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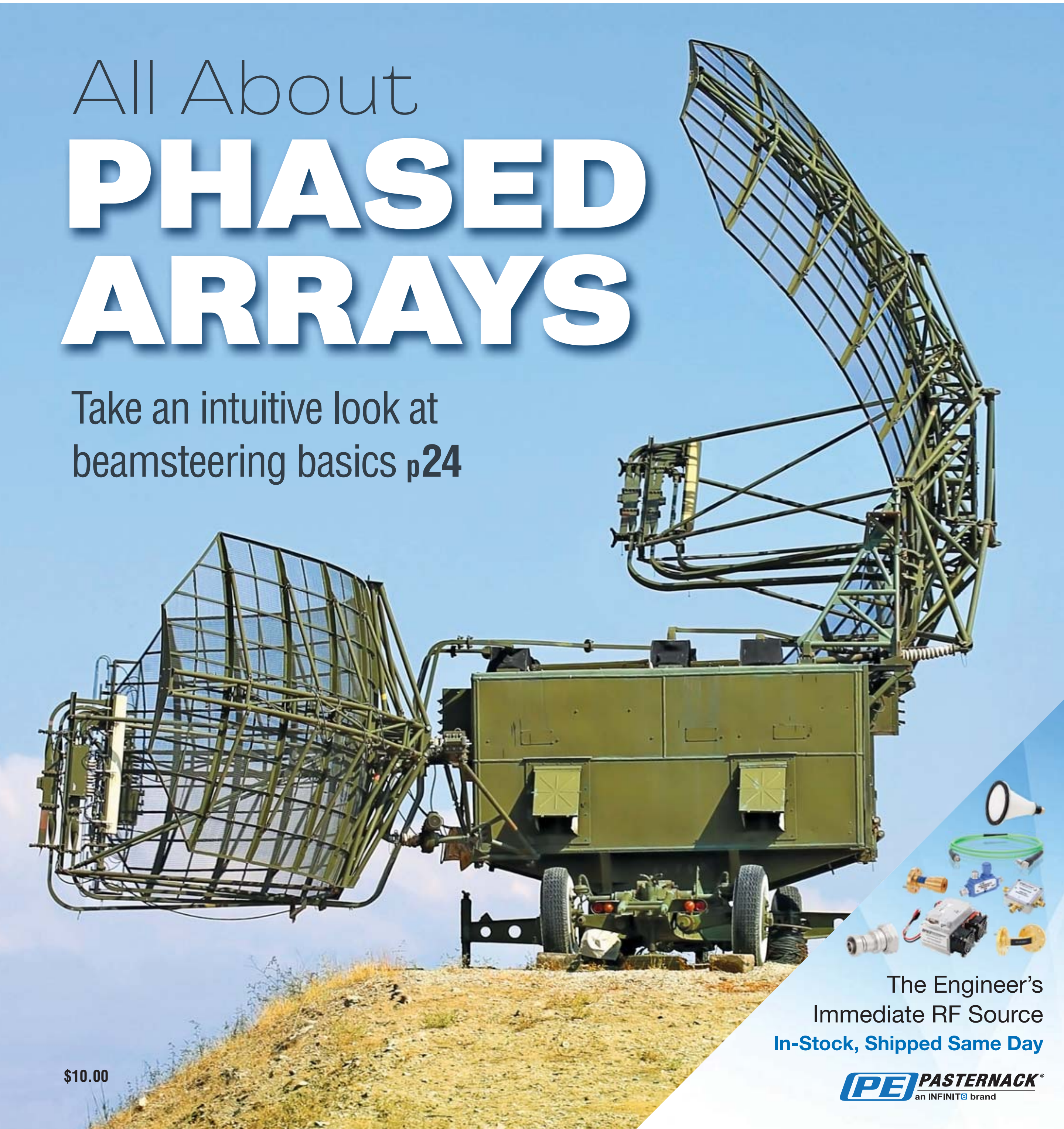

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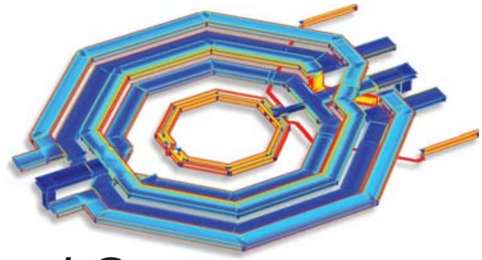

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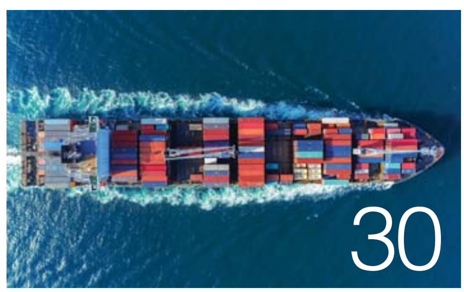

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Editorial

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Fueled by 5G, Watch Cloud Gaming and Video Take Off

We've been at home watching streaming video and gaming online for months, propelling rapid growth in 5G-related revenue that will continue to balloon. But who, ultimately, will benefit from it?

The last six months only seem to have taken six years. Many of us have chafed under coronavirus quarantine and have headed out for protests (or tacos, or both), while others remain sequestered. Either way, we've been home a great deal of the time, with kids and family, and that's meant a whole lot of video streaming and online gaming.

That's good news for the broadband industry, and the party is just getting started. Last year saw the initial deployments of 5G for consumers, but this year will be one of large-scale commercial adoption of the technology. According to the global tech advisory firm ABI Research, 5G-generated revenues for cloud-based entertainment services are expected to skyrocket until at least 2024. By then, 5G will be the driving technology behind revenues of nearly $1.9 billion in cloud gaming (42% of overall cloud-gaming revenues), and some $67 billion in cloud video (31% of overall cloud-video revenues).

Social distancing, quarantines, and school closings have all contributed to the surge in demand for cloud-based entertainment. Across the globe, network traffic has been up an average of 15% or more, with platforms like YouTube and Netflix being major beneficiaries. Thus, network operators and infrastructure providers have ventured toward targeting enterprise use cases in the media and entertainment arenas.

If they're to succeed in this direction, infrastructure vendors and network operators need to fully embrace a service-based monetizing strategy and depart from a capital expenditure-intensive model, say ABI's analysts. Should the telecom industry fail in this tactic, they could find themselves losing out to the Google/Amazon/Netflix sorts of large cloud-services providers. It'll be interesting over the next 12 to 18 months as this dynamic plays out and the (hopefully) post-COVID landscape materializes. mw

Microwaves&RF **JULY 2020**

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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

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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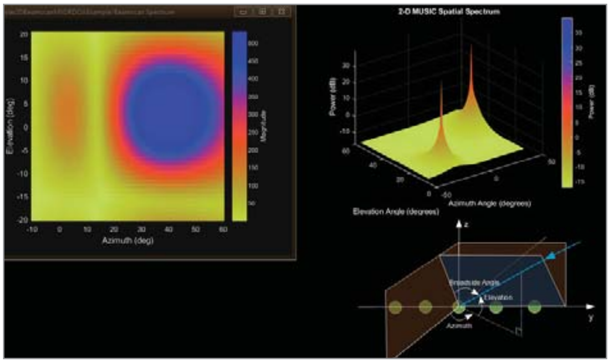

Developing Direction-of-Arrival Algorithms for Phased-Array Systems

Following up from the previous blog on beamforming algorithms and a development/test framework for beamformers, this "Algorithms to Antenna" installment delves into a related topic on spatial signal processing—namely, DOA algorithms.

https://www.mwrf.com/technologies/systems/article/21134254/algorithms-to-antenna-developing-directionofarrival-algorithms-for-phasedarray-systems

All that Glitters Is Not Gold: Interpreting Datasheet Data When Selecting Parts

Look deeper into those shiny front-page "sheet" specs—and search out the truly relevant data—to see if the part really is the best option for your application.

https://www.mwrf.com/technologies/components/article/21134017/all-that-glitters-is-not-gold-interpreting-datasheet-data-when-selecting-parts

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Dr. Ray Ridley, who has been designing and researching power supplies for over 35 years, has created a cartoon series that reflects the current climate in our industry.

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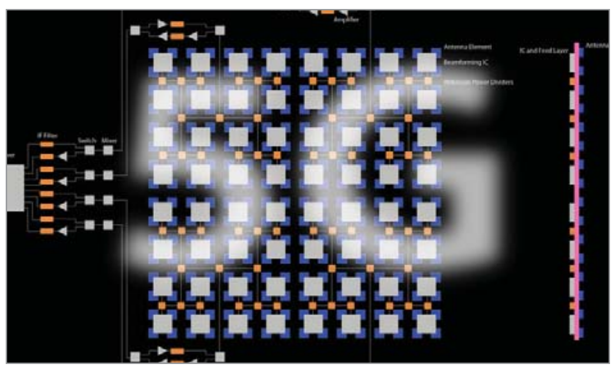

Building Blocks for 28-GHz Small Cells

One of the more significant 5G innovations is the ability to operate in the millimeter-wave spectrum. Support for high-frequency bands opens underused spectrum to bolster 5G network capacity and provides opportunity to leverage small-cell technology.

https://www.mwrf.com/technologies/systems/article/21131231/building-blocks-for-28ghz-small-cells

News

CORONAVIRUS Spurs Use of 3D Printing

In what may be an unexpected application for 3D printing, thousands of face shields were formed by Raytheon Technologies for emergency workers fighting the COVID-19 coronavirus.

(Credit: Raytheon Technologies)

Emergency responders have been faced with finding enough face shields for protection during the COVID-19 coronavirus disaster. Fortunately, major defense contractors such as Raytheon Technologies have been able to contribute what they know in three-dimensional (3D) printing to form thousands of secure face shields for first responders and other emergency crew members. The company could combine additive-manufacturing 3D-printing machines from all around the world to meet the emergency needs.

"It was unprecedented to bring the entire corporation together to print one single file across multiple processes and materials using somewhere around 100 machines in less than two weeks," said Jesse Boyer, fellow for additive manufacturing at Raytheon Technologies. "To ramp up to that volume that quickly is something that is touted using additive manufacturing, but rarely demonstrated. The opportunity was a great learning experience."

