How Does 5G Conformance Testing Stack Up in 2020? p20

These Three Wireless Trends Will Assume the Spotlight This Year p24

Kicking off the Decade of Ambient Computing with Bold Predictions p48

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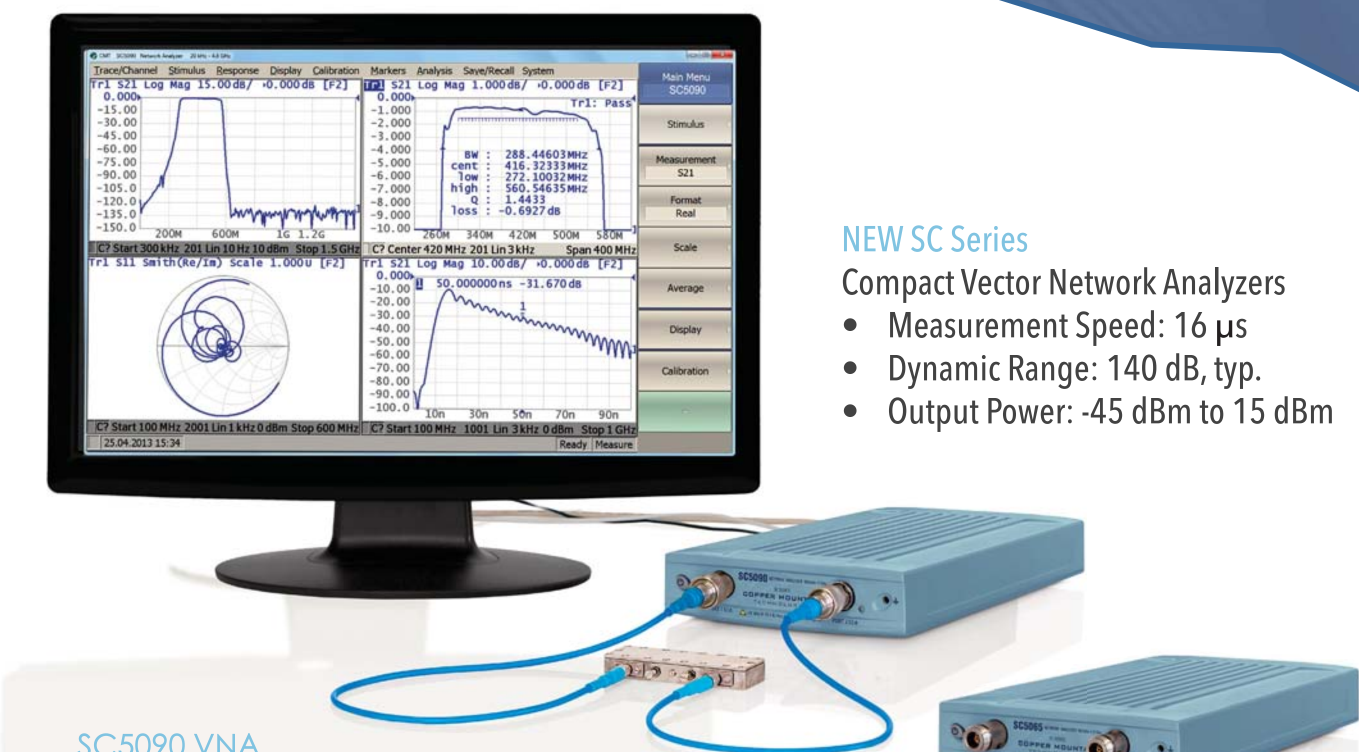

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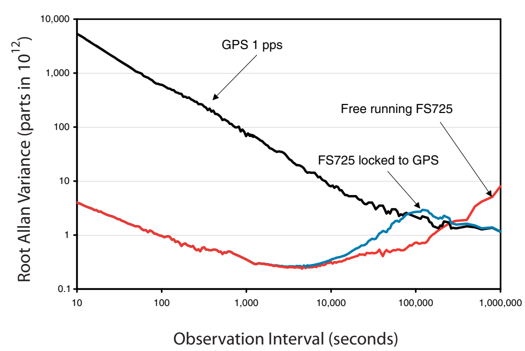

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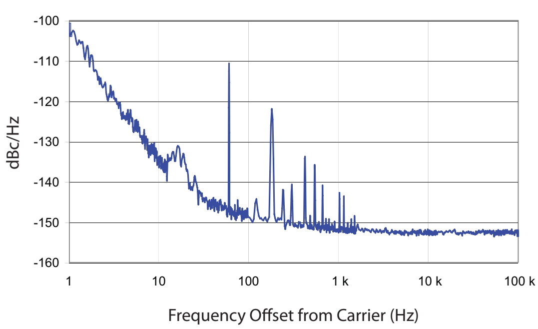

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PRODUCTS & TECHNOLOGY

Editorial

WILLIAM WONG | Senior Technology Editor

What's on Tap for Wireless in 2020?

A number of technological forces are driving wireless advances, from video streaming to IoT to automotive advanced driver-assistance systems (ADAS). They're pushing the limits of bandwidth and coverage with a host of solutions emerging, but challenges remain from testing and deployment to spectrum allocation.

The FCC's recent reduction in bandwidth available for dedicated short-range communications (DSRC) used in ADAS systems is just one change that can significantly affect the adoption and deployment of new technologies. The rise of 5G NR and this bandwidth revision could ultimately impact how V2X transportation technology is applied.

5G promises to improve both video-streaming support and low-bandwidth IoT deployment, but much of this is still in the future even as 5G deployment escalates. This leaves plenty of opportunity for Long Term Evolution machine-type communications (LTE-M) and Narrowband IoT (NB-IoT), as well as much of its competition in the unlicensed spectrum like LoRaWAN and Sigfox.

Local wireless-networking options in the unlicensed spectrum space continue to grow and improve, including protocols like Bluetooth, Zigbee, and 802.15.4. In particular, Bluetooth mesh is becoming a standard worth examining.

Wi-Fi's expansion is widening with Wi-Fi 5 (802.11ac) shipping in bulk and Wi-Fi 6 (802.11ax) on the horizon. It and other wireless standards need to meet the demand for more bandwidth, and that means support for 4K video.

Wireless communication is just one of the many topics that will be covered by *Microwaves and RF* in 2020. The latest in other application areas, especially test & measurement and RF, will continue to be fixtures of our publication. On top of that, 2020 is shaping up to be full of new hardware deliveries across the board, with plenty of platforms for developers to choose from. mw

Microwaves&RF **JANUARY 2020**

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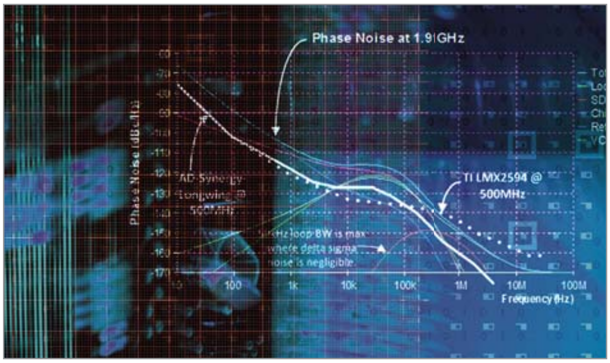


Low-Noise Synthesizer Design Examples

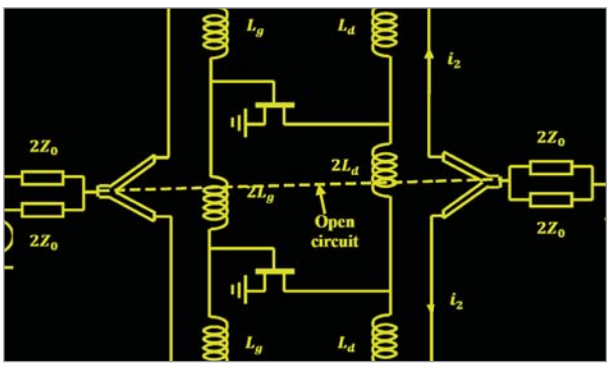
The final chapter of this five-part series looks at five different synthesizer designs, comparing fully integrated synthesizers to discrete implementations.

https://www.mwrf.com/technologies/components/article/21850038/lownoise-synthesizer-design-examples

The Car Radio of the Future

The support for the V2X movement is seemingly strong, bolstered by C-V2X developments. So why is its adoption still lumbering through the discussion phase?

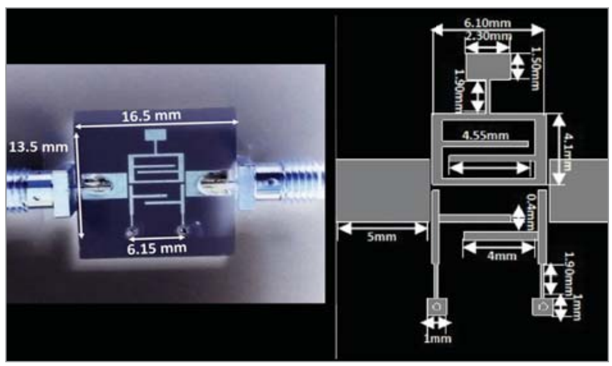
https://www.mwrf.com/technologies/systems/article/21850068/the-car-radio-of-the-future



Apply a New Approach to Dual-Fed Distributed Amplifier Design

This novel design method helps improve gain for the dual-fed DA by approximating gain using the Chebyshev polynomial.

https://www.mwrf.com/technologies/components/article/21850023/apply-a-new-approach-to-dualfed-distributed-amplifier-design



Quad-Band Resonator Depends on CRLH/D-CRLH Structures

The design of this multi-band resonator allows for multiple passbands while keeping size to a minimum.

https://www.mwrf.com/technologies/components/article/21849975/quadband-resonator-depends-on-crlhdcrlh-structures

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News

Alliance Gives Students a Gateway to the MOBILE TECHNOLOGY WORLD

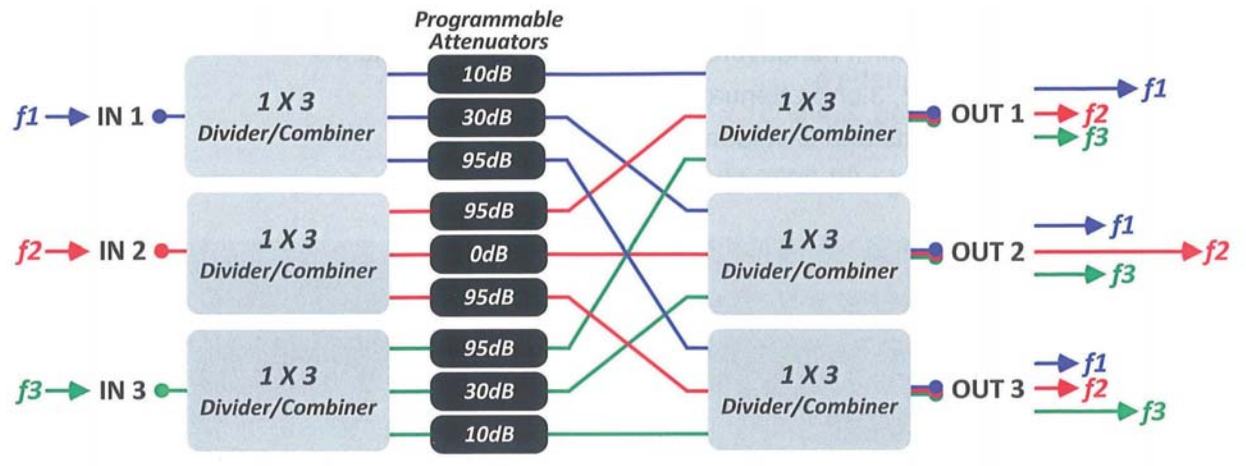
A previous column discussed how Queensborough Community College (QCC) in Bayside, N.Y., is focused on RF education with its array of industry-standard test equipment and more. Continuing that theme, QCC's commitment to technology education can be further validated by its partnership with Nokia Bell Labs. Thanks to this alliance, QCC is able to give students access to equipment provided by the company *(Fig. 1)*. On top of that, QCC will even be sending one of its own students to intern at Nokia Bell Labs—quite an accomplishment for a community college.

How did the partnership between QCC and Nokia Bell Labs begin in the first place? Enrique Haro, senior CUNY lab technician and adjunct lecturer at QCC, explains, "The partnership between QCC and Nokia Bell Labs began with the help of Joe Amato from RF Alliance and Bryan Walker from JFW Industries. They helped arrange a meeting with Dotti Evans, Carlos Sigas, Craig Polk, and other members of the mobile networks team at Nokia Bell Labs in Murray Hill, N.J.

"I was able to share the idea of providing technicians with hands-on training using commercial mobile radio equipment found in the field. The QCC-Nokia Connect project was then born with the mission of creating a talented workforce in mobile communications to help companies that use mobile technology compete globally."

As mentioned, QCC students can utilize equipment provided by Nokia Bell Labs. Specifically, the school was given a handover system along with a mini lab live (MLL) server that controls the handover RF hardware. *Figure 2* shows a block diagram of an equivalent handover system from JFW Industries.

1. Students at QCC will be able to utilize this equipment intended for mobile testing.



2. This is a block diagram of a handover system that corresponds to the system QCC received. *(Courtesy of JFW Industries)*

"We use GSM and LTE radios as signal sources to monitor handover signals from cell to cell and sector to sector on spectrum analyzers and on LTE user equipment as well," says Haro. "We are able to change the configuration for the number of cells and sectors. The configuration supports up to 18 student workstations and it is upgradeable. Students can also gain experience with automated testing software, which runs on a UNIX server."

What does Haro hope students will gain from having access to this equipment? He answers, "I hope that students become passionate about mobile technology by having access to the physical aspects of signal propagation from cell to cell or sector to sector to the handset. I also hope they become familiar with RF components that are not easily found in a classroom. The equipment we were given is the same equipment that's currently used for mobile configuration testing at Nokia Bell Labs. This initiative opens the door to other mobile-communication technologies."

