to pick up steam in the Mil/Aero embedded-computing market. In short, a primary goal of SOSA is to limit the wide variation of MOSA (Modular Open Standard Architecture) designs to a more manageable level. The benefits to the military (at least theoretically) are ease of integration, less training time, a more plug & play ecosystem, less confusion, less vendor lock, lower costs, and more. It also gives them the ability to have a more manageable innovation process.

By proving the military's design goals at the front end, this helps the engineering groups in the open standard committees to come up with appropriate solutions. This hand-in-hand approach keeps the design community focused and solutions-oriented.

SOSA is primarily focused on 3U and 6U OpenVPX-based open standard systems, but other specialty architectures are also emerging. SOSA is leading the "demand" for certain routing profiles for the backplane that accept certain slot profiles for the OpenVPX boards. From a chassis platform perspective, SOSA's efforts are driving the backplane speed requirements, hotter plug-in cards that require more advanced cooling solutions, the RF and fiber interfaces that lead to new I/O solutions, and chassis management.

Backplanes for SOSA-Aligned Systems

Backplanes requiring 100 GbE (4 lanes of 25 Gb/s) and often PCIe Gen4 (16 Gbaud/s) are common for SOSA-aligned systems. However, 40 GbE is often acceptable. The backplanes will typically have fiber and/or RF interfaces.

We're seeing clear delineations of which versions (NanoRF, SMPN, MT options, etc.) that are commonplace. The NanoRF is particularly notable as it offers up to 20 RF interfaces along with MT fiber and comes in various mixes/configurations. The MT ferrule options are expanding from the supplier base with 3 MT and even 4 MT options (which typically have 12- and 24-fiber options) that fit into the standard VITA 67.3c or VITA 66.1 envelop size, respectively.

Chassis Cooling

The high-wattage systems are driving more advances in cooling. A 19-in. Mil-rugged rackmount chassis *(Fig. 1)* can be designed to hold up to 16 slots of VITA 48.2-compliant conduction-cooled boards. With special card mats, the heat is dissipated to the fins where airflow can be applied with Mil-grade fans to cool the fins. The approach as a rule of thumb can cool approximately 100 W/slot.

1. One way to manage faster and hotter plug-in OpenVPX boards is via a SOSA-aligned enclosure, which provides airflow over the fins of specially made conduction-cooled card mats. It can cool over 1500 W in the system. Pixus Technologies

In a fully loaded 16-slot system, a mezzanine-based chassis manager can affix to the rear of the backplane, so that it doesn't consume any slots. The "Tier3+" SOSA-aligned chassis manager can monitor/control intelligent fans and SOSA VITA 62 power-supply units (PSUs), provide graceful shutdown and sequenced initialization of plug-in boards, and much more. The specification requires the use of a SOSA-aligned chassis manager in the enclosure platform.

Similarly, this approach can be utilized in an ATR format enclosure. The ATR *(Fig. 2)* can also be designed with special I/O interface boards both on the front and rear of the enclosure to provide more I/O space. It should be noted that not all applications would allow for this type of configuration.

For even hotter system requirements, there are newer airflow approaches *(Fig. 3)* such as VITA 48.7 (Air Flow By) with airflow over the fins of the plug-in cards, VITA 48.8 (Air Flow Through), and new concepts meant to optimize slot spacing with similar approaches. Liquid cooling is often the last resort with its own complications, high costs, smaller ecosystem, and infrastructure requirements. However, some of the high-end SOSA designs (and future aspirations) seem to make the use of liquid cooling inevitable.

I/O Considerations

As discussed, in the unit in *Figure 1*, these applications sometimes require a wealth of I/O interfaces. While SOSA may limit some of them (or shift more to fiber, etc.), many designs have almost more I/O than space is available by typical means.

One potential solution is the use of a special serial multiplexer board that provides for the condensing of multiple serial ports into one compact interface. This type of design can save significant I/O panel space in a chassis platform.

In this example, a single USB 2.0 Micro interface on the multiplexer mezzanine board allows for 28 UART connections, two USB interfaces, and a chassis manager interface on a board that measures approximately 50 × 112 mm. The board can be mounted to the rear of a backplane like a mezzanine in the same type of approach as the SOSA-aligned chassis manager described earlier.