Traditional manufacturing approaches cut a desired part from a piece of material, subtracting the material not required. In contrast, 3D printing or additive manufacturing builds a part by stacking layer upon layer as needed. The 3D approach can provide extremely efficient shapes and sizes that work well where space is at a premium, such as in aircraft. "The wild side is to continue to do that, to make very complex, yet optimized structures for areas we couldn't normally do in a jet engine," said Boyer. "We explore methods like bio-mimicry by looking at the best nature has produced. Additive then reduces the constraints of conventional manufacturing and substantially increases our ability to optimize what we can manufacture going forward."

When it came to the face shields, Paula Hay of Collins Aerospace, one of four businesses that form Raytheon Technologies, was able to apply 3D-printing technology to the creation of the face shields. As Hay explained, "One of the big complaints about additive is, if you do something on two different machines, you get two different answers." As Hay noted for the face shields for COVID-19, however, different machines should not make a difference: "When you have a good design and a good file, you get a repeatable product." This emergency application shows a bright future for 3D printing in many aerospace and defense applications. ■

MIXED-SIGNAL OSCILLOSCOPES COMBINE Eight Instruments in One

IN ITS NEW INFINIIUM MXR-SERIES mixed-signal oscilloscope, Keysight Technologies offers what is said to be the first oscilloscope with 8 analog channels at 6 GHz and 16 simultaneous digital channels. Thanks to advanced ASIC-driven processing, the MXR-Series scopes embody a highly versatile instrument, encompassing the functionalities of a real-time spectrum analyzer, oscilloscope, digital voltmeter, waveform generator, Bode plotter, counter, protocol analyzer, and logic analyzer. The result is less testbench complexity and a smoother workflow.

Many applications, such as high-speed digital designs, power-integrity verification, Wi-Fi 6, IoT, IIoT, and gallium-nitride (GaN) semiconductors operate at frequencies between 2 GHz and 6 GHz. Testing these new products requires time- and frequency-domain equipment capable of simultaneous analog and digital channels, ideally with software-enabled protocols, standards, built-in test assistance, and test team remote collaboration. The MXR-Series scope addresses these test applications armed with an extensive suite of software solutions focused on power integrity, high-speed digital test, and verification. Built-in software includes a fault hunter function that speeds root cause identification and resolution of rare or randomly occurring errors.

The Keysight Infiniium MXR series oscilloscope brings several key benefits:

- Incorporating a real-time spectrum analyzer achieves a 100% probability of detection in the frequency domain, even for asynchronous errors.
- A built-in fault hunter function learns normal signals and compares them over time to find abnormal signals, capturing everything else that occurs when the abnormal signals happen. The result: rapid problem resolution for troubleshooting irregular, random, or spurious signals.
- Simultaneous 8 analog channels and 16 digital channels enable monitoring and analysis of complex signal interactions. Coupled with 3X higher bandwidth than any other 8-channel oscilloscopes, it allows test engineers to open a wider and more insightful window into designs.
- Powerful remote collaboration with PathWave Infiniium Offline Analysis software enables design teams to do extensive analysis and data manipulation after bench measurements are complete, enhancing the efficiency and effectiveness of the testbench. ■

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MIPI's RF FRONT-END INTERFACE SPEC Expands its 5G Purview

IN THE LATEST VERSION of its RF Front-End Control Interface (MIPI RFFE) specification, the MIPI Alliance has expanded the spec's applicability to 5G use cases that move beyond mobile applications and into the realms of automotive, industrial, and the Internet of Things (IoT). MIPI RFFE v3.0 is designed to deliver the tighter timing precision and reduced latencies that manufacturers need to satisfy the RF requirements of the 3GPP 5G standard.

MIPI RFFE simplifies the design, configuration, and integration of the increasingly complex RF front end—which encompasses the power amplifiers, antenna tuners, filters, low-noise amplifiers (LNAs), and switches—connecting with the modem baseband and/or RFIC transceiver. As the number of RF bands involved in both uplink and downlink communications has exploded in the rollout of 5G, the subcarrier spacing (SCS) windows among RF packets have narrowed. MIPI RFFE v3.0 addresses the decreased reconfiguration windows and lower-latency switching among various bands and band combinations demanded in the 3GPP 5G standard by delivering enhanced triggering features and functionality, which results in fast, agile, semi-automated and comprehensive control of individual RFFE subsystems.

MIPI RFFE v3.0 utilizes multiple, complementary triggers to synchronize and schedule changes in register settings, either within a slave device or across multiple devices:

- Timed triggers—Allows for tighter, synchronized timing control of multiple carrier aggregation configurations
- Mappable triggers—Enables groups of control functions to be remapped to other triggers quickly and easily
- Extended triggers—Boosts the number of unique triggers available in the RF control system and accommodates increasingly complex radio architectures

With the enhanced triggering functions, MIPI RFFE v3.0 improves throughput efficiencies and reduces packet latency, while also improving the precision in trigger placement. For back-to-back triggering operations, for example, the specification delivers a 20X improvement in timing precision.

Because MIPI RFFE v3.0 is backward compatible with prior generations of the specification, original equipment manufacturers and device vendors can migrate to 5G systems more quickly and easily, without changes to the physical layer of the control interface. The RFFE specification was initially released in 2010 and has seen numerous revisions since that time. Each release has provided additional functionality for developers to aid in the demand for newer RF front-end features.

"With MIPI RFFE v3.0, the specification has been streamlined and optimized to deliver the specific capabilities required to thrive in today's 5G rollout across the Frequency Range 1 (FR1) of traditional sub-6-GHz cellular bands," said Jim Ross, MIPI RF Front-End Control Working Group Chair. "The working group is always looking to refine the specification to continue differentiating and benefitting our user community, and we welcome engagement in requirements gathering for Frequency Range 2 (FR2) and the ongoing evolution of the next-generation MIPI RFFE for the subsequent stages of 5G deployment." ■

R&S DEPLOYS 1.35-mm, E-band Coaxial Connector on Thermal Power Sensors

A NEW COAXIAL CONNECTOR optimized for E-band frequencies up to 90 GHz has emerged from a joint development effort involving four German entities, and that connector has been pressed into service by one of the four, Rohde & Schwarz, for use in a pair of thermal power sensors.

Emerging applications for automotive radar from 76 to 81 GHz, plus the WiGig extension (IEEE 802.11ay) operating up to 71 GHz, highlighted the need for a novel, robust coaxial connector suitable for industrial applications at frequencies up to 90 GHz. The development was carried out by Germany's national metrology institute, the Physikalisch-Technische-Bundesanstalt (PTB); Rohde & Schwarz; Rosenberger Hochfrequenztechnik; and Spinner Group.

The E connector closes the gap between the well-established 1.85-mm V-band connector and the 1.00-mm W-band connector. The V-band connector was introduced more than 30 years ago and is suitably robust for industrial applications; however, it is restricted to a maximum frequency of 70 GHz. While the W-band connector supports a maximum frequency of 110 GHz, it requires fine mechanical accuracy during assembly and frequently loosens in use.

The 1.35-mm connector sports a precise metric fine thread, a reliable pin-gap, and an integrated groove for optional push-pull locking. The design was accepted in 2019 for the next edition of the IEEE 287-2007 for precision coaxial connectors, and also by the IEC, which will publish it as the IEC 61169-65.

Rohde & Schwarz has implemented the E connector for the first time in a test-and-measurement instrument in the company's NRP90T and NRP90TN thermal power sensors for frequencies up to 90 GHz. Like all other members of the family, the new models feature both high accuracy and high measurement speed. The R&S NRPxxT power sensors operate locally, connected to a PC, selected Rohde & Schwarz instruments, or an R&S NRX base unit. The R&S NRPxxTN sensors can also be operated remotely via a LAN. ■

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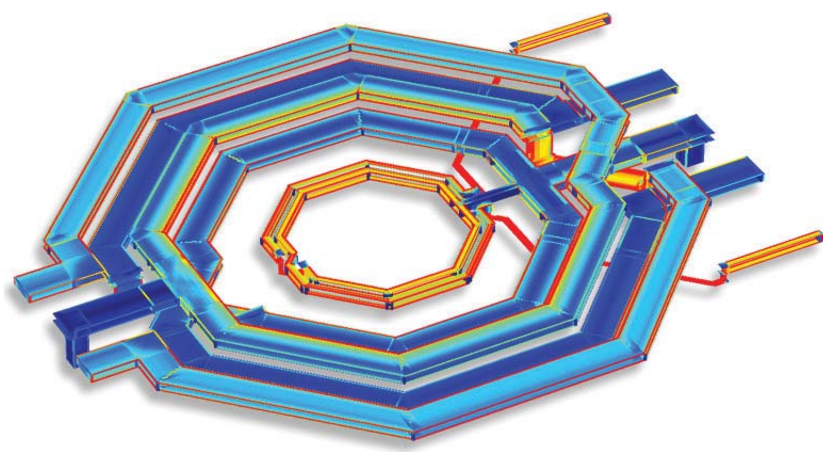
JACK BROWNE | Technical Contributor

Integrated Simulators Study EM Effects

Electromagnetic simulators are gaining in power and ease of use, but also becoming more available integrated into other high-frequency simulation software programs.

Computer software simulators come in many varieties, tackling everything from passive circuit elements to full electronic systems. As a form of "thread" that ties them together, electromagnetic (EM) simulators show the EM fields generated by devices, circuits, and systems. They may do it in planar or two-dimensional (2D) form or in three dimensions (3D), showing EM fields in all three axes. EM simulators are ever-evolving, providing increased insights into electronic designs. As part of this evolution, they're gaining in power as well as becoming easier to use, working more efficiently with other computer-aided-design (CAD) software.



1. Many EM simulators provide the precision needed to study the fields around sections of passive circuit elements or semiconductor ICs. *(Courtesy of Sonnet Software)*

Many EM simulators have been evolving for three or more decades and now take advantage of some of the luxuries of modern PC processing speeds and the ease of use provided by the latest graphical user interfaces (GUIs). In support of modern design efforts, many of the latest EM simulators can team with other CAD software programs, such as circuit and system simulators, for added power. For example, circuit element models created in an EM simulator can be imported into a circuit or system simulator to predict just what those models will do at the circuit and system levels.