Lastly, the partnership is also opening the door for QCC to send one of its students to intern at Nokia Bell Labs. "I'm very excited by this opportunity," says Haro. "A student from a community college is not the typical candidate for Nokia Bell Labs. Most interns are graduate or Ph.D. students. Such an opportunity will change a student's life. I believe the student will have a great future by starting his or her specialization early in life ahead of most traditional students. Also, students in general will perform better in class knowing there's an internship opportunity at one of the greatest telecom research facilities in the world." ■

IEEE HONORS Army-Funded Researcher for Signal Processing

THE IEEE IS RECOGNIZING U.S. Army-funded researcher Dr. Rama Chellappa for his work in the field of signal processing. The distinguished university professor of electrical and computer engineering at the University of Maryland will be formally honored with the 2020 IEEE Jack S. Kilby Signal Processing Medal in May 2020 at an awards ceremony in Vancouver, B.C., Canada. The IEEE board of directors specifically cited Chellappa's "contributions to image and video processing, especially applications to face recognition." The IEEE established the award in 1995 to honor Jack S. Kilby a pioneer in digital signal processing (DSP).

Chellappa is part of a research team funded by the Army and led out of Johns Hopkins University. Its research on data analysis has potentially far-reaching impact on machine learning (ML) and data science, attempting to develop improved algorithms for facial and general object recognition to enhance computer decision-making and situational awareness.

"The ability to break down data into semantic nuggets is profoundly important to quickly interpreting scene images and to making informed and intelligent decision making for autonomous agents," said Dr. Hamid Krim, program manager, information processing and fusion at the Army Research Office. "That could hence lead to new technologies for reconnaissance, surveillance and intelligence, robotic perception, precision targeting, counter-terrorism and homeland security." Chellappa has a permanent appointment in the University of Maryland Institute for Advanced Computer Studies, where he does much of his research. ■

Dr. Rama Chellappa

MINI-CIRCUITS EXPANDS Regional Sales Office to Serve Japan, South Korea

Shown are Ted Heil and Kai Lo along with two officials from the Office of the City of Yokohama Representative to the Americas: Toshikazu Yazawa (director) and Makoto Sekiyama (executive officer for global partnership and networking).

MINI-CIRCUITS *(WWW.MINICIRCUITS.COM)* just recently opened a regional sales office in Shin-Yokohama, Kanagawa Prefecture, Japan to expand its service to customers in Japan and South Korea *(see photo above)*. The new office will work in conjunction with Mini-Circuits' local sales representatives and distributors to offer additional resources and support in growing business and addressing customer needs.

The company has appointed Thomas Joyce as regional sales director, Japan and South Korea, to manage Mini-Circuits' office in Yokohama and to continue broadening its sales and service presence in the region. Mr. Joyce brings 33 years of experience in electronics design, management, and marketing, as well as extensive knowledge of the Japanese and South Korean markets.

Mini-Circuits' president Ted Heil commented, "Part of our mission to be the world's preferred supplier of RF and microwave products means ensuring we consistently deliver world-class service to our customers everywhere across the globe. Under Thomas' direction, the Yokohama office will augment the efforts of our channel partners in Japan and South Korea as a direct link to Mini-Circuits at the local level."

> "Part of our mission to be the world's preferred supplier of RF and microwave products means ensuring we consistently deliver world-class service to our customers everywhere across the globe."

Mini-Circuits Japan is one of Mini-Circuits' 14 corporate locations, joining design, manufacturing, and sales centers spanning nine nations. ■

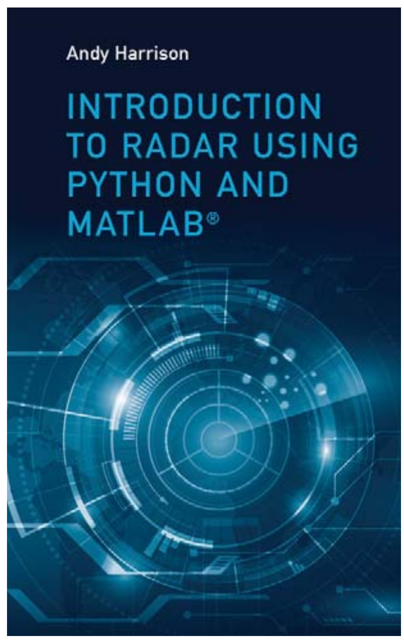

RF OUT

LEARN RADAR ENGINEERING with Python and MATLAB

INTENDED TO INTRODUCE and expound on a number of radar fundamentals, the book *Introduction to Radar Using Python and MATLAB* presents a tool suite that consists of Python scripts, as well as corresponding MATLAB scripts, to reinforce fundamental topics. The goal is to provide readers with a mechanism to analyze and predict radar performance for various scenarios and applications.

The author, Andy Harrison, a senior research engineer at Radiance Technologies, asserts that the book is well-suited for a senior-level undergraduate or first-year-level graduate course, as well as for professionals who are seeking to enter the arena of radar engineering.

Chapter 1 begins by presenting a history of radar before diving into the topic of radar classification. The author subsequently discusses radar classification by explaining that the military's need to detect enemy aircraft was the early driving force behind the development of radar systems. Since then, radar systems have been employed for many use cases, such as cancer detection, autonomous-vehicle navigation, weather forecasting, terrain mapping, and through-wall detection.



Therefore, according to the author, it's often convenient to categorize radar systems based on parameters like operating frequency band, type of waveform used, configuration, etc. To illustrate this, the chapter contains a table that depicts radar classification by operating frequency. It then describes typical radar waveforms, including continuous-wave (CW) and pulsed waveforms, as well as more complex types such as phase-coded

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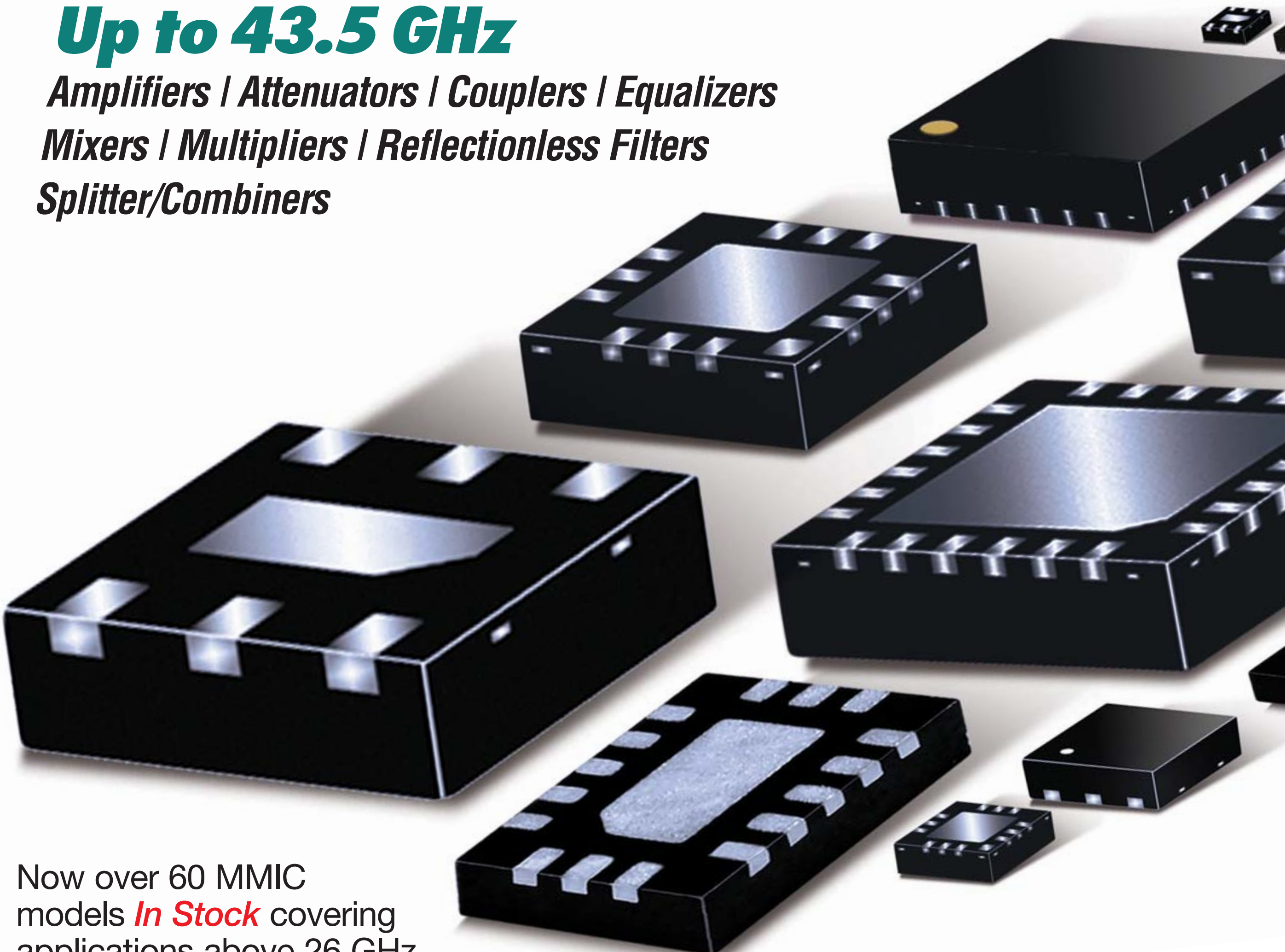

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The author, Andy Harrison, a senior research engineer at Radiance Technologies, asserts that the book is well-suited for a senior-level undergraduate or first-year-level graduate course, as well as for professionals who are seeking to enter the arena of radar engineering.

waveforms. Another table lists common waveform types and their applications. In addition, various radar-system configurations are defined, including monostatic, quasi-monostatic, bistatic, and multistatic systems. Corresponding illustrations are also shown of bistatic and multistatic systems.

Chapter 1 concludes by discussing the book's accompanying software. The tool suite, written in the Python programming language, includes a user-friendly graphical user interface (GUI) that updates plots and images automatically as the user changes parameters. Also included are scripts written in MATLAB that correspond to each of the Python scripts. The Python and MATLAB sets of code can be obtained from a GitHub repository.

The second chapter covers electromagnetic (EM) fields and waves. Of course, a discussion on EM fields and waves must include an overview of Maxwell's equations—and that's the case here. Among the additional topics touched on throughout the chapter include EM boundary conditions, wave equations and solutions, and plane waves. Subsequent chapters delve into topics like antenna systems, the radar range equation, radar receivers, target detection, radar cross section, and more. ■

MODELITHICS RELEASES VERSION 19.6 of the COMPLETE+3D Library for ANSYS HFSS

MODELITHICS *(WWW.MODELITHICS.COM)* recently announced the release of version 19.6 of its COMPLETE+3D Library for use with ANSYS *(www.ansys.com)* HFSS, which houses 117 new full-wave 3D electromagnetic (EM) models.

The library's extended selection of highly scalable models for capacitor, inductor, and resistor families draws from many popular vendors. It also includes an expanding collection of Modelithics' 3D geometry models for Coilcraft *(www.coilcraft.com)* and TDK *(www.global.tdk.com)* inductors, as well as a connector model for SV Microwave (*www.svmicrowave.com*). Version 19.6 features 15 new part value-, pad-, and substrate-scalable models in addition to the 117 new full-wave 3D EM models.

New scalable circuit models include five for Knowles *(www.knowles.com)* (four DLI and one Syfer), as well as models for Exxelia *(www.exxelia.com)* and Würth Elektronik *(www.we-online.com)* capacitor families. On top of that, the release presents three new inductor models for Coilcraft, a Vishay FC0402 resistor series model, and two capacitor and three inductor models for Würth Elektronik families.

Through the Modelithics Vendor Partner (MVP) program, 90-day free model use is being sponsored by Coilcraft, TDK, and Würth Elektronik. In addition, 30-day trials are offered by Exxelia and Vishay, as well as Knowles for the DLI and Syfer models. To request a dedicated vendor trial of one of these selected MVPs, visit *www.modelithics.com/mvp/vsl.*

For more information about this new release or to request a free trial, visit the Modelithics website or contact the company at sales@modelithics.com. ■

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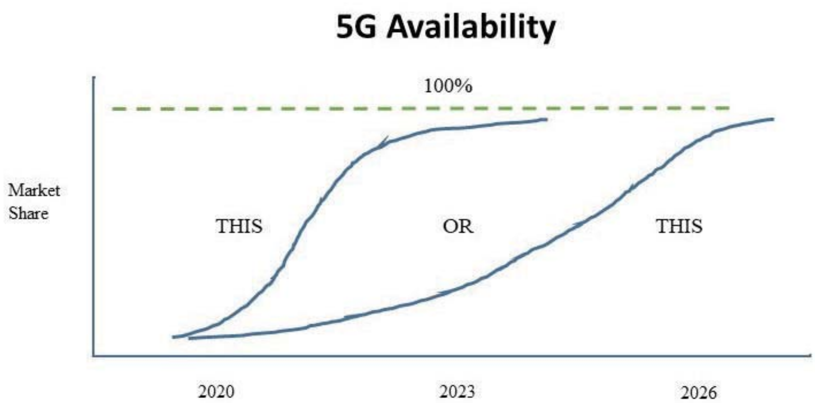
5G: How Much is Real vs. Marketing?

Is 5G ready for prime time? Breaking down the marketing hype versus what's really going on in the industry.



A June 2019 forecast made by Canalys has global 5G smartphone shipments crossing 4G smartphone shipments in 2023.

The new 5G protocol is in the news virtually every day, with proclamations that encompass everything from cellphones to autonomous vehicles to thermostats. One might already believe that if you don't own a 5G device, you clearly aren't "In Style."

Soooo, marketing claims 5G is pervasive. The question is when: 2020 or is it 2025?

First, let's define 5G also known as 5G New Radio, or 5G NR.

- There is sub-6-GHz 5G for the cellphone protocol that requires LTE: 5G NSA.
- There is sub-6-GHz standalone 5G: 5G SA.
- There is 20- to 60-GHz 5G: 5G mmWave.