An Exciting Future

While SOSA applications look to have a bright future, a wealth of other designs still don't need to meet those requirements. As mentioned, SOSA has many benefits, but it can be overkill, or conversely, too restrictive for many design needs. It will be exciting to see the continued evolution of SOSA and other MOSA technologies for Mil/Aero applications. ■

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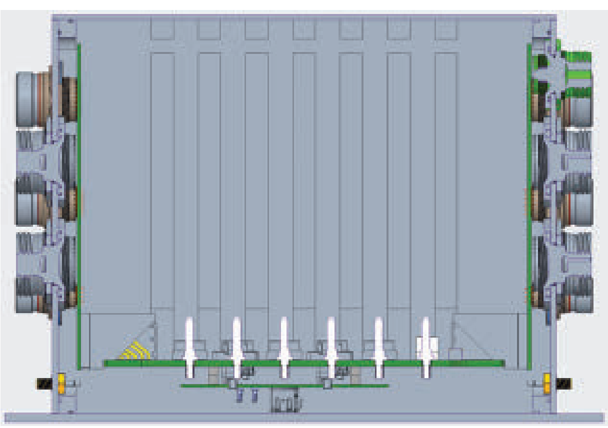

2. Placing a mezzanine-based, SOSA-aligned OpenVPX chassis manager below the backplane saves a slot from being consumed. Pixus Technologies

3. The VITA 48.8 specification provides for airflow to go through the modules themselves, enabling more heat to be dissipated in the system.

LTCC Bandpass Filter Screens 6.7 to 8.6 GHz

Mini-Circuits' model BFHKI-7851+ is a low-temperature-cofired-ceramic (LTCC) bandpass filter with passband of 6.7 to 8.6 GHz. Passband insertion loss is typically 3.4 dB, with return loss of typically 13 dB. Lower stopband rejection is typically 70 dB from 0.1 to 4.6 GHz, with upper stopband rejection of typically 50 dB from 10.9 to 16.5 GHz and 42 dB from 16.5 to 18.5 GHz. The surface-mount filter measures just 4.95 × 3.65 mm but handles signal levels to 1 W.

MINI-CIRCUITS

https://tinyurl.com/yoc3wyl4

Four-Channel Attenuator Adjusts 95 dB to 8 GHz

Mini-Circuits' model RC4DAT-8G-95PE is a four-channel programmable attenuator with attenuation range of 0 to 90 dB in 0.25-dB steps from 1 to 8000 MHz. It has USB Type C and RJ45 ports for computer control, including power-over-Ethernet (PoE). The four female SMA RF channels are independently controllable, with more than 100-dB isolation between them and 650-ns typical attenuation transition time. The 50-Ω attenuator, well-suited for C-band radar testing, measures 3.00 × 5.17 × 0.60 in. with full software support.

MINI-CIRCUITS

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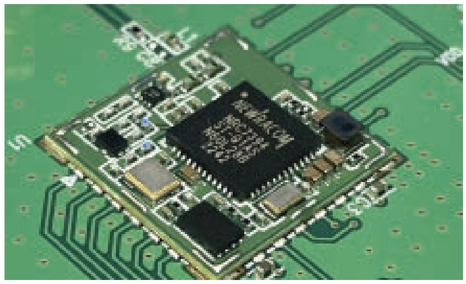

Cost-Effective Wi-Fi HaLow SoC Addresses IoT Applications

Newracom's NRC7394 Wi-Fi HaLow SoC offers improvements in power consumption, size, and costs from its previous models. A long-range implementation of Wi-Fi technology based in the 750- to 950-MHz spectrum, Wi-Fi HaLow is designed for a variety of IoT industries. The NRC7394 incorporates a baseband (MAC and PHY), sub-1-GHz radio transceiver, and an ADC/DAC in a small 6- x 6-mm 48-QFN package. Fully compliant with IEEE 802.11ah, the long-range and low-power version of the Wi-Fi standard, it supports 1/2/4-MHz channel bandwidth for a 150-kb/s to 15-Mb/s PHY rate.

NEWRACOM

https://tinyurl.com/yu2ne8qq

5G Amplifiers Operate from 10 MHz Up to 8 GHz

Fairview Microwave introduced a series of advanced 5G amplifiers provided in compact coaxial packages, addressing a frequency spectrum ranging from 10 MHz up to 8 GHz. The amplifiers target multiple market bands from VHF and UHF to L, S, and C bands. The 5G LNA offers a noise figure as low as 0.6 dB, with P1dB levels between 1 and 2 W. Select models are available with integrated heatsinks. Built to withstand challenging MIL-STD-202 environmental test conditions, the models have SMA female connectors and provide solder pins for voltage and ground connections, facilitating installation.

FAIRVIEW MICROWAVE

https://tinyurl.com/yldaegtq

Compact Spectrum Analyzer Touts Frequency Accuracy

Signal Hound's latest spectrum analyzer, the SP145, offers excellent frequency accuracy in a compact format for field, test, or other applications. The SP145 can perform drive test, vector signal analysis, RF survey, and even airborne measurement functionality. The analyzer is specialized for accurate remote spectrum monitoring and analysis in a portable, durable format.

SIGNAL HOUND

https://tinyurl.com/yrkanzn8