EM simulators function by solving the equations bearing James Clerk Maxwell's name. Those four coupled partial-differential equations describe the generation and propagation of magnetic and electric fields. They can calculate EM field strengths for different current and voltage conditions and analyze the effects of different transmission-line widths and materials, different circuit structures, and different dielectric materials. Furthermore, they're able to analyze how changes to different material and structural elements will affect the expected performance of the structure or circuit.

Perhaps one of the strongest trends in the use of modern EM simulations, whether performed in 2D or 3D versions, is how many newer EM simulation programs can now operate in partnership with another simulation package, such as a circuit or system simulator. Such capability, for example, makes it possible to explore the electrical and thermal effects of a nonstandard dielectric or packaging material on the performance of a circuit element or component.

While material effects due to temperature changes are often associated with physical stress, they're also typically responsible for variations in electrical performance. Especially at higher frequencies, a design that depends on tight amplitude and phase responses can be strongly impacted by amplitude and phase unbalance as a function of temperature. An EM simulator can reveal such concerns: By working in conjunction with, for example, a system simulator, the models developed within the EM simulator can be imported within the system simulator to compare the amplitude and phase matching of multiple channels in a radar system.

EVOLVING POWER

Evidence of the multiple-decade lifespan of many EM simulation tools can be found in the latest version of Sonnet Software, which is currently available in v17. Not always the easiest program to use, it now enjoys a straightforward GUI that's a result of user feedback and working within the limits of the Windows operating system (OS) to provide an interface that anyone with even a little experience in EM simulation can operate. It's possible to modify design environments as needed to suit different workflows, and controls can be moved almost anywhere needed on the computer screen.

Sonnet has always been appreciated for its attention to detail *(Fig. 1)*, and its capability to define minute structures such as sections of passive circuit elements and semiconductor ICs. This latest version of Sonnet Software is designed to perform EM simulations on its own as well as within the Advanced Design System (ADS) from Keysight Technologies, where EM models can be integrated within an ADS circuit or system simulation.

For example, a component like a filter or antenna that's been simulated with the Sonnet Electromagnetic Co-simulation (SEC) capability can be integrated within an ADS circuit simulation to explore the effects of that component on a higher-level simulation, such as a receiver front end. By using SEC models within an expected performance range, production variations at the component level using a Sonnet EM simulation can be reflected in the final performance predicted by the ADS system-level simulations.

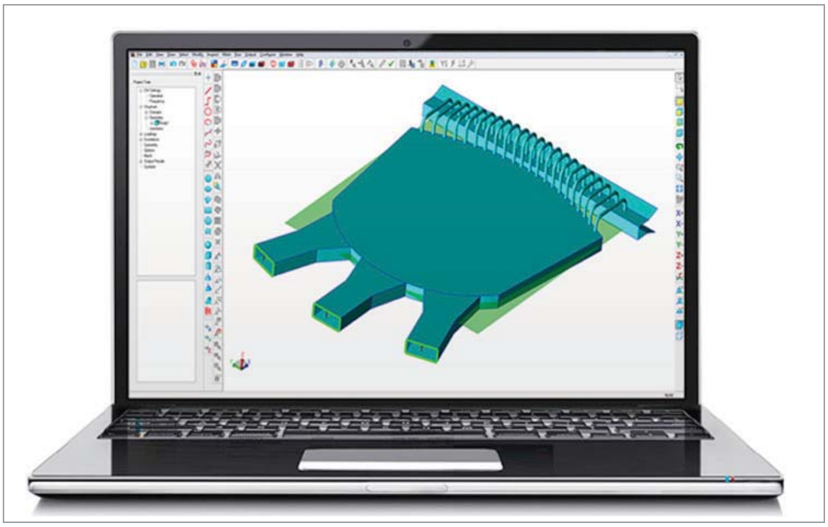
For its part, Keysight offers EM simulation software nominally for use with or without ADS. RFPro EM simulation software, which was developed for integration within its ADS software, can be used within ADS with little or no setup time. It provides the capability to study the EM behavior of shields, packages, and interconnections among a wide range of circuit structures while simulating a circuit or system within ADS. Design layouts are used as is within the ADS environment, without modifications needed to account for EM junctions. The typical setup time for RFPro in ADS is about one minute.

Keysight's EMPro, on the other hand, offers much more extensive modeling features, although without the ease of use provided by RFPro's integration into ADS. EMPro is capable of modeling and simulating EM effects from passive devices (e.g., inductors, capacitors) to full system levels like radars, although it requires much longer setup times to perform tasks such as defining model parameters. It has the functionality to create its own device and circuit layouts for EM simulations (where RFPro uses the layouts in ADS) and can export connector and package models into ADS, but they must be fully parameterized.

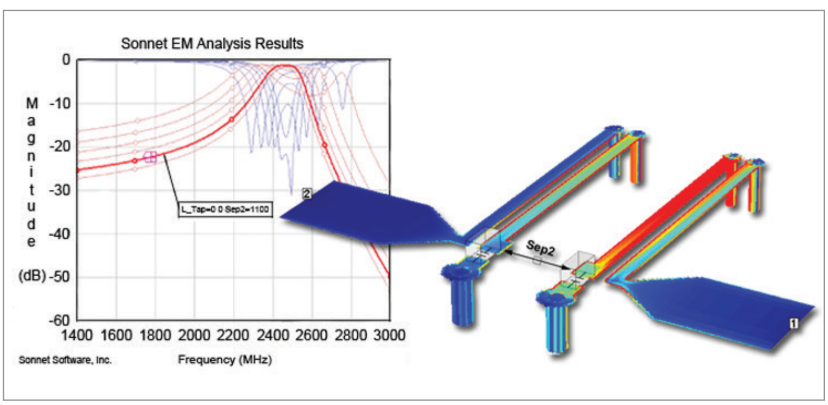
EMPro is equipped with full EM simulation capabilities based on finite-difference-time-domain (FDTD) and finite-element-method (FEM) simulation engines. It can perform 3D EM analysis of designs from component through complex system levels at frequencies well into the mmWave range. Keysight also offers PathWave EM design software with EMPro as its simulation core. The EM simulator is designed to work within the PathWave circuit simulator to study the EM effects of different components within a circuit design. It's also available in a version that's fully integrated with ADS.

HFWorks is a 3D EM simulator fully integrated within the SOLIDWORKS suite of software design tools from Dassault Systèmes' SolidWorks Corp. It uses the FEM of EM analysis to study passive circuits and structures such as resonators, antennas, and interconnects. It's designed to work seamlessly with SOLIDWORKS so that data for EM models needn't be imported each time simulations run at system or circuit levels.

The Ansoft High-Frequency Structure Simulator (HFSS) from Ansys, one of the most widely used EM simulators for analysis of RF/microwave components, circuits, and systems, is a 3D EM simulator well-suited for analyzing high-frequency and high-speed electronic circuits and devices. It features an intuitive GUI for ease of use and integration with thermal, structural, and fluid-dynamics modeling tools, delivering a multiphysics approach to simulation.



2. Modern EM simulators can simulate the EM behavior of relatively large surfaces even when running on a standard PC. *(Courtesy of WIPL-D)*



3. Sonnet Lite is a free version of the 3D EM simulator for analysis of planar structures such as coupled transmission lines. *(Courtesy of Sonnet Software)*

The Ansys HFSS simulation suite of EM solvers is also designed to handle anything from a passive circuit element to a full radar- or communications-system analysis. The simulator features automatic meshing in which EM meshes can enclose the most irregularly curved and shaped surfaces for accurate predictions of the EM fields being produced around those surfaces. The software suite has become a proven tool for large-scale EM simulation challenges, especially at high microwave and mmWave frequencies, such as automotive radar systems. With generous computer memory, the software can draw upon saved simulation "scenes" in traffic and potential accident setups as part of the analysis of an automotive advanced driver-assistance system (ADAS) in a vehicle.

For less-complex 3D EM simulations, the WIPL-D software suite from WIPL-D employs method-of-moments (MoM) solvers to determine the EM fields around different types of metallic surfaces, as might be found in high-frequency antennas. It employs quadrilateral meshing techniques to surround a surface under analysis for high accuracy, but also employs adaptive meshing to achieve a practical solution in a short amount of analysis time for computer power available. As a result, WIPL-D software *(Fig. 2)* can be used to cover relatively large surfaces under simulation even when running on a standard PC.

As noted, the number of commercial EM simulators is on the rise, although not all are available fully integrated into circuit and system simulators. Remcom, for example, offers a trio of application-focused EM simulators that simplify the simulation of automotive and wireless experiments.

The firm's Wireless Insite is so named for its capability of performing site-specific analyses on wireless networks, including all antennas, sensors, cables, and other interconnecting hardware. But this is really a system-level simulator that also can analyze radar system performance at all frequencies. The company's XFdtd EM simulation software is well-suited not only for antenna design, but for ensuring that the antennas are optimally placed within a system design. The third EM software tool, Wayfarer, is designed to aid with radar simulation within ADAS vehicles.

FREE TRIALS

As EM simulation becomes a more routine part of the RF/microwave design process, especially as a growing number of wireless communications and radar technologies reach well into the mmWave frequency ranges, more sources are developing and supporting EM simulators—whether for integration with circuit or system simulators or as standalone software tools. Engineers interested in exploring the capabilities of some of these tools can do so on a trial basis, free of charge. While these may not be full-power versions of the software, they provide the opportunity to examine the GUI, which can be as important as the accuracy of the EM calculations.

Sonnet Lite is a free version of the 3D EM simulator for analysis of planar structures such as coupled transmission lines *(Fig. 3)*. It can be downloaded from the company's website and even be integrated for use with multiple-function circuit and system simulators like ADS and Microwave Office from AWR (now part of Cadence). It's one of many EM simulators available for no charge or free trial periods.