One June 2019 forecast made by Canalys has global 5G smartphone shipments crossing 4G smartphone shipments in 2023 *(see figure)*.

In evaluating whether 5G is ready for "prime time" in any of its incarnations, one must one must look into several areas:

- What is the status of the 5G standards?
- What is the status of technologies in the various frequency spectrums?
- What is the status of 5G in the geopolitical arena?
- What is the status of the component suppliers?

There have been 5G protocols published by various organizations since 2012. However, the initial release of a 5G standard by the 3GPP ("Third Generation Partnership Project" international standards committee) was in 2017. The release (R15 NSA) addressed "non-standalone" 5G, which is 5G coexisting with LTE.

In 2018, 3GPP issued an updated version of R15 for standalone 5G (R15 SA). Then 3GPP released another version of R15 in mid-2019 to address outstanding issues from R15 SA. R16, considered to be the first "full" 5G standard, is scheduled for release in mid-2020. While the scope for R17 has not yet been agreed to, it's intended to address the enhancements needed for reliable operation in 20+ GHz for autonomous vehicles, commercial industry connections, etc. Sounds like there might be a possibility that coming updates could affect the silicon implementations of 5G and maybe obsolete some implementations?

DEALING WITH DATA RATES

A significant enhancement in 5G over the previous protocols (4G, 3G, WCDMA, CDMA, and GSM) is its increased data rates, which allow it to connect a variety of devices above and beyond traditional smartphone functions. Devices for industrial IoT, autonomous vehicles, and industrial connectivity are thought to depend on the increased data rates supplied by 5G sub-6-GHz and the millimeter-wave (mmWave) portion of the 5G protocol; that is, frequencies in the 20- to 60-GHz range.

(Continued on page 55)

MAJEED AHMAD KAMRAN | Contributing Editor

Where Does 5G Conformance Testing Stand in 2020?

The 5G test cases presented here encompass RF characteristics, radio resource management (RRM), and protocol suites that work at the chipset, device, and base-station levels on sub-6-GHz and mmWave frequencies in both lab and field environments.

The 5G test and conformance era is far more challenging than 4G wireless amid a broad range of new services and technology paradigms. There's a large matrix of test cases that vary widely, and these changes reinforce the importance of adequately validating the device performance on 5G networks as specified in the New Radio (NR) standard *(Fig. 1)*.

The 5G conformance test spans RF characteristics, radio resource management (RRM), and communication protocol suites, and that calls for flexible test solutions that can eventually be customized for specific use cases and certification requirements. At the same time, it's also critical that both chipsets and devices are rigorously tested under linear and nonlinear conditions across the entire workflow, from design validation to product manufacturing *(Fig. 2)*.

There are other pressures as well when it comes to accelerating the conformance to advance 5G commercialization. For instance, network operators, as well as chipset and device manufacturers, are striving to ensure successful device testing and acceptance on the first attempt. But that's easier said than done.

For starters, 5G conformance testing encompasses two technology realms: sub-6-GHz bands with new multiple-input multiple-output (MIMO) antenna systems and higher-frequency millimeter-wave (mmWave) bands with highly focused beamsteering. The conformance testing matrix further expands with different spectrums operating across the globe and the need for 5G devices to work in both non-standalone and standalone modes.

That calls for engineers to thoroughly test the parametric performance, physical-layer (PHY) characteristics, and protocol functionality of the device's chipset using the same emulated network and communication channels employed by 5G carriers. The following section provides highlights of the extended matrix of 5G test cases that includes functional testing, negative testing, regression testing, KPI testing, data-throughput testing, and overall device performance testing.

5G CONFORMANCE MATRIX

The conformance test requirements, as specified in the 3GPP 5G NR standard, include a wide range of RF demodulation and RRM test cases. And they can be validated by the Global Certification Forum (GCF) and PCS Type Certification Review Board (PTCRB), a certification platform comprised of the leading U.S. mobile operators.

Start with the Testing and Test Control Notation version 3 (TTCN-3) conformance testbed, a core language that 3GPP uses to specify different types of reactive system tests over a variety of communication ports. The TTCN-3 conformance use cases employ real user equipment (UE) and real hardware in the form of network simulators to verify 5G designs.

Next, RAN5, a workgroup within 3GPP, focuses on the conformance testing specification for the radio interface of UE devices. It's organized in the RF subgroup and the signaling subgroup, respectively, and it encompasses both RF and RRM conformance tests. The RAN5 workgroup approves the Protocol Conformance Tests as defined in the 3GPP TS38.523 requirements.

The 5G conformance testing ranges from device R&D and design validation to conformance verification to carrier acceptance and manufacturing. Thus, the 5G mobile ecosystem is being streamlined from early prototyping to design validation to device manufacturing. Take, for example, the Chinese phone maker Oppo, which unveiled the 5G handset "Reno" in April 2019. It demonstrated the world's first 5G signaling and data connection for a video call in November 2018 *(Fig. 3)*.

According to James Kimery, director of wireless research at National Instruments (NI), assessing the performance of video and data delivery is crucial for 5G devices. It's worth mentioning here that 5G device manufacturers like Oppo are employing the same tools that chipmakers use to validate 5G NR designs.

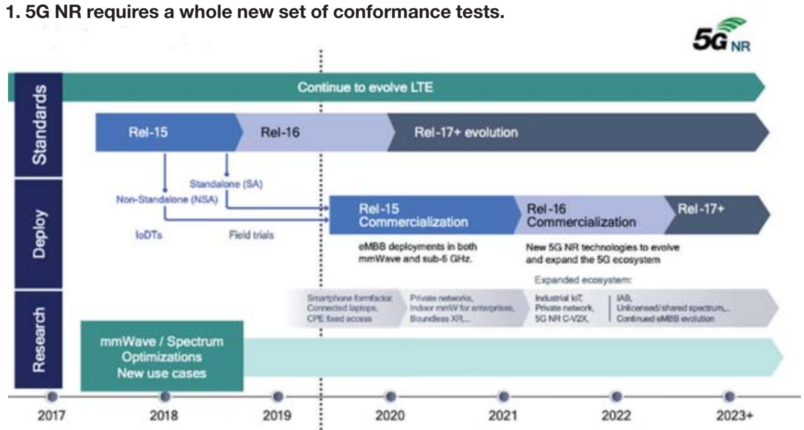
Moreover, protocol conformance tests for both chipsets and devices are a key enabler in validating the performance of 5G designs. And they mandate the availability of complete protocol stacks on a software platform with fully developed, carrier-based test cases.

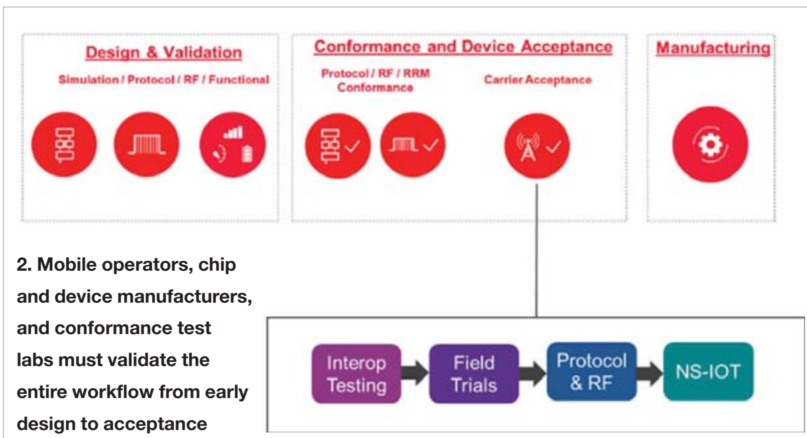
Below is a sneak peek into various conformance test cases that demonstrate how chipset and device manufacturers are validating the 5G NR designs across the entire workflow.

5G CONFORMANCE TEST CASES

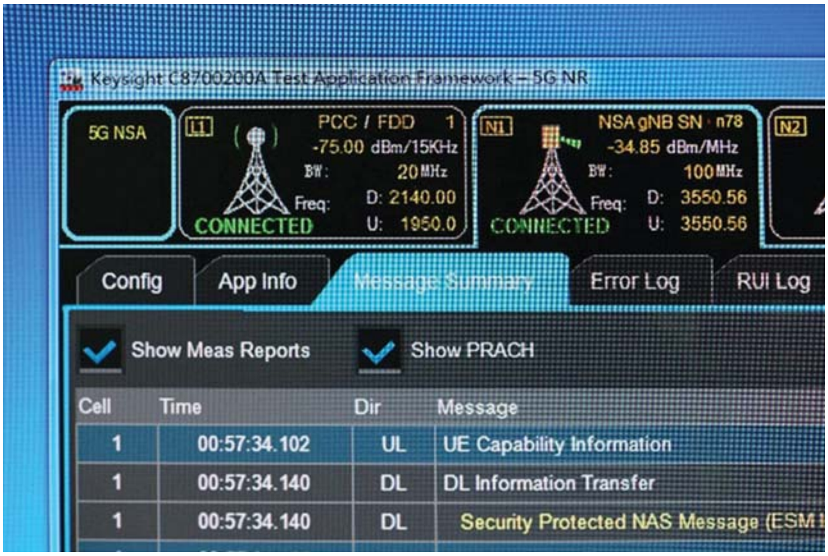
Samsung's Exynos Modem 5100, compatible with 3GPP Release 15, supports both sub-6-GHz and mmWave spectrums with a single-chip solution. The company has conducted an over-the-air (OTA) 5G NR data call test under a wireless environment utilizing a 5G base station and 5G end-user equipment prototype embedded with the Exynos Modem 5100.

1. 5G NR requires a whole new set of conformance tests.





2. Mobile operators, chip and device manufacturers, and conformance test labs must validate the entire workflow from early design to acceptance to production. *(Source: Keysight)*



3. This is a view of the conformance test framework of Oppo's 5G smartphone. *(Source: Keysight)*

4. The new architectural options in 5G reinforce the need for test solutions with modular hardware and software components. *(Source: Rohde & Schwarz)*

"5G wireless is evolving much faster than previous cellular technologies," said Woonhaing Hur, vice president of System LSI Protocol Development at Samsung Electronics. "Especially after 3GPP officially approved the first round of 5G specifications in the summer of 2018."

Marvin Test Solutions has developed a manufacturing test platform for beamforming ICs under linear and nonlinear conditions. Beamforming IC testing is crucial in 5G mmWave systems, utilizing component- and system-level simulation tools to facilitate high-precision measurements at mmWave bands.

"The test systems need to be ready for a new class of 5G beamforming devices," said Alastair Upton, chief strategy officer at Anokiwave. The company offers mmWave ICs for active antenna arrays and has demonstrated OTA validation of antenna-in-package (AiP) devices in collaboration with NI.

The OTA-based RF validation significantly shortens development schedules and helps test professionals achieve faster speeds compared to traditional point-by-point software-controlled test systems *(Fig. 4)*.

"The 5G NR systems demand modular hardware and software platforms that address the testing needs of today and well into the decade," said Mike Thorpe, product manager at Rohde & Schwarz. The test-and-measurement company is working with quality-assurance specialist Intertek and conformance test labs to test the signaling, RF parameters, and data-throughput rates of simultaneous LTE/5G links in dual-connectivity mode.

As the aforementioned test cases show, the 5G conformance initiatives are starting to accelerate after the early rollout of 5G NR networks in 2019. And these activities are likely to gather pace in 2020 and beyond when 5G reaches the cusp of commercial deployment.

THE CASE FOR UNIFIED TEST PLATFORMS

The race to 5G commercialization is on, currently led by customer-premises-equipment (CPE) units for the fixed wireless access service, which is promising to offer multi-gigabit wireless throughput in select U.S. cities. Furthermore, mobile hotspots and 5G smartphones are being launched around the world.

It all begins with demonstrating stability and high data rates in clean and ideal channel conditions. The toolsets allow test engineers to emulate the real-world complexities related to 3D fading and channel interference conditions inside the lab environments.

Once test professionals have done that, they must validate the mobile-device or base-station performance under real-world conditions, where the channel is non-ideal, complex, faded, and filled with interference. So, 5G test professionals require reliable tools to characterize the system performance of mobile devices and base stations across all 5G NR signal bandwidths.

The latest initiatives and developments regarding 5G conformance, as well as the recent test cases outlined in this article, also call for a holistic approach. That's because a unified system can efficiently handle the RF, IF, and mmWave frequencies in the most realistic replication of a real-world environment. mw

DANIEL COOLEY | Chief Strategy Officer, Silicon Labs

Connecting the Future: Three Wireless Trends on the 2020 Horizon

We expect even more wireless innovations to come into play in 2020 and beyond as wireless indoor tracking technologies, the next-gen Wi-Fi 6 standard, and LPWAN protocols reach the mainstream.

Home and work life, commerce, industry, and transportation are all about connectivity these days. The Internet of Things (IoT) has impacted our lives and transformed industries over the past decade, and we expect even more wireless innovations to make their presence felt in 2020 and beyond.

I'm excited about three wireless technologies that are poised to enhance how we find and track things; share and stream data in our homes, offices, and public spaces; and enable long-range connectivity for smart cities, factories, and agriculture. Let's take a closer look at wireless indoor tracking technologies, the next-generation Wi-Fi 6 standard, and LPWAN protocols reaching the mainstream this year.

LOCATION, LOCATION, LOCATION

Tech companies have been trying to solve the problem of "where is my stuff" for a long time, well before the rise of the IoT. While global-positioning-system (GPS) technology can be used to locate and track some devices such as smartphones, GPS is typically expensive and power-hungry, and it must be used outdoors to receive satellite signals. Indoor location tracking isn't a practical option with GPS. Until recently, device makers have been solving the problem of indoor location services with a mix of technologies such as RFID and Bluetooth beacons, enabling precision location services.