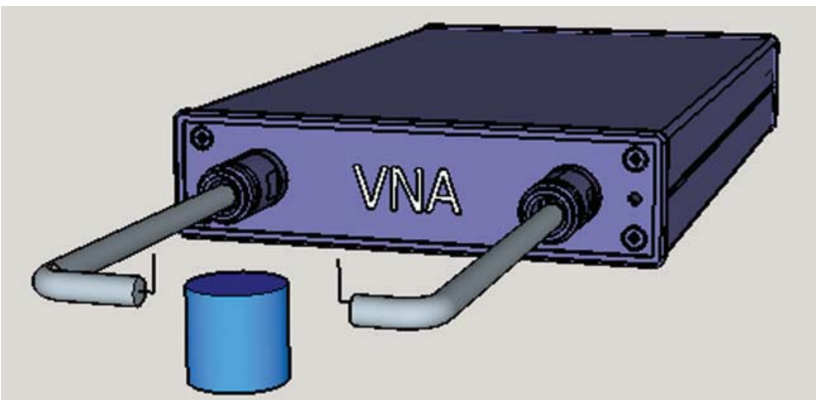
Autodesk, perhaps best known for simulation software to analyze construction sites, provides a 2D/3D CAD version of its modeling software as part of a free, 30-day trial period. Dassault Systèmes' SolidWorks Corp. offers an online trial of its SOLIDWORKS 3D EM simulation software by creating a folder on the company's website. The company also provides its CST Studio Suite and latest version (5.1) of its EM simulator for free download.

A review copy of the Ansys HFSS 3D EM simulation software is available for download from Software Informer in three steps, installing required software drivers for a particular PC and Microsoft Office OS. The highly accurate EM solver has been used at all levels, from devices to commercial/military communications and radar systems. mw

BRIAN WALKER | Senior RF Design Engineer, Copper Mountain Technologies

Determining Resonator Q Factor from Return-Loss Measurement Alone

Engineers often want to measure the Q factor of a resonator. But did you know you could affordably and accurately determine that Q factor from a return-loss measurement?



1. For a 2-port Q measurement of a resonator, establish very light input and output coupling to reduce the loading effect of the 50-Ω source and load impedances.

It's not uncommon to want to measure the Q factor of a resonator. One may need to determine its suitability for use in a coupled resonator filter or evaluate the performance of an RFID tag. Generally, this measurement is made with very light input and output coupling to reduce the loading effect of the 50-Ω source and load impedances.

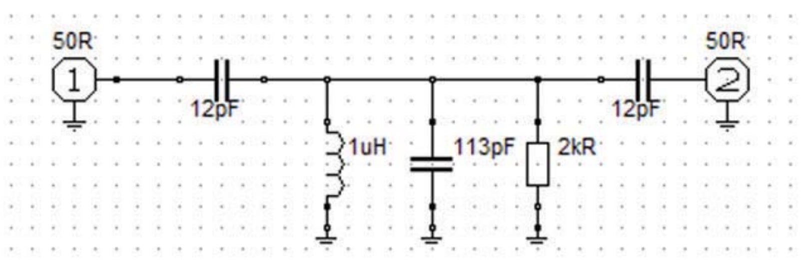
Coupling to and from the resonator might be done with two electrically short antennas or loops to couple to the electric or magnetic fields of the resonator *(Fig. 1)*. One instrument that could make such a measurement is Copper Mountain Technologies' TR1300/1, a 1.3-GHz vector network analyzer (VNA) *(Fig. 2)*.

2. Copper Mountain Technologies' TR1300/1 VNA can be used to make resonator Q measurements.

After measuring an S_{21} S-parameter in this fashion, the data is analyzed to extract the resonant frequency and Q factor of the resonator. The peak of the response is taken to be the resonant frequency, and then two markers are placed 3 dB down from the peak value. The peak frequency divided by the 3-dB width of the peak is then equal to the Q factor.

For example, a sweep of the circuit shown in *Figure 3* results in the measurement shown in *Figure 4*. That graph gives us an experimental Q factor of 13.62/(13.99 – 13.28) = 19.2.

The approximate Q factor from the schematic, neglecting the effects of the 12-pF coupling capacitors and the 50-Ω source and load, is equal to the admittance of the 113-pF capacitor at 13.62 MHz divided by the conductance of the resistor, or 9.673e-03/5e-04 = 19.3. This shows that there's reasonable agreement with the experimentally determined value.



3. Shown is the 2-port example circuit used for VNA measurements.

With reduced coupling, it's possible to obtain a slightly better measurement, allowing the S_{21} peak to fall to −40 dB or so to reduce the loading effect. However, the S_{11} reading would become very small.

With reduced coupling, it's possible to obtain a slightly better measurement, allowing the S_{21} peak to fall to −40 dB or so to reduce the loading effect. However, the S_{11} reading would become very small. We will show that the Q factor may be derived from the S_{11} measurement, but the numbers need to be large enough to work with.

So how can this be done? Clearly, it isn't a matter of looking for the points on the S_{11} curve that are 3 dB higher than the minimum. The trace shown in *Figure 4* has a minimum of −1.6 dB, so that's clearly out of the question. It turns out that in a lossless circuit, there's a relationship between S_{11} and S_{21}:

$$S_{11}^2 + S_{21}^2 = 1$$

From the earlier graph we can calculate a value for S_{21}:

If:

$$S_{11}(Linear) = 10^{\frac{-1.6522}{20}} = 0.8268$$

Then:

$$S_{21} = \sqrt{1 - S_{11}^2} = \sqrt{1 - 0.8268^2} = 0.5625$$

This S_{21} isn't a real value per se, but we can still use it. Calculating the value of S_{21}, which is 3 dB down, means multiplying by $1/\sqrt{2}$:

$$S_{21}(3dB) = \frac{0.5625}{\sqrt{2}} = 0.3977$$

Now we take that back to S_{11}:

$$S_{11} = \sqrt{1 - S_{21}^2} = \sqrt{1 - 0.3977^2} = 0.9175$$

Or, −0.748 dB.

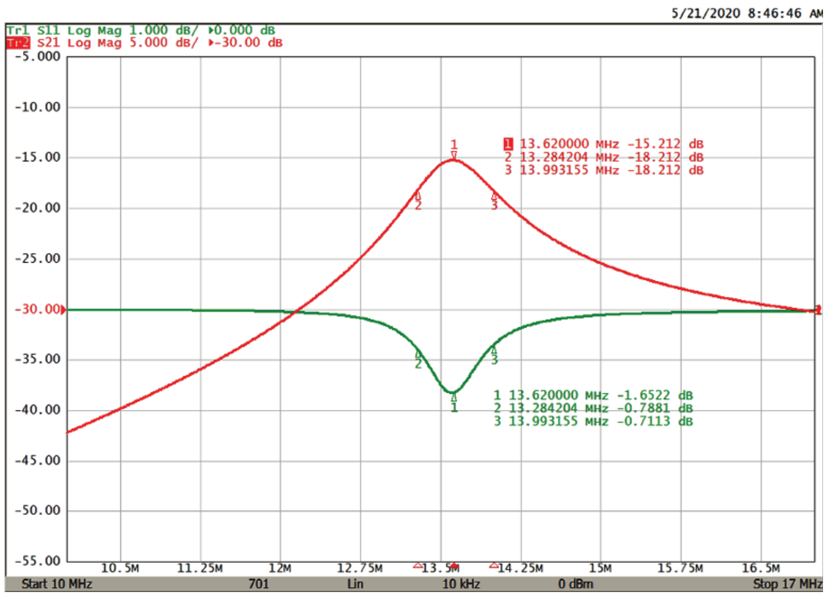
If we find this value of S_{11} on each side of the minimum from the earlier measurement, we get the result shown in *Figure 5*.

From the three frequencies shown, we can calculate the Q factor:

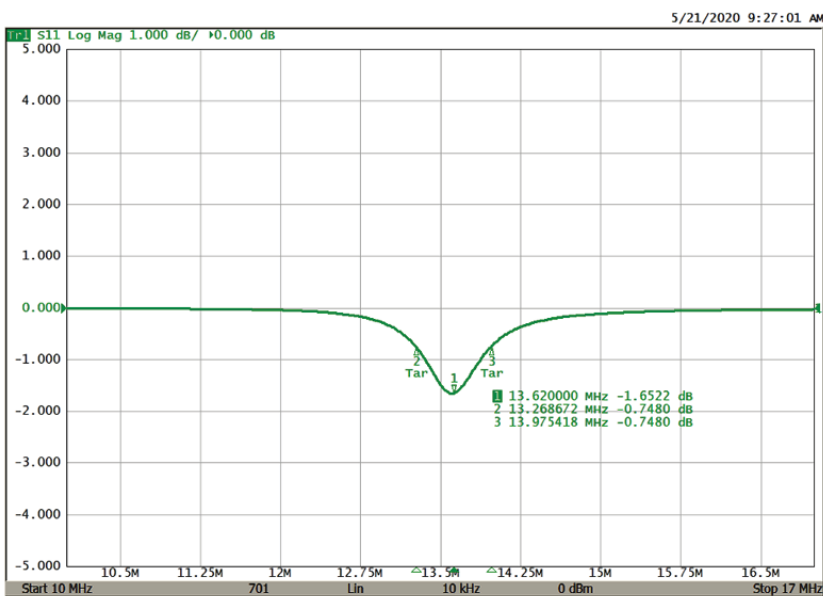
$$Q = \frac{13.62}{13.97 - 13.27} = 19.4$$

That result is quite close to the calculated value of 19.2.