We've seen two significant innovations in indoor tracking and location services gain traction this year: angle-of-arrival (AoA) and angle-of-departure (AoD) direction finding introduced in the Bluetooth 5.1 specification and ultra-wideband (UWB) radio technology. Both wireless technologies are being integrated into smartphones. Mobile phones have included Bluetooth LE radios as a standard feature since the early 2010s, and leading smartphone manufacturers are adding UWB radios to their latest models, such as Apple's inclusion of UWB in the iPhone 11 and 11 Pro.

Historically, two trends occur when a new technology enters the smartphone ecosystem: cost and power consumption plummet. We will see this happen with the integration of both AoX and UWB technologies in the latest smartphones.

Historically, two trends occur when a new technology enters the smartphone ecosystem: cost and power consumption plummet. We will see this happen with the integration of both AoX and UWB technologies in the latest smartphones.

Consumers will be able to use their smartphones to locate things with precision in a way they haven't before. For example, users can pinpoint the exact location of their phones, key fobs, and tracking tags.

In parallel, equivalent tracking technologies can be embedded in infrastructure itself. For example, AoX and UWB can be used to create asset management and tracking systems for locating packages in warehouses. It's time to bring GPS-like tracking capabilities to indoors applications. As Bluetooth AoX and UWB tracking technologies become ubiquitous this year, you won't have to wonder where your stuff is much longer.

WI-FI 6 FEATURES

Feature	Description	Benefit
Downlink and uplink OFDMA	This technique divides the radio channel into multiple smaller sub-channels, each with slightly different frequencies.	Higher client density
Downlink and uplink MU-MIMO	Wi-Fi 5 first introduced multi-user multiple-input multiple-output (MU-MIMO), which enables apps to transmit data downstream to several devices at once. Wi-Fi 5 was limited to 4x4 configurations, while Wi-Fi 6 increases this to 8x8 to support eight clients. In addition, Wi-Fi 6 adds support for uplink MU-MIMO, enabling multiple clients to transmit to the AP at the same time.	Higher data rates
Target wake-up time	This allows clients to schedule pre-defined times to wake up, permitting longer sleep periods. There are also options to enable clients to power down the receiver to avoid receiving unwanted frames while dynamically reducing transmit power.	Longer battery life
Spatial reuse techniques	In dense environments, clients will be in the range of multiple access points. Wi-Fi 6 allows clients to listen for a unique identifier for their associated access point and modify transmission characteristics accordingly.	Higher client and access point density
1024 QAM	Extending from 512 QAM to 1024 QAM brings about a 25% increase in the PHY data rate.	Higher data rates
Long OFDM symbol	Wi-Fi 6 extends the OFDM FFT size from 64 to 256, a 4X increase. The longer symbol time helps to increase robustness in use cases with large physical distances. This is akin to Bluetooth 5.x LE Coded (S=8) PHY configuration.	Longer range

Wi-Fi 6: THE NEXT-GEN WIRELESS STANDARD

Wi-Fi 6, also known as IEEE 802.11ax, is a major milestone in the Wi-Fi standard's 20-year journey of continuous innovation. The standard builds on the strengths of 802.11ac while adding greater efficiency, flexibility, and scalability that gives new and existing networks increased speed and capacity for next-generation applications.

The IEEE proposed the Wi-Fi 6 standard to deliver the performance and versatility of high-speed Gigabit Ethernet wireless combined with the reliability and predictability of a licensed radio. For reference, the Wi-Fi Alliance has rebranded the wireless standard. In the past, Wi-Fi versions were branded according to the IEEE standard nomenclature, but this approach was confusing to consumers. Going forward, here's the Wi-Fi "decoder ring":

- Wi-Fi 4 = IEEE 802.11n
- Wi-Fi 5 = IEEE 802.11ac
- Wi-Fi 6 = IEEE 802.11ax

Wi-Fi 6 is the first short-range wireless standard developed to enable a high density of devices embedded into the specification. Previous Wi-Fi versions focused on speed and performance first and foremost. Think of Wi-Fi 5 (802.11ax) like a bullet train. Data can move around quickly, but there won't be many high-speed trains on the track at the same time.

Wi-Fi 6 was built from the ground up with device density in mind. The standard supports a host of new features addressing density, battery life, and wireless range, in addition to other features designed to increase raw data throughput capabilities, *as shown in the table on page 25.*

LTE-M is a good option for LPWAN applications requiring a combination of long battery life, LTE reliability, and low latency. LTE-M is also compatible with existing LTE networks and in the future will coexist with 5G technologies.

Equivalent non-cellular LPWAN technologies operating in the sub-GHz band, such as LoRaWAN (a protocol managed by the LoRa Alliance running on Semtech's LoRa RF platform), are beginning to go mainstream. A recently unveiled LPWAN option to watch closely this year is Amazon's 900-MHz Sidewalk protocol, designed to connect sensors, lightbulbs, trackers (for things and pets), and other long-range IoT devices.

By operating in the sub-GHz band or a licensed cellular spectrum and keeping the data bandwidth relatively low (tens of bits per message), LPWANs can achieve a range measured in the tens of kilometers. This wider coverage range has broad implications in leveraging the IoT and machine-to-machine (M2M) communications for smart cities, building and home automation, and industrial IoT.

With the arrival of Wi-Fi 6, we will see an increase in the number of devices able to connect to a Wi-Fi network, along with reduced latency, longer battery life, and an enhanced overall user experience. Wi-Fi 6 chips are already hitting the market, and several access-point manufacturers are releasing products compliant to the specification. Smartphone manufacturers are expected to add Wi-Fi 6 to next-generation handsets, while connected-device manufacturers will include the new wireless technology in a range of IoT products this year.

LPWAN FOR THE LONG HAUL

Cellular technology is starting to migrate from smartphones and into the IoT as a viable option for low-power wide-area-network (LPWAN) connectivity. Several semiconductor suppliers including Nordic Semiconductor, Qualcomm, Sequans Communications, and Sony (Altair) are releasing chipset products supporting the NB-IoT and LTE-M (also known as CAT-M1) cellular standards, and interesting startups like Riot Micro also are entering the cellular IoT market.

IoT device manufacturers now have many options for deploying LPWAN connectivity at lower costs, enabling a rapidly improving developer experience for long-range, low-data-rate, low-power applications. By operating in the sub-GHz band or a licensed cellular spectrum and keeping the data bandwidth relatively low (tens of bits per message), LPWANs can achieve a range measured in the tens of kilometers. This wider coverage range has broad implications in leveraging the IoT and machine-to-machine (M2M) communications for smart cities, building and home automation, and industrial IoT.

According to ON World, LPWAN services are expected to reach $75 billion USD by 2025, serving more than 30 different applications in a broad range of market segments globally. LPWAN technology is now finding its way into transportation, from long-haul trucking to electric dockless scooters; urban infrastructure such as parking meters and gas and water meters; and smart farming applications, including precision agriculture and livestock monitoring.

With so many new and emerging wireless technology options coming onto the market this year, connected device makers will continue to drive innovation in the IoT, and end users everywhere will be the ultimate beneficiaries. mw

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Semiconductors

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More than Microchips—How the Semiconductor Industry Keeps Evolving

Here's a look at how the chip industry is ushering in a new era of tech-driven economic growth.

Major chipmakers are gradually starting to increase spending on research and development. According to IC Insights, an industry market research firm, this growth is expected to continue into the early part of the next decade. That's a promising sign for the tech sector. Semiconductor innovation is an important precursor to broader technological innovation, which tends to occur in waves.

Moreover, a renewed focus on semiconductor R&D also bodes well for the economy at large. The observation that every company is now a tech company has been a repeated ad infinitum since at least 2013. But each year, this seems to become a more accurate statement. In nearly every industry, venerable incumbents have suddenly found themselves competing with tech-driven disruptors. It fuels sector-wide arms races, and semiconductors are today's big winners.

As more companies rely on technology to enhance the production and delivery of goods and services, the importance of semiconductor innovation continues to grow. Should innovation come to a halt, the global economy would inevitably falter. Fortunately, chipmakers aren't slowing down. The chips they're producing today—and the software capabilities they have already developed—will usher in a new era of tech-driven economic growth.

LOOKING TOWARD THE FUTURE

Semiconductor manufacturers live in the future—they simply have no choice. The typical manufacturing lifecycle takes around two years. After a chip goes to a vertical solution, it takes another year or two of data collection to build the intelligence required to deliver it to the marketplace. Four or five years might elapse before a chip is fully ready for widespread adoption.

The incredible technology powering modern machines is a testament to the industry's foresight. If you want to see the future, you should certainly work with a semiconductor company. The 5G revolution hasn't truly arrived, yet chipmakers are already thinking about the next generation of 5G.

Based on my experience working with chipmakers on both hardware design and software integration, here are two trends that will determine the industry's long-term direction:

1. Heightened Consolidation

Business-level consolidation is rife among semiconductor companies. We're not seeing as many acquisitions as we did in 2015 or 2016, but reports on industry merger and acquisition activities indicate that the total value of deals completed over the past year are still significantly higher than they were during the beginning of the decade.

As the industry becomes increasingly consolidated, chipmakers are placing greater emphasis on focused integration and collaboration. A big part of that involves integrating the various information technology systems these companies rely on to power the manufacturing process. Moving forward, this will likely become even more important.

2. Seamlessly Integrated Solutions

Another significant trend is a growing demand from historical semiconductor markets for a more integrated offering. Five years ago (and before), manufacturers were almost entirely focused on building microchips as components of larger vertical-specific systems. Today, technology companies expect chipmakers to provide not only the underlying hardware solution, but also fully integrated software systems and business intelligence capabilities to accompany that hardware.

As tech companies continue to look to chipmakers to provide more comprehensive, integrated offerings, the industry's biggest players will continue to complement existing capabilities. Don't expect the acquisitions to come to a halt anytime soon. The next evolution of the semiconductor industry is just getting started. mw

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NICOLE FAUBERT | Industry Solutions Marketing Director, Communication Solutions Group, Keysight Technologies

The Gen5 Revolution

The move to 400-GbE speeds to meet 5G demands, supported by next-gen computing standards like DDR5, PCIe 5.0, CCIX, and others, creates test challenges. To keep pace, compliant software is needed.

Consumers demand more and faster data. They no longer tolerate even the smallest delay to data access. In some applications, such as autonomous driving and medical IoT devices, delayed communication can lead to life-and-death situations. 5G's high-bandwidth and real-time capabilities open the door to these and many other new exciting applications. But the core communication network and data centers must be ready to support the insatiable demand for data and ultra-fast data-transfer rates.

Many data centers are currently at maximum capacity with 100-Gigabit Ethernet (GbE) speeds. Thus, data-center networks need to move from 100- to 400-GbE speeds to support the requirements of emerging technologies. And faster networking speeds require faster memory and faster serial bus communications.

In addition to moving to 400-GbE speeds, data-center operators must move to the next generation of high-speed computing interfaces, such as Peripheral Component Interconnect Express (PCI Express or PCIe) and double-data-rate (DDR) memory. Data-center operators also need to consider new specialized interconnect technologies that offer alternatives to PCIe.

PCIe expansion bus speeds will switch from PCIe 4.0 to PCIe 5.0 to support 400-GbE speeds. The same is true for memory, as DDR moves from DDR 4.0 to DDR 5.0. Increasing the speed of serial data communications requires high-speed precision testing at every level. Testing at these faster speeds demands full compliance testing to the latest standards.

Each generational change of high-speed computing standards provides new features and faster data-transfer rates, creating new test challenges for digital designers. The *figure* shows a roadmap of high-speed computing interface standards. The need to measure complex specifications complicates the design and validation process and requires a long learning curve for test engineers. Since standards evolve quickly from one generation to the next, test engineers can save significant time and get their designs to market faster using test solutions that ensure full compliance with industry standards.

DDR5 DOUBLES DDR4's DATA RATE

Each new generation of the DDR synchronous dynamic random-access-memory (SDRAM) standard delivers substantial improvements over the previous generation, including increased speeds, reduced footprint, and improved power efficiency. DDR4 is designed for the computing server industry and supports data-transfer speeds up to 3.2 GT/s.

The Joint Electronic Devices Engineering Council (JEDEC), the organization that defines the DDR specifications, is currently working on the next generation of DDR memory—DDR5—to fulfill the need for faster data rates. DDR5 will operate at up to 6.0 Gtransfers/s (GT/s) or higher and will effectively double the data rate of DDR4.

PCI EXPRESS EVOLVES TO PCIe 5.0

Server speeds increased from 16 Gb/s to over 30 Gb/s in about a year, and future technologies will use PAM4 to push data rates above 50 Gb/s to support 400 GbE in the data center. PCIe 4.0, with a data rate of 16 GT/s, is no longer sufficient to support 400 GbE speeds. As a result, the PCI Special Interest Group (PCISIG), the standard body that defines the PCI Express specifications, has fast-tracked the development of the PCIe 5.0 standard, which is due for completion by the end of 2019. With a data rate of 32 GT/s, PCIe 5.0 provides twice the throughput of PCIe 4.0.

Emerging new standards offer alternatives to PCI. They include Open

Coherent Accelerator Processor Interface (OpenCAPI), Gen-Z, and Cache Coherent Interconnect for Accelerators (CCIX). These bus standards specialize in areas where PCIe isn't customized.

OpenCAPI ACCELERATES COMPUTING

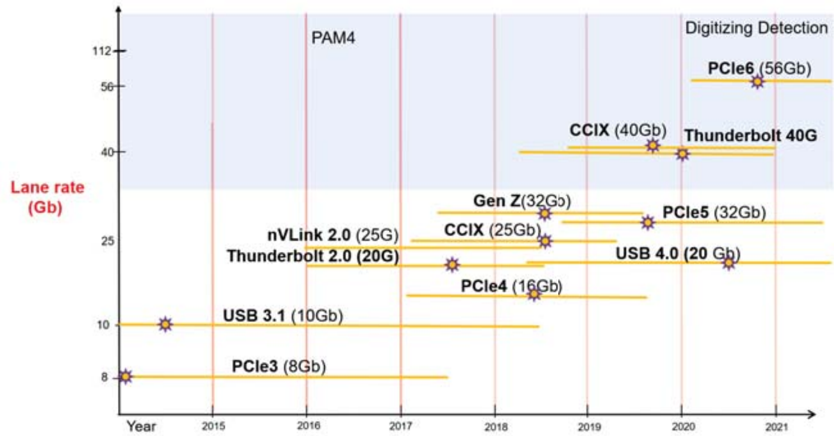
OpenCAPI is an open, coherent, high-performance bus standard that accelerates computing through tighter integration of different types of technologies, such as advanced memory, accelerators, networking, and storage, within servers. The OpenCAPI standard, defined by the OpenCAPI Consortium, provides a 25-Gb/s data rate and aims to improve server performance by moving computing power closer to the data. OpenCAPI enables a very-low-latency interface between the CPU and an attached device, removing bottlenecks caused by I/O inefficiencies.