So, with a relatively simple calculation, one can determine the Q factor of a resonator from the return-loss measurement alone. **mw**



4. This graph illustrates a 3-dB Q factor measurement of the circuit shown in Figure 3.



5. In this graph, we see the S_{11} measurement alone.

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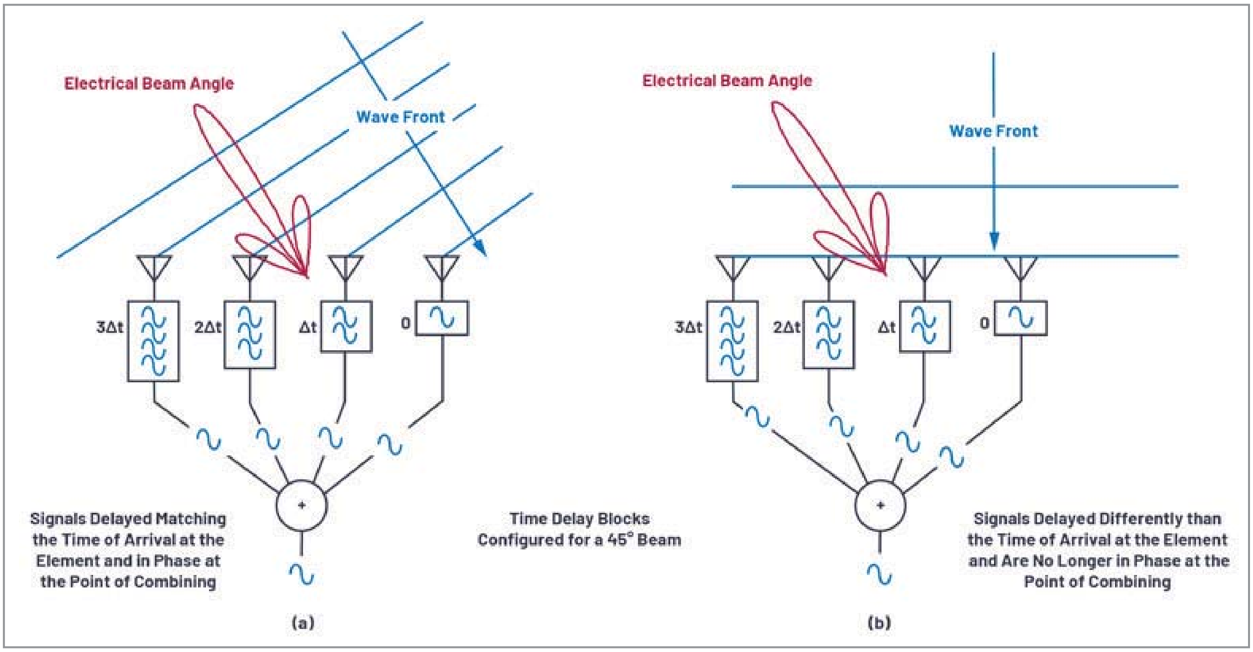
PHASED-ARRAY ANTENNA PATTERNS

(Part 1)—Linear-Array Beam Characteristics and Array Factor

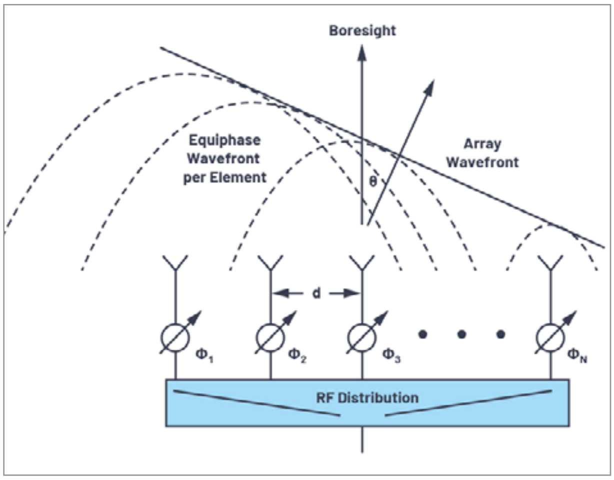
In this first of three articles, learn some of the basics of phased-array antenna patterns, starting with the simpler example of a linear array.

With the proliferation of digital phased arrays in commercial as well as aerospace and defense applications, there are many engineers working on various aspects of the design who have limited familiarity with phased-array antennas. Phased-array antenna design isn't new, as the theory has been well developed over decades. Most of the literature, though, is intended for antenna engineers who are proficient with the electromagnetic mathematics.

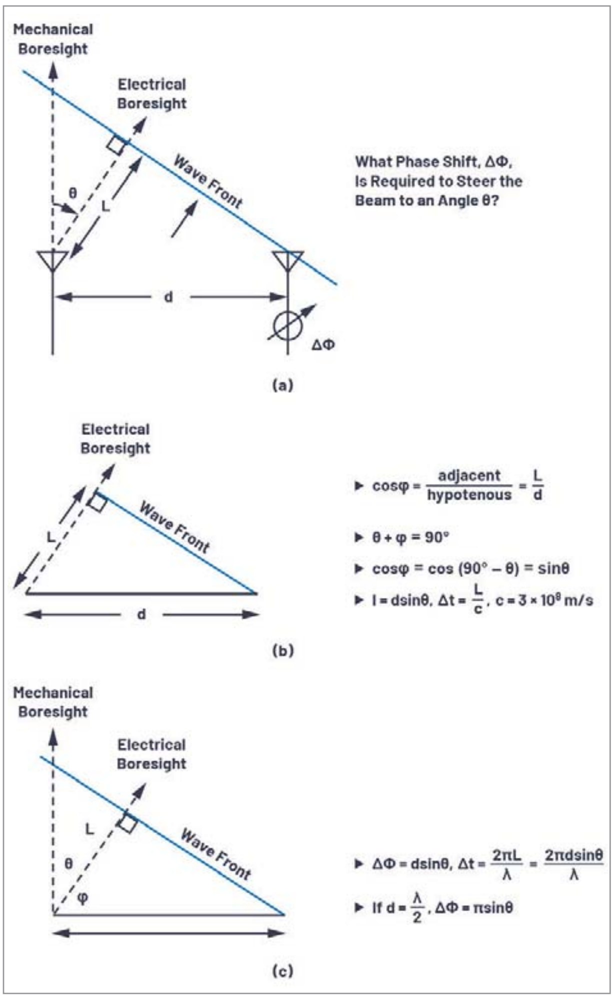
However, as phased arrays begin to include more mixed-signal and digital content, many engineers could benefit from a much more intuitive explanation of phased-array antenna patterns. As it turns out, many analogies exist between the behavior of phased-array antennas and the discrete time-sampled systems that the mixed-signal and digital engineers work with every day.



1. This example of beamsteering shows a wavefront striking four antenna elements from two different directions.



2. This phased-array arrangement uses phase shifters rather than time delay.



3. To visualize the phase shift needed for beamsteering, a set of right triangles can be drawn between adjacent elements, where ΔΦ is the phase shift between those adjacent elements.

In a phased array, time delay is the quantifiable delta needed for beamsteering. But time delay can also be emulated with a phase shift, which is common and practical in many implementations. We will discuss the impact of time delay vs. phase shift in the section on beam squint. For now, though, let's look at a phase-shift implementation, and then derive the calculation for beamsteering with that phase shift.

BEAM DIRECTION

First, let's look at an intuitive example of steering a phased-array beam. *Figure 1* provides a simple illustration of a wavefront striking four antenna elements from two different directions. A time delay is applied in the receive path after each antenna element, and then all four signals are summed together. In *Figure 1a*, that time delay matches the time difference of the wavefront striking each element. And in this case, that applied delay causes the four signals to arrive in phase at the point of combination. This coherent combining results in a larger signal at the output of the combiner.

In *Figure 1b*, that same delay is applied. But in this case, the wavefront is perpendicular to the antenna elements. That applied delay now misaligns the phase of the four signals, significantly reducing the output of the combiner.

In a phased array, time delay is the quantifiable delta needed for beamsteering. But time delay can also be emulated with a phase shift, which is common and practical in many implementations. We will discuss the impact of time delay vs. phase shift in the section on beam squint. For now, though, let's look at a phase-shift implementation, and then derive the calculation for beamsteering with that phase shift.

Figure 2 shows this phased-array arrangement using phase shifters rather than time delay. Note that we define the boresight direction (θ = 0°) as perpendicular to the face of the antenna. A positive angle θ is defined to the right of boresight, and a negative angle is defined to the left of boresight.

To visualize the phase shift needed for beamsteering, a set of right triangles can be drawn between adjacent elements *(Fig. 3)*, where ΔΦ is the phase shift between those adjacent elements.

Figure 3a defines the trigonometry between those elements, with each element separated by a distance (d). The beam is pointed in a direction off boresight, θ, which is an angle, Φ,

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800.981.0363 847.639.6400 www.coilcraft-cps.com from the horizon. In *Figure 3b*, we see that the sum of θ + Φ = 90°. This allows us to compute L, the delta distance of wave propagation, as L = dsin(θ). The time delay to steer our beam is equal to the time it will take for the wavefront to traverse that distance, L.

If we think of L as a fraction of the wavelength, then a phase delay could be substituted for that time delay. The equations for ΔΦ can thus be defined relative to θ, as shown in *Figure 3c*, and repeated in Equation 1:

$$\Delta\Phi = \frac{2\pi d sin\theta}{\lambda} \qquad (1)$$

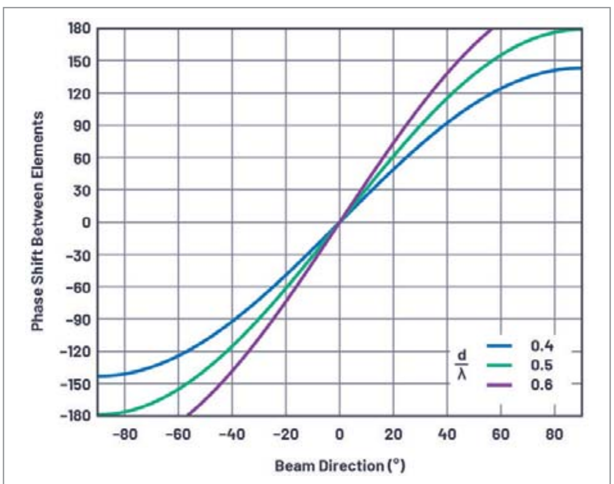
If the spacing between elements is exactly one half of the signal wavelength, then this can further be simplified to:

$$\Delta\Phi = \pi\ sin\theta,\ \text{for}\ d = \frac{\lambda}{2} \qquad (2)$$

Let's work out an example with these equations. Consider two antenna elements spaced 15 mm apart. If a 10.6-GHz wavefront is arriving at 30º from mechanical boresight, then what's the optimal phase shift between the two elements?

- θ = 30° = 0.52 rad
- λ = c/f = (3 × 108 m/s)/10.6 GHz = 0.0283 m
- ΔΦ = (2π × d × sinθ)/λ = 2π × 0.015 × sin(0.52)/0.0283 m = 1.67 rad = 95º

So, if our wavefront is arriving at θ = 30°, and we then shift the phase of the neighboring element by 95°, we will cause the individual signals of both elements to add coherently. This will maximize the antenna gain in that direction.



4. Shown are plots of phase shift (ΔΦ) between elements vs. beam direction (θ) for three cases of d/λ.

A linear array is a single element wide with N number of elements across. The spacing may vary, but often it's uniform. Therefore, for purposes of this article, we will set the spacing between each element to a uniform distance, d *(Fig. 5)*. Although simplified, this uniformly spaced linear-array model provides the foundation for insight into how the antenna pattern is formed in light of various conditions.