GEN-Z TARGETS MEMORY-TO-CPU CONNECTIONS

Gen-Z, defined by the Gen-Z Consortium, is an open interconnect standard optimized for storage technology to increase the speed of memory-to-CPU connections. Gen-Z version 1.0, based on IEEE-802.3 physical-layer specifications, provides 25-GT/s and 28-GT/s interconnect speeds and is scalable to 112 GT/s and higher. Gen-Z components use low-latency read and write operations for direct data access with minimal application or processor involvement.

CCIX INCREASES DATA THROUGHPUT

The principle behind CCIX, defined by the CCIX Consortium, is to use the PCIe physical layer (PHY) but change the function of the bus for increased efficiency and faster speeds. The CCIX standard currently supports data rates up to 25 Gb/s and is expected to extend that to 40 Gb/s soon.



Shown is a roadmap of high-speed computing interface standards.

In addition to faster interconnect speeds, CCIX enables cache coherency. Cache coherency quickly propagates any changes to data in one area of memory to all other instances of the data stored in different memory locations throughout the entire system. For example, there can be a copy of data in main memory as well as one in the local cache of every processor that has previously requested the data. With cache coherency, CPUs can communicate faster with the rest of the system.

400 GbE INTRODUCES NEW TEST CHALLENGES

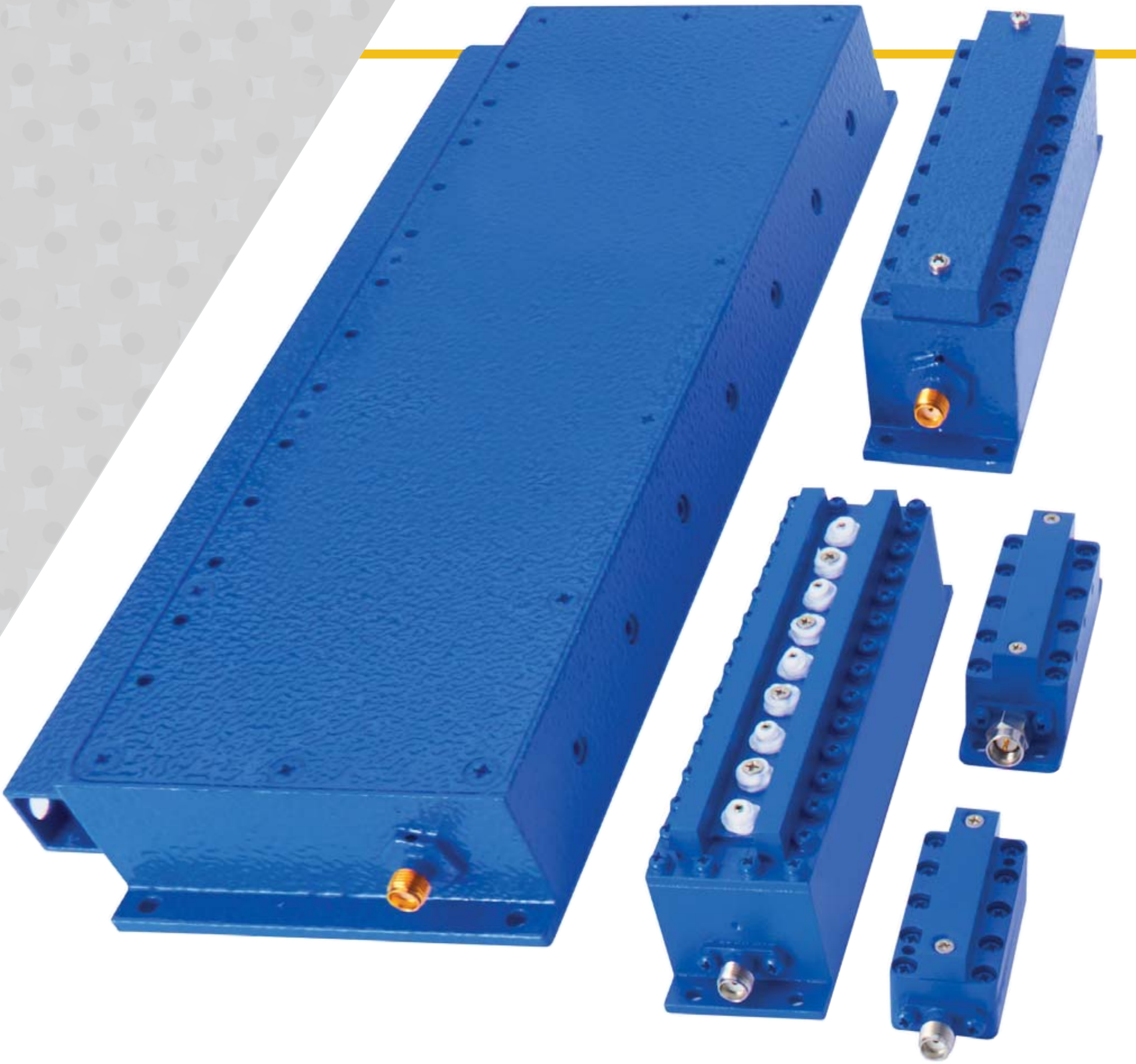
The design of high-speed serial data links becomes significantly more complex as data rates increase—channel topologies become more diverse, and the number of parameters tuned for active components multiply. Signal integrity at 400-GbE speeds is a critical challenge for high-speed computing interface designers.

Design and simulation tools enable the optimization of the transmitter, receiver, and channel designs for best performance and reliability at the desired data rate. Such tools enable designers to plan upfront to resolve signal-integrity issues, ensure power efficiency, and stay within tight error margins before the first prototypes.

Test engineers must develop comprehensive test plans to ensure compliance with industry standards and interoperability with devices from other vendors. Testing next-generation standards is particularly challenging when test requirements differ drastically from one generation to the next.

For example, the DDR5 standard specifies that test engineers need to test both the transmitter and the receiver. Previous DDR technologies required only transmitter testing. Testing new interconnect technologies, such as OpenCAPI, Gen-Z, or CCIX, is equally challenging since test engineers have never tested them before and need to ramp up on test requirements and procedures.

Compliance test software developed in accordance to industry standards can reduce test time down from days or weeks to hours. Industry-compliant test solutions ensure that next-generation devices comply with industry standards and are interoperable with devices from other vendors. Using fully compliant test solutions, engineers can focus on designing next-generation devices, instead of learning the details of each new standard. mw



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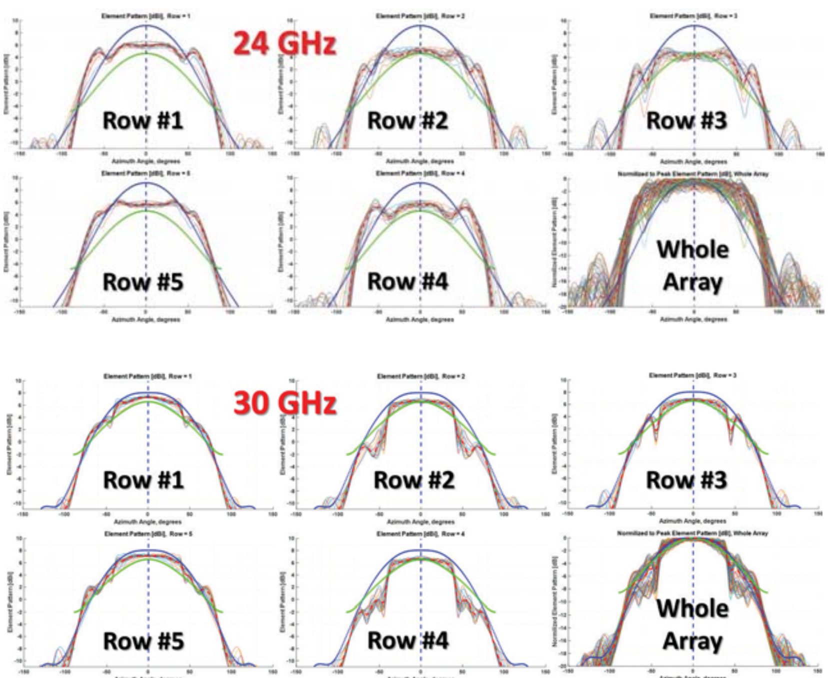
Analysis of a 24- to 30-GHz Phased Array for 5G Applications (Part 2)

Wrapping up this two-part series examining 5G phased-array platform/wizard development, the focus turns to the design and evaluation of a broadband planar array.

Here, we'll begin by exploring full-wave simulation of the 5-×-16 array shown in *Figure 1* of Part 1. The last resort is a numerical simulation of the entire array using commercial 3D full-wave software, such as CST Microwave Studio (MWS), ANSYS HFSS, COMSOL Multiphysics, EMPIRE XPU, etc. All data can also be obtained via testing inside the antenna range. Thus, we can generate an embedded database of 3D patterns and scattering (S) or impedance (Z/Y) matrices for each element in the array.

This approach leads to an outcome with a massive database *(see footnote 1 from Part 1)* and assumes access to high-performance computers. It's desirable to implement parallel processing, as well as GPU and cache accelerating.[6] All of the numerical simulation data that follows was obtained using CST MWS.



1. Shown are the active patterns of the 5-×-16 array in rectangular lattice at 24 GHz (top) and 30 GHz (bottom).

We can start from the active directivity (in dBi) patterns of the elements that belong to the 5-×-16 panel in *Figure 1* of Part 1. Remember that the term "active impedance" means that a single array element is driven while all others are connected to dummy loads. The set of plots in *Figures 1a* and *1b* illustrate the patterns of all 80 elements split into the row groups at 24 and 30 GHz, respectively. The red dotted line depicts the averaged pattern for each row.

For comparison purposes, the azimuthal cut of the pattern shown in *Figure 6* of Part 1 is marked by a blue asterisk symbol. The green circular lines reflect the azimuthal cut of the pattern in *Figure 9* of Part 1. Note that the latter is not an active pattern, since the element and an infinite number of its neighbors are uniformly driven.

PATTERN ENVELOPES

As expected, in the ±45-degree angular sector, the element patterns in the rim and next-to-rim rows are practically identical. The set of curves titled "Whole Array" (bottom right corner) shows all 80 patterns being normalized to their peak to demonstrate the shape of the patterns and evaluate the array beamsteering performance. The steepest pattern envelope at 24 GHz describes the no-mutual-coupling element, while the infinite-array element is closed in its shape to the active pattern. In this case, we can expect the overestimated scan loss to be close to the theoretical level of $10 \times \log_{10} (\cos\theta_{scan})$.[6]

At 30 GHz, the infinite-array simulation can be considered overoptimistic. A closer look at the active patterns reveals that the patterns are not only different, but mainly asymmetrical relative to θ = 0. The expected consequence is the slim asymmetry in scan loss as the main beam is steered to $+\theta_{scan}$ or $-\theta_{scan}$.

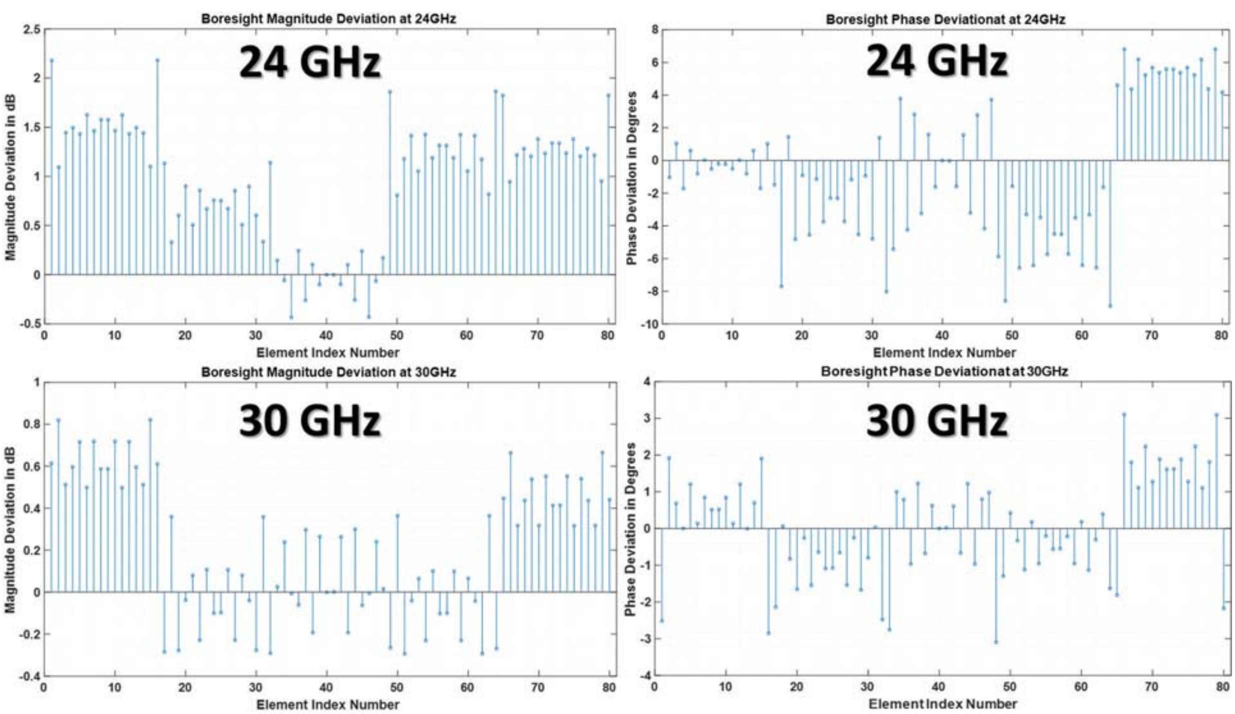
Furthermore, the beams slightly squint to the right or left with the ripples, droops, and overshoots on the top. All such terminology is typical for the analysis of a square-wave passing low-band filter. This similarity is not occasional because both the pattern and signal envelope are formally defined by similar-in-structure Fourier and so-called Fourier-Floquet series.

The pattern envelopes can be described by the set of spatial harmonics, while the signal processing is based on a similar series in the frequency domain. This means that a finite periodic array is somehow equivalent to a low-band filter that "cuts off" the radiation of high-order spatial harmonics and keeps them nearby in the form of reactive fields. Such an analogy not only lets us control the numerical simulation process, but often predicts its outcome without any simulation.

The stem plots in *Figure 2* reflect the deviation of boresight active directivity (two left plots) from the peak-versus-element position in the array. Such differences can reach −2.5 dB at 24 GHz and diminish to −0.8 dB at 30 GHz. Finally, notice that the pattern variations are more noticeable at 24 GHz near the lowest resonance because of strong proximity coupling. The plots on the right reveal that the phase of boresight radiation slightly varies within a few degrees. Therefore, to avoid antenna performance degradation, an internal diagnostic and calibration system should be implemented.

The graphs in *Figures 3a* and *3b* demonstrate the normalized-to-boresight beamsteering up to 45 degrees in azimuth at 24 GHz and 30 GHz, respectively. As predicted, there's no grating lobe at 24 GHz. The full-wave simulation produces a scan loss of −2.02 dB, while the no-mutual-coupling and infinite-array approaches result in −4.5 dB and −1.5 dB, respectively.

At 30 GHz, the full-wave simulation produces a scan loss of −4.0 dB. The no-mutual-coupling and infinite-array



2. The deviation of boresight active directivity and phase versus element index number are presented in these plots.

approaches result in −2.83 dB and −1.5 dB, respectively. These last two results are overly optimistic.

The same situation exists with respect to predicting the grating lobe level. The full-wave, no-mutual-coupling, and infinite-array approaches predict −2.71 dB, −1.83 dB, and −8.67 dB, respectively, relative to the peak at θ_{scan} = 45 degrees. The infinite-array number is certainly too good to believe. Therefore, the accuracy of the scan loss and grating-lobe level should be verified via full-wave simulation.

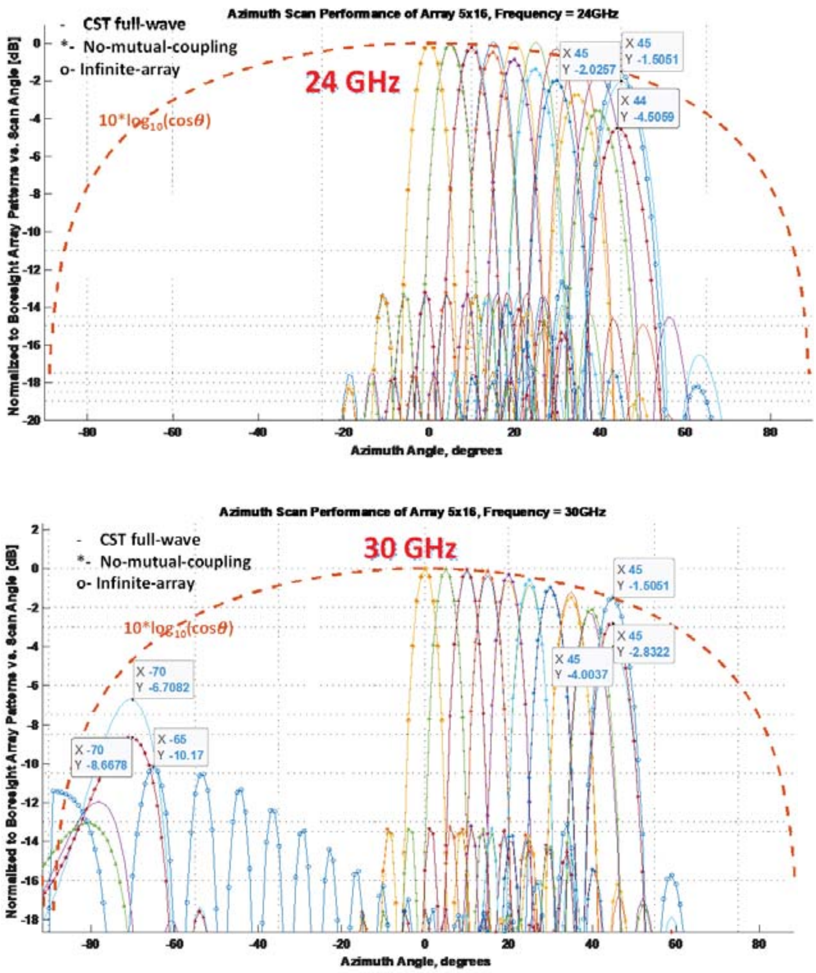
BORESIGHT RETURN LOSS AND INPUT IMPEDANCE

Figure 4 depicts the return loss in dB of all 80 elements driven uniformly in magnitude and phase to form the boresight beam. As predicted from the array symmetry, three sets of curves have comparable frequency dependency: rows 1 and 5 (light blue oval) that mostly include the rim elements, rows 2 and 4 (light green oval) that mostly include the next-to-rim elements, and row 3 (light red oval) that includes the center elements.

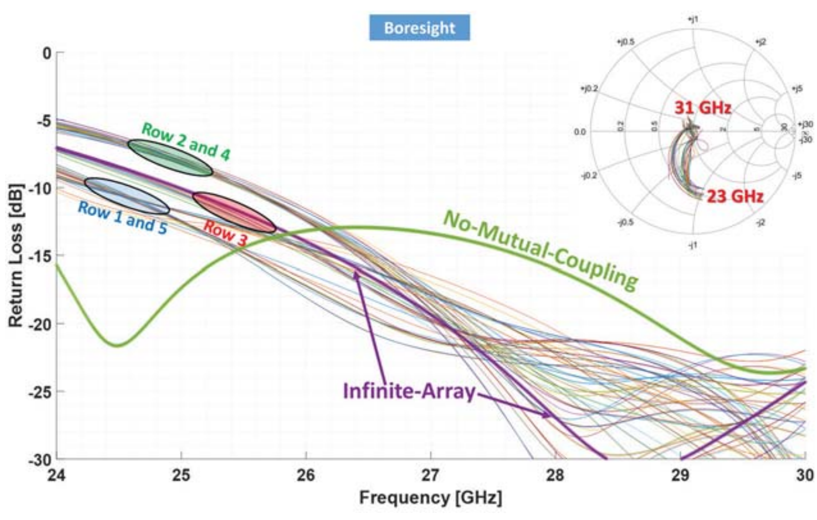
The solid green line is shown for comparison and reveals that disregarding mutual coupling leads to incorrect results. A much better method is the infinite-array approach. As expected, this curve closely follows only the center elements, while purely reflecting the frequency behavior of the rim and near-rim elements. The enclosed Smith chart reveals the input impedance (normalized to 50 Ω). This means that the consistent model platform's database should include the digital images of a minimum of three essential elements: one from the rim, one from the next-to-rim, and the last from the center elements.

FULL-WAVE SIMULATION OF 5-×-16 ARRAY WITH TRIANGULAR LATTICE (*FIG. 2* OF PART 1)

Readers can find more detailed data regarding the 5-×-16 array-with-triangular-lattice geometry by visiting the website *https://emfieldbook.com*.



3. Normalized-to-boresight beamsteering performance is revealed at 24 GHz (top) and 30 GHz (bottom).



4. This graph shows return loss and impedance of elements driven uniformly.

Just several substantial results are presented. The active-pattern deviations become more noticeable not only from element to element, but from row to row. The same is true for the active return loss. Despite this, the input impedances of the elements of the boresight radiating array continue to be well-collimated around the center of Smith chart.

The grating lobe in *Figure 5* drops to −6.3 dB as the beam is steered to 45 degrees at 30 GHz. Though not a very significant reduction, it is enough for the scan loss to diminish to −2.83 dB. This is primarily explained by the fact that the element-active patterns become slightly wider in a triangular lattice versus the rectangular lattice. One can notice the increase in side-lobe level relative to the rectangular lattice. For more details and comments, visit *https://emfieldbook.com.*

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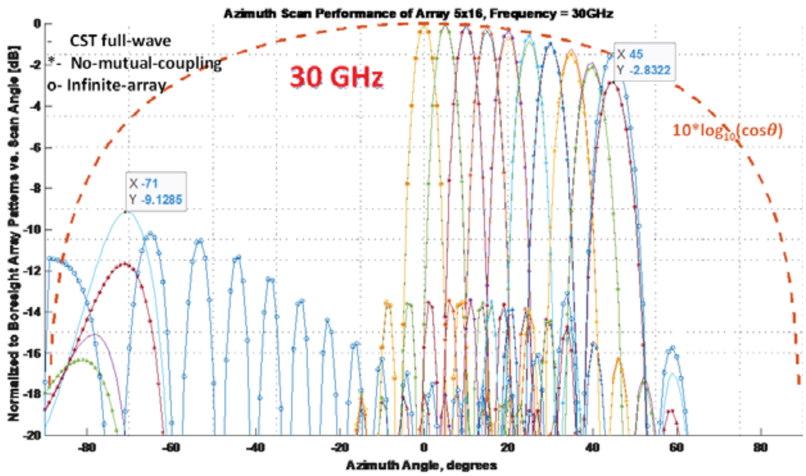

5. According to this normalized-to-boresight beamsteering performance result, the grating lobe drops to –6.3 dB as the beam is steered to 45 degrees at 30 GHz.

CONCLUSIONS

Now, we possess all of the essential information needed to compare the results using different approaches: no-mutual-coupling, infinite-array environment, and full-wave CST simulation of the array in a triangular and rectangular lattice. All data concerning directivity, scan loss, and grating-lobe level (column 4, after the slash symbol) are summarized in the *table*. Referring to the data from *Figure 2*, we can come to these conclusions:

- Any model can be used to obtain a practically correct estimation of boresight directivity.
- A minimum of three different elements (rim, near-rim, and center) must be considered to reach an accurate scan-performance estimation, especially for the wideband array at a higher end of the frequency band.
- The scan and grating-lobe performance of an array in triangular lattice generally requires the full-wave examination.
- As a rule of thumb, the scan loss/input impedance versus frequency requires the full-wave analysis. Some rough estimation might be obtained using the infinite-array environment model, but that issue needs additional investigation. mw

THIS WORK has been encouraged by Victoria Pereira, president of Otava Inc., and partially funded by her company.

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AZ Scan Angle	Boresight		45degrees		Scan Loss at 45 degrees	
Frequency	**24GHz**	**30GHz**	**24GHz**	**30GHz**	**24GHz**	**30GHZ**
No-Mutual-Coupling	**24.2dBi**	**25.8dBi**	**22.6dBi**	**22.3dBi/-5.8dB**	**-1.6dB**	**-3.5dB**
Infinite-Array	**23.7dBi**	**25.6dBi**	**22.2dBi**	**24.1dBi/-8.7dB**	**-1.5dB**	**-1.5dB**
Finite Rectangular	**24.0dBi**	**25.8dBi**	**22.5dBi**	**21.3dBi/-2.3dB**	**-1.5dB**	**-4.5dB**
Finite Triangular	**24.1dBi**	**25.8dBi**	**22.8dBi**	**23.0dBi/-6.3dB**	**-1.3dB**	**-2.83dB**

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A New Approach to Over-the-Air Production Test

Noise sources and peak power meters are the key ingredients in a novel over-the-air test methodology that's faster and more cost-effective than current techniques.

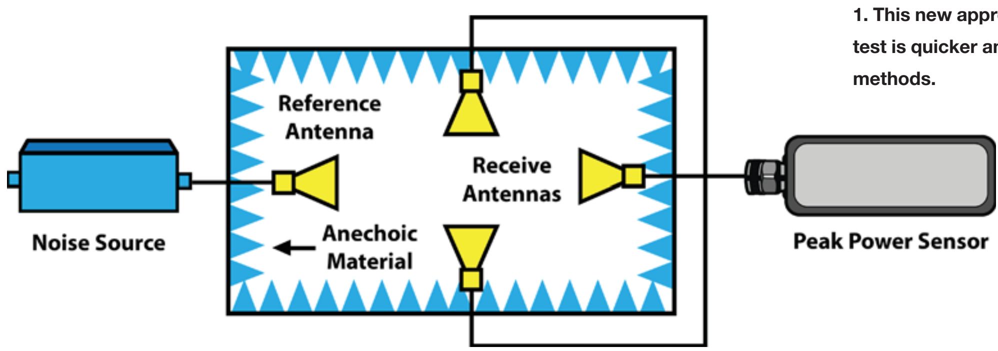
Approximately 1.5 billion mobile phones are sold each year—and that quantity is expected to continue for the foreseeable future. With such high volumes, it's critical to have fast, cost-effective production test capability.

However, the technologies needed to meet the requirements for 5G communication systems are challenging manufacturers like never before. 5G devices are operating at higher frequencies, which require smaller geometries and incorporate even greater levels of component integration, making it nearly impossible to utilize conducted RF testing in production. Add to this the incorporation of increasingly sophisticated multiple-input, multiple-output (MIMO) technology and utilization of beamsteering techniques, it's clear that over-the-air (OTA) testing has never been more important. But historical implementations of OTA testing are complicated, expensive, and slow.