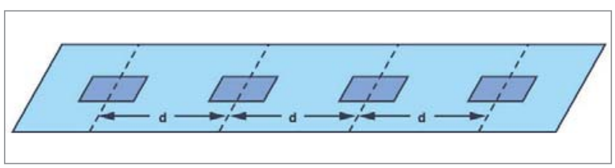
For a better appreciation of how the phase shift varies with the beam direction (θ), these equations are plotted for a variety of conditions in *Figure 4*. Some interesting observations can be made from these graphs.

For the case of d = λ/2, there's an approximate 3 to 1 slope near boresight, which is the π multiplier in Equation 2. This case also shows a full 180° shift between elements, which provides a theoretical 90° shift in beam direction. In practice (with real element patterns), this isn't realizable; yet, the equations do show the theoretical ideal. Note that for d > λ/2, no amount of phase shift provides a full beam shift. Later, we will see that this case can lead to grating lobes in the antenna pattern, and this graph provides a first indicator that something is different with the d > λ/2 case.

A UNIFORMLY SPACED LINEAR ARRAY

The equations developed earlier have applied to just two elements. Yet, a real phased array can be thousands of elements spaced across two dimensions. But for now, let's just consider one dimension: a linear array.

A linear array is a single element wide with N number of elements across. The spacing may vary, but often it's uniform. Therefore, for purposes of this article, we will set the spacing between each element to a uniform distance, d *(Fig. 5)*.

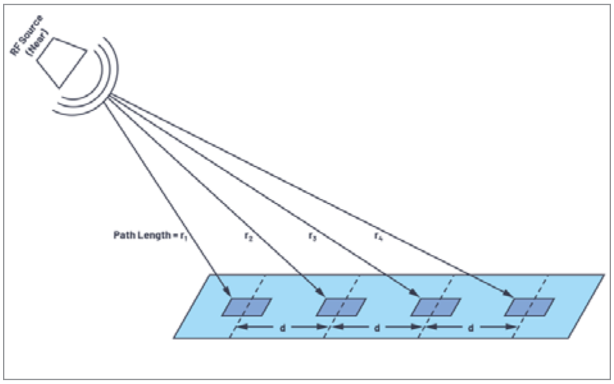


5. In this example of a linear array, spacing between each element is uniformly spaced (N = 4).

Although simplified, this uniformly spaced linear-array model provides the foundation for insight into how the antenna pattern is formed in light of various conditions. We can further apply the principles of the linear array to understand two-dimensional arrays.

NEAR FIELD vs. FAR FIELD

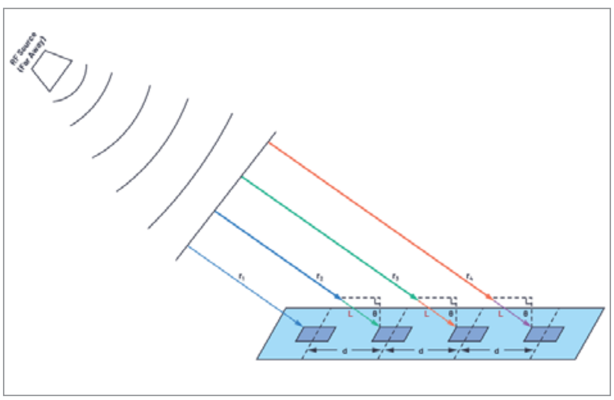
So how can we take the equations previously developed for an N = 2 linear array and apply them to an N = 10,000 linear array? Right now, it seems that each antenna element has a slightly different angle pointing to the spherical wavefront *(Fig. 6)*.



6. In the case of an RF source near the linear array, the angle of incidence varies for each element.

With the RF source near, the incident angle varies for each element. This situation is called the near field. We can work out all of these angles, and sometimes we need to do this for antenna testing and calibration as our test setup can only be so large.

But if we assume that the RF source is far away *(Fig. 7)*, the large radius of the spherical wavefront results in wave propagation paths that are approximately parallel. Therefore, all of



7. If the RF source is far away from the linear array, the large radius of the spherical wavefront results in wave propagation paths that are approximately parallel.

For a small array (small D) or a low frequency (large λ), the far-field distance is small. But for a large array (or high frequency), the far-field distance could be many kilometers. That makes it hard to test and calibrate the array. For such conditions, a more-detailed near model may be used, and then bridge this back to the far-field, real-world use of the array.

our beam angles are equal, and each adjacent element has a path length that is $L = d \times \sin\theta$ longer than its neighbor. This simplifies the math and means that the two-element equations we derived earlier can be applied to thousands of elements, provided they have uniform spacing.

But when can we make the far-field assumption? How far is far? It's a little subjective, but in general, far field is considered anything greater than:

$$\text{Far Field} > 2\,D^2/\lambda \qquad (3)$$

where D is the diameter of the antenna ($(N-1) \times d$ for our uniform linear array).

For a small array (small D) or a low frequency (large λ), the far-field distance is small. But for a large array (or high frequency), the far-field distance could be many kilometers. That makes it hard to test and calibrate the array. For such conditions, a more-detailed near model may be used, and then bridge this back to the far-field, real-world use of the array.

In Part 2, we'll cover antenna gain, directivity, and aperture, as well as array factors. mw

AUTHORS' NOTE: This series of articles is not intended to create antenna design engineers, but rather to help the engineer working on a subsystem or component used in a phased array to visualize how their effort may impact a phased-array antenna pattern.

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LPWANs Help Realize Supply-Chain Monitoring's Potential

IoT is enabling a new era of end-to-end supply-chain monitoring and actionable analytics. Low-power, wide-area networks provide the connectivity to make this possible.

Real-time, transparent, and seamless tracking of assets, both indoors and out, while optimizing logistics and supply chains, has long been the focus of innovative companies around the globe. Internet of Things (IoT) technology is on the cusp of ushering in a whole new era of end-to-end supply-chain monitoring and actionable analytics. In particular, the recent emergence of low-power, wide-area networks (LPWANs) is driving this transition.

As the volume of goods transported globally continues to rise, organizations face greater complexity but also more opportunities to optimize their supply chains. The Council of Supply Chain Management Professionals' annual State of Logistics report found that in 2017 in the U.S. alone, total spending on logistics rose to a record of nearly $1.5 trillion. That's up 6.2% from the year before, and totaling about $250 billion more than companies spent on logistics in 2008.

Analyst firm Berg Insight reports that the number of active tracking devices deployed for cargo-loading units, including trailers, intermodal containers, rail freight wagons, air cargo containers, cargo boxes, and pallets, reached 6.1 million worldwide in 2018. Growing at a compound annual growth rate (CAGR) of 27.3%, this number is expected to reach 20.4 million by 2023.

The highly diverse supply chain spans a wide range of different attributes and requirements, requiring intercontinental and global solutions. Routine activity encompasses everything from the shipping of large products from factories to distributors and customers to the minutiae of ensuring the tiniest parts arrive punctually at just-in-time production lines.

Supply-chain management also is at the heart of the retail sector: Ensuring

stock is available and swiftly dispatched to customers or stores is integral to ensuring the right equipment is in the right place and in the right condition to enable the activities of many other industries.

As economies combat the COVID-19 pandemic, it will take even greater visibility into supply chains to enable factories that depend on just-in-time delivery of goods to reopen and adapt to new operational requirements.

SUPPLY-CHAIN MANAGEMENT DEMANDS GREATER VISIBILITY

Because traditional patterns can no longer be relied on, facilitating decision-making by providing timely data that can be analyzed and acted upon is a vital capability for manufacturers, retailers, and distributors. Deloitte's "Global Chief Procurement Officer Study 2018" found that only 6% of organizations have full visibility into their supply chain, and 65% of organizations have poor or no visibility beyond their tier-1 suppliers.

To gain further knowledge of their supply chains, organizations need connectivity to freight transport down to the individual package or parcel. Besides being cost-effective, connectivity must be set up rapidly, flexibly, and simply so that networks can be turned on, moved, or switched off as required. In addition, there must be a vibrant developer ecosystem to create the devices and applications around the connectivity that enable data to be gathered and analyzed to deliver actionable insights.

LPWAN TECHNOLOGY TRANSFORMS SUPPLY-CHAIN MANAGEMENT

LPWANs enable low-cost wireless connectivity that makes it viable to add connectivity to lower-value assets as well as traditionally tracked equipment like trucks, shipping containers, and rail freight. The price point means individual lower-value items (or packages of them) can be tracked at a sustainable cost and at enormous volume. In such scenarios, LPWANs can communicate important data for analysis that yields actionable insights into the location, condition, and predicted arrival time of assets.

In *Figure 1*, analyst firm IoT Analytics projects LPWAN connections will exceed one billion in 2023. In contrast to short-range solutions such as Bluetooth and Zigbee, which provide a good solution for hyper-local tracking and tracing of assets, LPWAN connectivity can be enabled many miles from the nearest gateway, thereby covering large industrial sites.

Cellular solutions, which are near-ubiquitous, are more complex to manage globally. They require roaming agreements between multiple providers and often necessitate adoption of multiple technologies across the GSMA stack of protocols. 4G and 5G are not fully rolled out and, where available, remain relatively costly solutions for low-value asset tracking both in terms of connectivity and module cost.

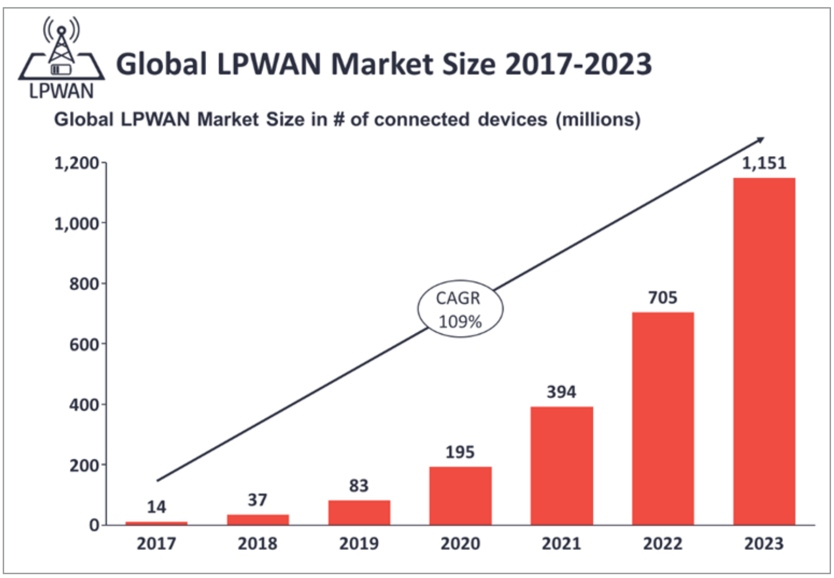
Satellite solutions offer excellent global coverage and are ideal for tracking higher-value, larger assets. In these cases, the higher cost of satellite connectivity makes sense and the larger device size, including antennas, can be more easily accommodated. An example might be a truck or a shipping container. However, for smaller packages, the power requirements, antenna size, and cost make satellite-based approaches unsuitable.