This article introduces a new approach to OTA production test. It utilizes a noise source to stimulate the device under test (DUT) with a signal that's an accepted surrogate to a high sub-carrier orthogonal-frequency-division-multiplexed (OFDM) signal. In addition, a peak power meter (or USB sensor) is used to more accurately determine signal distortion caused by amplifier compression. The result is a new approach that's faster, simpler, and more cost-effective *(Fig. 1)*.

CURRENT CHALLENGES ASSOCIATED WITH OTA TESTING

Traditionally, RF performance of devices like mobile phones was optimized using OTA and conducted tests in the research-and-development phase. When manufacturing these devices, production was performed utilizing primarily conducted RF testing supplemented with offline OTA sample testing.



1. This new approach to OTA production test is quicker and simpler than other test methods.

However, as these devices move to higher frequencies and greater levels of integration, it may no longer be possible to perform conducted measurements. Couple this with the increasing performance requirements on these devices for 5G communications, such as more sophisticated MIMO technology and beamsteering to help meet the demand for higher data rates, and all roads lead to the need for OTA testing.

2. Noisecom's NC1000 series of amplified AWGN noise modules produce AWGN as high as +13 dBm.

Extensive research has shown how a noise source provides an excellent signal to simulate the multi-tone signals used in actual operation. When employing noise sources like the Noisecom NC1000 series, manufacturers can provide a 100-MHz additive white Gaussian noise (AWGN) signal to stimulate their devices with a 5G representative signal *(Fig. 2)*.

OTA METHODOLOGIES BEING CONSIDERED

Starting with the distance at which the measurements will be made, three OTA techniques are being considered: direct far field, indirect far field (using compact ranges), and near field (utilizing a near-field to far-field transformation). The type of signals to be used must then be determined.

For simpler applications, such as characterizing a single-element antenna, vector network analyzers (VNAs) have been the instruments of choice. When more complex parameters must be measured, instruments like vector signal generators (VSGs) and vector signal analyzers (VSAs) are often used. For complete end-to-end analysis, engineers generally turn to instruments that can emulate a mobile phone or base station.

In research-and-development applications, only a small amount of OTA chambers is needed. Higher costs for doing various tests can be tolerated. The same can be said for traditional offline performance verification. Today's challenge is that OTA must be performed as part of the in-line manufacturing process.

TAKING MANUFACTURING OTA TESTING ON A DIFFERENT PATH

A concept being explored involves device manufacturers performing extensive testing in research and development using the methods described. With a thorough understanding of device performance, they will only need to conduct performance verification OTA testing in production. Moreover, they will want to do it in the most cost-effective, time-efficient, and simplest way.

Using a mobile phone or base-station emulator is very expensive and time-consuming. Using a VNA is still expensive and only provides verification with a continuous-wave (CW) signal, which is not representative of the environment that the devices will reside in. With 4G, 5G, and Wi-Fi 6 including thousands of sub-carriers, a CW verification process may not provide sufficient information to correlate how the devices will function with a multi-tone signal. On top of that, VNAs are complicated to use.

In the proposed new approach, manufacturers would use noise sources to stimulate their devices. Extensive research has shown how a noise source provides an excellent signal to simulate the multi-tone signals used in actual operation. When employing noise sources like the Noisecom NC1000 series, manufacturers can provide a 100-MHz additive white Gaussian noise (AWGN) signal to stimulate their devices with a 5G representative signal *(Fig. 2)*. These noise sources are a fraction of the price of a VSG or radio emulator, and they are very fast and easy to use.

AWGN sources can generate broadband OFDM-like signals at a wide variety of frequencies, including millimeter-wave (mmWave) frequencies with MHz to GHz signal bandwidths, much more cost-effectively than alternatives. Crest factors (peak-to-average powers) can be generated and varied in excess of 10 dB, and power levels can be varied for wide dynamic ranges. With these capabilities, noise sources are not only ideal for stimulating devices, but also an excellent tool for characterizing and calibrating the system response within the anechoic chamber used to make the OTA measurements.

PEAK POWER MEASUREMENT IS KEY

For the measurement, peak power meters are proposed. The most common instruments for measuring RF power are average power meters. However, in this application, average power measurements do not provide a complete picture of the device performance. Because the devices will be used with multi-tone signals, the signal will have a high crest factor: It's not uncommon for these signals to have crest factors in the 10- to 15-dB range. If a device is not behaving as intended, an average power reading may not tell the whole story.

3. Boonton's RTP5000 series of real-time peak USB power sensors achieves up to 195-MHz VBW.

For example, an average power measurement may show that amplifier is in compression by a small, tolerable amount and would not reveal what's happening to peak power due to modulation or intermodulation products. In many instances, it's possible to have less than 0.1 dB of compression in average power, while the crest factor compresses by 1 dB or more. Compression of 0.1 dB may be tolerable, but perhaps not so much with a value greater than 1 dB.

For this reason, it's crucial that a peak power meter be used—and it must have sufficient video bandwidth (VBW). The Boonton RTP5006 real-time peak power meter offers up to 195-MHz VBW, which is more than sufficient to measure 100-MHz 5G channels *(Fig. 3)*. The next closest competitor USB peak power meter has 30-MHz VBW.

Peak power meters are simple to use, fast, and a fraction of the price of a VSA or radio emulator. They also have much lower measurement uncertainty than analyzers and radio emulators. Multiple sensors can be placed throughout the OTA test chamber and synchronized for measuring average and peak power to characterize device beamsteering and directivity performance.

SUMMARY

With the sheer volume of wireless devices like mobile phones being produced every year, fast and cost-effective product test solutions are essential. The movement to higher frequencies and greater levels of integration coupled with utilization of increasingly sophisticated MIMO technology as well as beamsteering techniques in 5G technologies mandates that OTA testing be incorporated into the manufacturing process.

Traditional OTA testing approaches are too slow, expensive, and complicated to implement. To overcome those issues, a new approach to OTA test for manufacturing applications uses easy-to-use, fast, and cost-effective noise sources and peak power USB sensors. mw

Traditional OTA testing approaches are too slow, expensive, and complicated to implement. To overcome those issues, a new approach to OTA test for manufacturing applications uses easy-to-use, fast, and cost-effective noise sources and peak power USB sensors.

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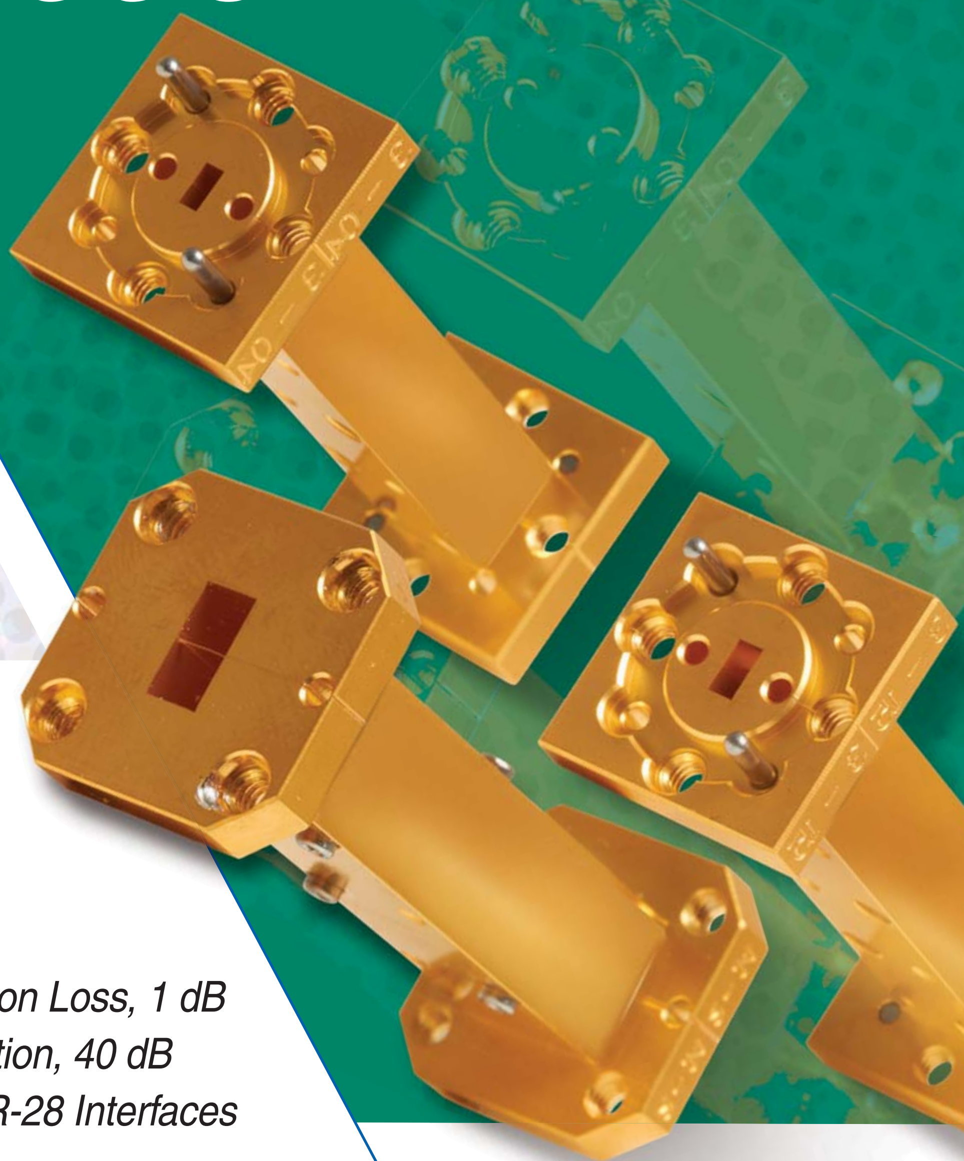

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CHRIS T. BURKET | Senior Marketing Engineer, TDK Corporation of America

EMI Suppresion Shields: Understanding the Basics

With so many different magnetic materials to choose from, one must discern the frequencies and noise levels where EMI problems are prevalent and deduce how the materials' parameters can impact noise suppression to comply with regulatory limits.

You may have heard of "EMI suppression" or "RF antenna" sheets, which are thin, flexible magnetic shields. Maybe they have been seen laying around the laboratory, typically black or gray in color, but sometimes they're exotic and silver-looking and appear to have come off the mysterious aircraft that crashed in Roswell, New Mexico in 1947. You may have physically touched them, and/or maybe actually used them, but do we really know how they work or if the best material was used?

It all starts with magnetic materials. Those thin, flexible magnetic sheets are utilized in a variety of applications: to suppress unwanted EMI signals (for both radiated and susceptibility); for magnetic-field (H) shaping and directionality in NFC and RFID applications; to provide shielding and coil optimization in both magnetic induction and magnetic resonance wireless power applications; to lessen eddy-current losses of other resonance applications; to being used as an ESD protection device; and more.

Many suppliers have various materials documented by differing datasheets and data curves. But without a deep background in material science or vast experience, choosing the right material can become a challenge. Each application may have a different set of key parameters, e.g. which frequencies need to be attenuated or which frequencies need to have to the lowest losses?

Magnetic sheets come in metal powder-, ferrite-, polymer- and metallized-based materials with each supplier's material being unique. Each supplier can also feature data of their materials' strengths and target applications in a variety of ways, thus leaving the intended user, at times, with many questions.

Magnetic shields are considered by many as a "band-aid" for EMI suppression applications; that is, only used, maybe temporarily as a quick fix when all other solutions have been exhausted. The fact is, there are times when traditional solutions don't work or would take too long to implement and that the "band-aid" may be the most cost-effective solution. There are also applications where magnetic shields must be used.

This article aims to help educate the reader and make the selection process easier and more efficient specifically for EMI suppression issues (due to limited space).

THE FUNDAMENTALS BEHIND IT

For EMI suppression (i.e. attenuating unwanted signals as compared to NFC/RFID applications where optimizing wanted signals and frequencies is key), the following equation can be used to help understand:

$$\mu = \mu' - j\mu'' \quad (1)$$

where μ' is the material's permeability (hence related to inductance) and μ" is related to the material's losses (resistance) and is a result of frequency and phase shift at the grain level of the material. Over frequency, both of these parameters may (will) change, depending on the material.

For EMI suppression applications:

μ' = higher yields lead to better shielding performance through H field containment or absorption

μ" = higher yields lead to better noise suppression/attenuation through material losses

Permeability defines the ability of a material to support the formation of a magnetic field within itself and contain magnetic flux. Therefore, containing more magnetic flux enables the higher μ' material to keep more of the unwanted radiated magnetic field within the magnetic material and away from sensitive areas. When μ" is at higher values, a more resistive path is created for any magnetic field passing through the material, and it allows for the unwanted magnetic field noise to be absorbed and converted to heat. Each unique material composition, density and inner grain size and shape will impact both μ' and μ".

The quality factor (Q) of the material, a figure of merit that describes the potential to store energy relative to the loss within the material, is related to both μ' and μ"and is given by:

$Q = \mu'/\mu''$ (2)

For EMI suppression applications, one typically selects a low-Q material that's lossy at the problem frequencies and thus increases the attenuation at those frequencies. This contrasts with NFC/RFID and other similar resonant low-power communication systems, where the emphasis is on increasing Q. Therefore, it's critical to obtain the μ', μ" curve to select the best material. Examples of material curves are shown in *Figure 1*.