LPWAN ISN'T ONE-SIZE-FITS-ALL

The LPWAN tag describes a number of different technologies that have low-power, wide-area attributes. This field is becoming increasingly crowded with options such as narrowband IoT (NB-IoT), Sigfox, and LoRaWAN, each of which must be carefully evaluated for the application at hand.

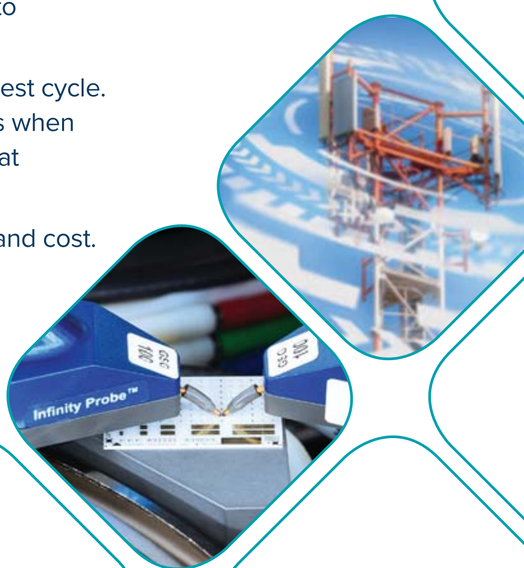
LoRaWAN specifically is an excellent fit because it brings together competitive cost with the capability to handle extremely high device density at a given site. Think of a logistics facility with the tens of thousands of containers, assets, and parcels that traverse it daily. The ability to have deep indoor coverage, which is vital inside the large warehouses that form the core of international logistics, some of which involve underground capacity, is extremely valuable. LoRaWAN can penetrate these large

(Continued on page 38)



1. Projections assert that the number of LPWAN connections will exceed one billion in 2023. *(Source: IoT Analytics)*


5G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MARC PEGULU | Vice President, IoT Strategy and Products, Semtech

Three 2020 Predictions for LPWAN and IoT

What's in store in this technology space for the second half of 2020? Semtech's Marc Pegulu weighs in on new business models, asset tracking, and an edge/cloud hybrid.

As we approach the third quarter of 2020, the Internet of Things (IoT) persists as a focus area for the technology community. It's no surprise, considering the sheer breadth of this technology across nearly every aspect of our lives.

Cisco estimates that there will be 50 billion IoT devices by 2020 and 500 billion by 2030. Not only that, but leading industry analyst firm IHS Markit anticipates that up to 43% of all low-power wide-area-network (LPWAN)-based IoT applications will be based on LoRa devices and/or LoRaWAN networks by 2023. As IoT and LPWAN technologies grow more pervasive, here are a few key things to keep in mind for the rest of 2020:

1. NEW BUSINESS MODELS WILL EMERGE

As more and more LPWAN and IoT devices deploy in 2020, we'll see an increase in new business models. The traditional connectivity model that we're accustomed to seeing will eventually represent less than 10% of all use cases.

Simply put, companies no longer want vendor lock-in. The traditional connectivity business model means a company is paying a certain amount of money for each device they have connected to the network. Driving this adoption is the need for more standardization and true open-source projects as enterprises move away from proprietary solutions.

Other factors driving this shift are evolving service-level agreement (SLA) requirements, access and ownership of data, demand for complete solutions, and ongoing requirements at the edge.

2. GROWTH ACROSS CONSUMER AND ASSET-TRACKING APPLICATIONS

A lot of early volume in the LoRaWAN segment was in the smart-meter market. We've seen continued adoption in the smart building, industrial, agriculture, and oil and gas industries because of the low-power advantages of this technology.

Looking ahead, new asset-tracking systems enabled by new indoor solutions, along with the improved ROI of indoor/outdoor solutions with much lower device and infrastructure costs, will begin driving significant volume in 2020.

We're also seeing relevant use cases in the consumer market. As IoT continues to mature, there will be a lot more convergence of industrial and consumer apps and the networks that target both of those different sectors

3. HYBRID EDGE/CLOUD MODELS WILL WIN OUT

When it comes to the edge and the cloud, a hybrid model will emerge as the solution. A lot of enterprises require on-premises decision-making, but they also want to have some sort of ownership from an initial standpoint before they have the comfort to move to the cloud. The optimal solution to satisfy these needs is a hybrid deployment. With this type of hybrid, you should be able to make decisions to move things to the edge, and still have a connection to the cloud where you can take advantage of coverage, provisioning, and more.

If you look at this history of technology adoption, you'll see that it's typical for enterprises to own new solutions end-to-end before starting to contract components of the system out to the ecosystem for SLA improvements or cost reduction.

With that said, we'll also see a rise in the role of major cloud providers within the LPWAN space. The market began with a mix of key players, including the cable operators, traditional equipment and networking providers, enterprise solution providers, and more. As the market for IoT has grown and matured, the demand for standardization and open source also rose. Cloud providers have realized that the critical way to access IoT data and volumes is to offer and abstract the complexities of wireless connectivity and device hardware. mw

LOU FRENZEL | Technical Contributing Editor

TUBES: Luckily, They're Still Around

As Noah said to his family after dinner, "Those unicorn steaks were excellent!"

So, unicorns are gone for good. But not vacuum tubes. It doesn't seem that tubes will ever disappear completely—they're still with us and that's a good thing. I was reminded of that several times over the past weeks.

For example, I was scanning the ads for a high-power ham-radio amplifier. Most of the popular transceivers top out at about 100 W. For good long-distance (DX) communications around the world on the high-frequency bands (3 to 30 MHz), more power is desired. A number of companies make accessory power amps to boost power level to the FCC legal limit of 1500 W.

Both transistor and tube models are available to choose from. The solid-state amps use multiple RF MOSFETs to get to levels of 500 to 1000 W. These are very expensive. To get to that same power level, you can buy an amp with one or two tubes at about half the price of the transistor model. The old but apparently still good 811 tubes are widely used. And air-cooled tubes like Eimac CX800A7 and Svetlana 4CX800A are other favorites. The tube amps are quite a bargain.

SOUNDING OFF: TUBE OR SOLID-STATE AMP?

My other reminder about tubes was in looking for a new guitar amplifier. These come in all shapes and sizes with power levels of 10 to 20 W up to over 100 W. Both tube and solid-state amps are available. Some of the smallest amps use class D switching amps that give you lots of power in a very small package.

As it turns out, there are more vacuum-tube guitar amps than solid-state amps. Most guitar players, except maybe for a few heavy-metal types, prefer the sound of a tube amp. The tube sound is said to be warmer, fat-toned, and organic. It's a personal thing as the sound difference is subtle. You have to hear the two versions to feel it or "get it." That difference is real. The tube amps just sound better and louder with nuances.

The most popular tube amps use a pair of EL84 power tubes. These are also known as 6BQ5s. Virtually all are made in the U.K., Russia, and Europe. Like most tubes, they must be replaced every now and then. You can still get replacements for $10 to $20 each. I have also come across vacuum-tube guitar amps that still use the old 6V6 or 6L6 power tubes. I did not know these were still around, but I guess they can be had.

Guitar amps also use tubes in their preamps. Most common among them are the popular dual triodes 12AX7 and 12AU7. Some use ECC83s. There are also hybrid amps with tube preamps and solid-state power amps. You can even buy a solid-state power amp with a DSP feature that makes the amplifier sound like a tube version. Called modeling amps, these programmable units make it possible to create your own unique sound. You can also add effects like delay, tremolo, distortion, reverb, and others.

The inexpensive solid-state amps at the 10- to 20-W level sell for $100 to $200. A 100-W tube amp can sell for several thousand dollars depending on the accessories.

Vacuum tubes are still a big deal in the guitar world. And much of the appeal of tube amps to guitarists exists in those high-end audio enthusiasts. You can still buy big-buck high-fidelity amps with tubes, and many fans swear by them. It's easy to identify a high-end audio person and some guitarists by their hearing aids or lack of hearing. Huh….

BY THE BOOK

But that's not all….

My other reminder about the ongoing existence of vacuum tubes came in the form of a new book from Artech House titled *Microwave and Millimeter-Wave Vacuum Electron Devices* by A.S Gilmour. This up-to-date 900-pager covers the wide range of available microwave/mmWave vacuum tubes.

Dr. Gilmour points out in the preface that you should never use the term "tube." These are vacuum electron devices (VEDs). The book includes all the well-known devices like traveling-wave tubes (TWTs), klystrons, magnetrons, and a few I wasn't familiar with. This book really stands out because it uses full-color illustrations throughout to explain theory of operation and applications. It's heavy on the theory but easy to read.

If you work with VEDs, you probably should have a copy of this for reference. And if you're contemplating the use of VEDs, definitely get a copy of this to help you understand and select an appropriate product.

With the demise of the cathode ray tube (CRT) from TV sets and scopes, I figured that the vacuum tube era was over. It definitely is not, and maybe it never will be…completely. Don't think of tubes as archaic losers to be avoided at all cost but rather as viable alternatives in your new electronic designs. mw

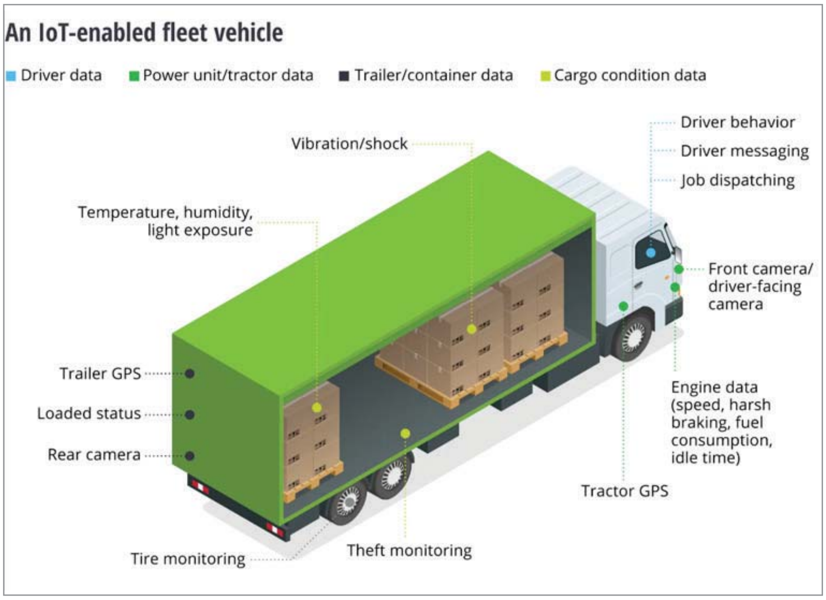
(Continued from page 32)

buildings, ensuring uninterrupted asset tracking.

At these facilities, LoRaWAN offers the option of public or private networks, which is attractive to large site operators because it can drive economies, assure performance, and is perceived to be highly secure. In either type of deployment, it's worth noting LoRaWAN's mature security, which been developed over many years.

A further strength of LoRaWAN devices is their typically very long battery life. It makes them ideal for multiple long journeys, such as for the months involved in intercontinental shipping, or for more complex applications like daily updates on the location and status of a truck *(Fig. 2)*.

Asset tracking isn't performed in controlled environments and logistics, and by its nature involves shock, vibration, temperature extremes, and other factors otherwise not present in smooth, non-mobile environments. LoRaWAN is rugged, so it can continue to operate in most extreme situations.



2. Shown are the typical connected devices that feed supply-chain management from an IoT-enabled fleet vehicle. *(Source: Deloitte)*

HOW LoRaWAN DELIVERS SUPPLY-CHAIN BENEFITS

LoRaWAN provider Semtech has supplied a car manufacturer with connected racks used in the vehicle-manufacturing process. These racks, which typically have an active life of 10 years, are used to transport key components such as gearboxes from their point of manufacture to the assembly plant. These racks cost about €500 and manufacturers use hundreds of thousands of them. Approximately 10% are replaced each year, resulting in €10 million in operating expenditures.

Semtech also has supplied Pallet Alliance, a provider of pallet-management programs for multi-site organizations, with its IntelliPallet, an IoT-based pallet-monitoring platform. The platform integrates location and environmental sensors into wooden pallets, which comprise more than 90% of the worldwide palletized shipping market. The flexible LoRaWAN-based platform offers customized tracking capabilities, including entry and exit notifications from a geo-fenced area, stationary time and arrival/departure from designated hubs, and environmental monitoring for factors including temperature, humidity, and motion.

Another LoRaWAN supply-chain example can be found at United States Cold Storage (USCS), a provider of public refrigerated warehousing (PRW) and logistics services. The company wanted to offer enhanced visibility into shipments of perishable goods as part of its integrated third-party logistics service offering.

LoRaWAN network operator Senet and NanoThings—a developer of long-range, temperature-tracking smart labels and a platform to monitor temperature and manage cold chains with inter-company communication—have partnered to combine the affordability and small form factor of NanoThings' NanoTags with LoRaWAN network connectivity to address USCS's needs. The partners provide customers with autonomous temperature monitoring and touchpoint tracking that could transform how data on perishable goods is collected and used throughout the retail supply chain.

THE CONNECTED SUPPLY CHAIN OF THE FUTURE

LoRaWAN and other LPWA technologies imbue supply-chain management with the power to continuously connect items in transit and cost-effectively monitor them globally for the lifespan of the device. These capabilities have the potential to radically transform the industry. To date, visibility has been obtained by tracking large assets such as shipping containers, trucks, or rail wagons. LPWANs open the next stage of opportunity by enabling connectivity down to the individual item to be viable.

This isn't a high-bandwidth, multimedia experience. Rather, it's the simple transmission of data, robustly and securely, that can feed supply-chain management systems with a flow of accurate data that informs important decisions. Its value will be proved in increased efficiency, greater accuracy, and fewer failures because of lost assets or spoiled goods. mw

MMIC Splitter/Combiner Channels 12.0 to 43.5 GHz

MINI-CIRCUITS' MODEL EP2-561+ is a two-way, 0-deg. power splitter/combiner fabricated with GaAs IPD technology for applications from 12.0 to 43.5 GHz, including 5G and radar systems. Supplied in a 2- x 2-mm surface-mount-technology (SMT) housing, the 50-Ω power splitter/combiner has full-band VSWR of 1.70:1 or better at all ports. Insertion loss (above the 3-dB split) is typically 1.1 dB from 12.0 to 24.0 GHz, 1.3 dB from 24.0 to 30.0 GHz, and 1.4 dB from 30.0 to 43.5 GHz. Isolation is typically 15 dB from 12.0 to 24.0 GHz, 23 dB from 24.0 to 30.0 GHz, and 16 dB from 30.0 to 43.5 GHz. The splitter/combiner provides outstanding amplitude and phase balance, with typical full-band amplitude unbalance of 0.2 dB or better and typical full-band phase unbalance of 1.7 deg. or better. The SMT MMIC handles as much as 0.5-W power as a splitter or combiner and has an operating temperature range of -55 to +105°C.

MINI-CIRCUITS, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, https://www.minicircuits.com/WebStore/dashboard.html?model=EP2-5G1%2B

Directional Coupler Passes DC to 65 GHz

MINI-CIRCUITS' MODEL ZCDC130E1653+ is a wideband directional coupler for a wide range of applications from 1 to 65 GHz. Well suited for mobile communications, satellite communications (satcom), and test-and-measurement applications, the RoHS-compliant directional coupler features 13-dB typical coupling with ±0.9-dB typical coupling flatness across the full frequency range. The typical mainline insertion loss is 0.7 dB from 1 to 18 GHz, 1.3 dB from 18 to 40 GHz, 1.8 dB from 40 to 50 GHz, and 2.3 dB from 50 to 65 GHz. The typical directivity is 29 dB from 1 to 18 GHz, 22 dB from 21 to 40 GHz, 21 dB from 40 to 50 GHz, and 19 dB from 50 to 65 GHz. The directional coupler handles as much as 11-W input power at room temperature and passes as much as 0.46-A dc current from input to output. It measures 3.50 × 0.70 × 0.50 in. (88.90 × 17.78 × 12.70 mm) with female 1.85-mm connectors and is designed for operating temperatures from -55 to +100°C.

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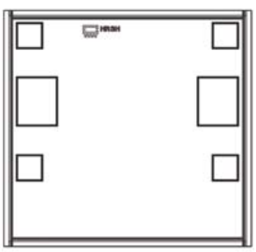
GaAs MMIC Die Helps Equalize Gain Responses



MINI-CIRCUITS' MODEL EQY-3-453-D+ is an absorptive gain equalizer die with negative insertion loss slope from dc to 45 GHz. Supplied in chip form on nonstatic material, the 50-Ω, RoHS-compliant gain equalizer exhibits insertion loss of 4.6 dB at 10 MHz, 4.3 dB at 10 GHz, 3.6 dB at 20 GHz, and 1.1 dB at 45 GHz. VSWR is typically only 1.14:1 through 10 GHz, 1.22:1 or less from 10 to 30 GHz, and 1.23:1 from 30 to 45 GHz. Well suited for a wide range of gain equalization functions in commercial and military communications and test-and-measurement applications, the MMIC handles as much as +30-dBm (1 W) input power at operating temperatures from -55 to +105°C.

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INTELLICONNECT, www.intelliconnectusa.com/cable-selector

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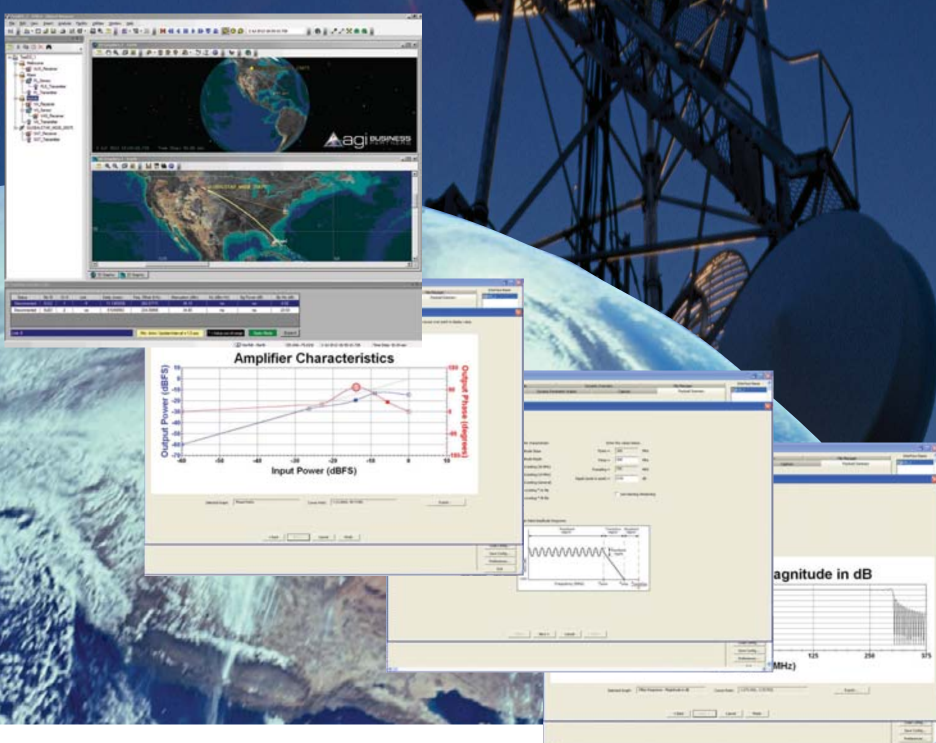

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