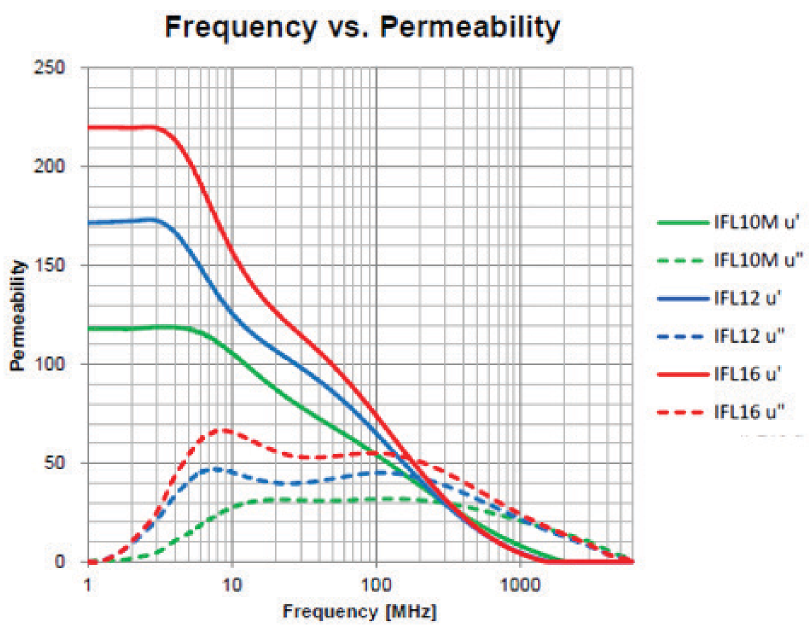
As can be seen from these sets of curves, the behavior of the materials goes from low loss, high Q at the 1 MHz range to high loss (μ"), low Q (hence high attenuation) starting in the 2- to 4-MHz range and continuing up to 2- to 3-GHz range. Usually, this broad spectrum of attenuation isn't required; therefore, the user can focus on choosing the best material at each individual problem frequencies.

E & H FIELDS

Another key area are the impacts of the magnetic (H) and electric (E) field strengths. The magnetic field strength for an inductor (a common EMI generator in switch-mode power supplies—SMPS—and just one of many equations) is given as:

$H = N \times I$ (3)

where N = the number of turns of the coil pattern used within the power magnetics, and I = current through the coil (A).



1. The plots illustrate μ', μ" curves for various materials.

Typically, the number of turns within an inductor isn't provided by suppliers, as is commonly done for transformers. Thus, the user doesn't always know the true H field strength. For power applications that use higher currents, these create both stronger predictable H fields and stronger, potentially spurious H fields. In turn, it creates more magnetic flux (density given as "B" in a typical B-H curve) subjected upon the magnetic shield.

The stronger the magnetic field, the better the shielding needs to be. This can be achieved by either increasing μ' in Equation 1 to contain more magnetic flux or by increasing the physical thickness of the magnetic shield. This relationship is given in the following figure of merit:

$\mu' \times t$ (4)

where μ' = permeability and t = thickness of the magnetic sheet.

In *Figure 1*, the curve in red, labeled as IFL16, which has the highest attenuation, also possesses the highest permeability (μ' = 220). This enables the material to better contain the flux energy. The performance impact of shield thickness is highlighted in *Figures 2a* and *2b*.

In *Figures 2a* and *2b*, "-200," "-100," "-050," and "-025" are the respective thicknesses in microns (μm) so that, for example, "-100" is 100-μm thickness. Additional thickness also means more magnetic material mass is present and can support higher levels of magnetic flux. In certain EMI suppression applications, attention needs to be paid to the magnetic-flux-density (Bs) value of the material. One must ensure that the magnetic material doesn't saturate and lose its shielding effectiveness through diminished attenuation performance and thus allow some level of the noise energy to pass through.

For E fields, the electrical-field strength can be specified as:

$E = F/Q = kQ/D^2 = V/D$ (5)

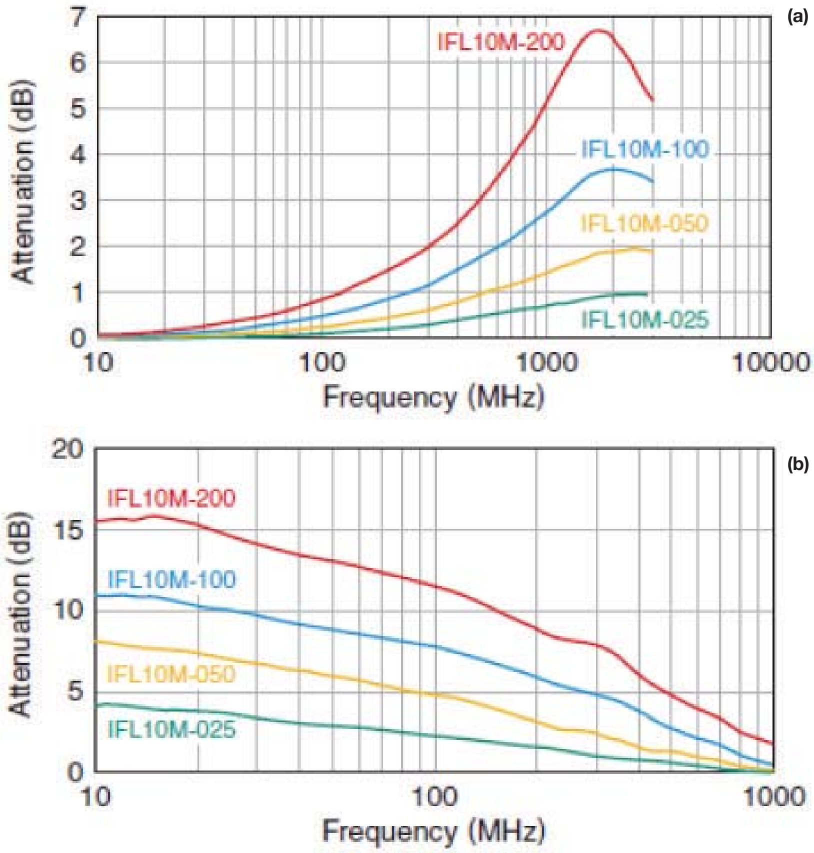
where E = electric field (vector) strength (N/C); F = electric force (N); Q = volume of charge (C); k = electrostatic (coulomb) constant (8.99 x 10^9 Nm^2/C^2); D = distance between charge source and point of reference (m); and V = voltage (V) across distance (D).

It's then apparent that the higher the voltage, the stronger the electrical-field strength. One of the key applications for EMI suppression sheets is to reduce the voltage induced on other components in proximity to the voltage source.

Why two sets of attenuation curves in *Figures 2a* and *2b*? In applications where one is trying to suppress (protect) noise being generated from traces on a PCB, FPC, ribbon cable, or other signal path medium, magnetic sheets are applied directly on top of these electrically conductive paths.

The curves shown in *Figure 2a* are measuring the impedance (/Z/) of the transmission line. Since adding a magnetic shield increases the inductance (L), the inductive reactance ($X_L = 2\pi fL$) increases with frequency and becomes a larger portion of the overall impedance. Consequently, attenuation continues to increase until the resonant frequency—between 1 and 2 GHz as shown in *Figure 2a* for the red curve (labeled IFL10M-200). This is an alternative option to placing a choke inductor, ferrite bead, or line filter directly in the signal path, which adds direct-current (dc) resistance that may not be desirable.

The proximity attenuation values shown in *Figure 2b* are those of a "shield" application. The magnetic sheets are used to block and/or absorb unwanted EMI signals and provide isolation. This approach doesn't need to be directly adjacent to the area needing protection.



2. Shown are curves for transmission attenuation (a) and proximity attenuation (b).

ABSORPTION VS. REFLECTION

When there are physical constraints on the EMI suppression shield thickness, one needs to decide whether to sacrifice shielding performance (with thinner shielding), consider other materials with better performance, or change to a different shielding approach (e.g., using a metal cover to shield).

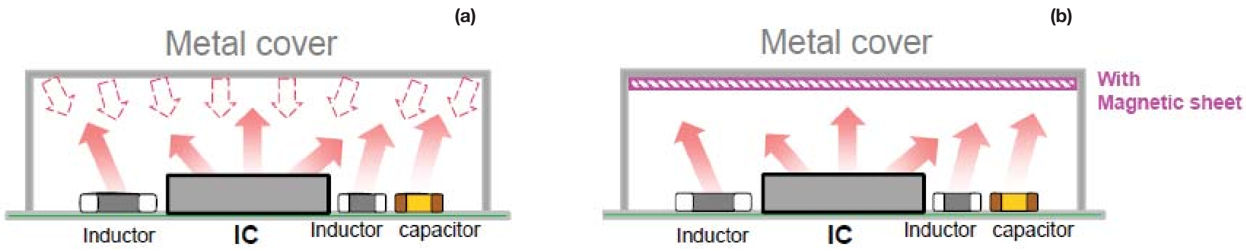
As addressed above, going with a thinner shield will yield less attenuation and allow for a higher level of the undesired EMI noise to pass through. Is this an issue? It depends on the frequency and the level of noise energy. Attenuating a few more dB may be the difference in passing regulatory limits versus non-compliance.

Another problem with allowing more noise energy to pass is if there's metal on the other side of the magnetic shield—the energy can introduce eddy-current losses on the metal surface and create heat issues. This is particularly true for SMPS power applications. These are not only at the fundamental switching frequencies and harmonics, but also at frequencies orders of magnitude higher due to FET (switch) turn ON/OFF ringing.

For newer power switch technologies used in much higher frequency and voltage (and E field) applications (think GaN and SiC switches), the potential ringing is at a much higher level, and for a longer period. When saturation isn't an issue, but higher attenuation is still needed, then the designer would need to focus more on higher loss material (higher μ") rather than higher μ'.

Frequency has a major impact on the material to be used, and how it needs to be used. In *Figure 2b*, all of the plotted materials completely lose their attenuation properties at or near 1 GHz. If the EMI noise problem is above 1 GHz, then the designer may be forced to use a hybrid material or some other specialty material just to achieve some attenuation of the high-frequency noise. Below 1 GHz, the designer would need to look at the data (or something similar) provided in *Figures 1* and *2*.

Cost also becomes an issue and needs to be considered. Obviously, the thicker the material, the higher the



3. No magnetic shield allows the reflected wave to be additive (a); the magnetic shield absorbs the reflected wave (b).

cost. This may also be the case when going to a superior performing material. High-end, exotic, hybrid materials all demand a price premium. At times, the user has no choice but to use the best performing material and cost becomes a lesser issue.

METAL CANS AND HYBRIDS

Alternative approaches are also a possibility. Metal "cans" are a common noise-suppression technique placed over critical areas of a circuit board and/or components with high EMI susceptibility or those that may be the noise generator. Though some of the unwanted noise is absorbed by the metal, a large percentage is actually reflected; where it goes from there requires a much more thorough analysis (and article space) to fully understand.

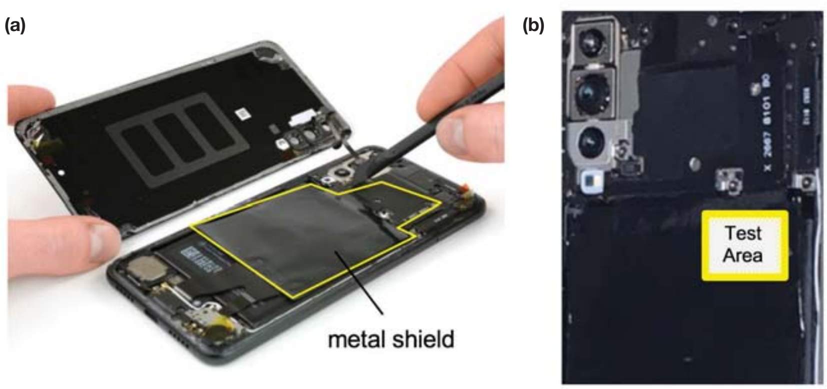
One major advantage of magnetic sheets is that they actually absorb the noise energy and remove it from the circuit and/or environment in terms of heat—something metal cans can't do. Therefore, for metal-can applications that are put over internal noise generating components (radiated noise), adding a magnetic EMI suppression on the inside of the metal can further suppresses the EMI noise.

In some scenarios, there just isn't enough thickness available to attenuate the EMI noise to the needed level with just a magnetic shield. In those cases, hybrid materials are a good choice. These are magnetic sheets with a metallized layer on the back side. This approach yields two passes of the EMI noise through the magnetic layer (incident on the metal backing and then the reflected signal). This has a doubling effect on attenuation plus the advantage of having a Faraday "cage" created by the metal layer, which also adds to the attenuation. A metal can, plus ferrite layer is shown in *Figures 3a* and *3b*.

In a typical SMPS, noise can be generated not only by the aforementioned inductor and switches, but also the IC, capacitors, and other circuit components. With just a metal cover (can), the noise energy generated is free to be reflected off the metal and subsequently re-introduced back into the circuitry, and it can add to the original noise source. Adding a magnetic shield to the metal shield assists in completing a better EMI suppression solution. In this case, both μ' and μ" need to be considered and will be dictated by magnetic shield thickness.

There are cases when the individual values of both μ' and μ" for low-Q material are important. One example is in wireless magnetic-resonance applications where EMI suppression is required, and stable inductance is critical. If a high μ' EMI suppression material is used to achieve better shielding performance, and is close the power coil, due to magnetic coupling, the permeability of the shielding material can *increase* the inductance value of the resonance coil. As a result, it may shift the resonance frequency and decrease performance. In this scenario, having a low μ' value but a much higher μ" would be desired.

Another similar resonant power application is when a metal enclosure is used to prevent EMI emissions. If the magnetic field (flux) goes into the metal, this will cause a decrease of magnetic flux lines in the field and *decrease* the inductance, ultimately shifting the resonance frequency higher. In this case, the user should target a higher μ' material to limit the impact on the desired magnetic field and not attenuate this field via a high μ" value.



4. For testing, a Huawei P20 phone was used (a). The highlighted area shows the size and location of the existing metal shield. A test area was then selected (b).

REAL-WORLD APPLICATION

A Huawei P20 Pro handset was tested. This handset incorporates a metal shield that protects the address and data bus lines controlling the phone's display *(Fig. 4a)*. The yellow outlined area shows the size and location of the existing metal shield.

A test area was selected *(Fig. 4b)* and with the existing solution removed, a baseline was established using a near-field EMI tester. It was then compared to:

- The existing solution
- A hybrid ferrite + copper solution
- A permalloy material ungrounded solution
- A grounded permalloy material solution

The measured E-field (dBµV) level results are shown in *Figures 5a* through *5e*.

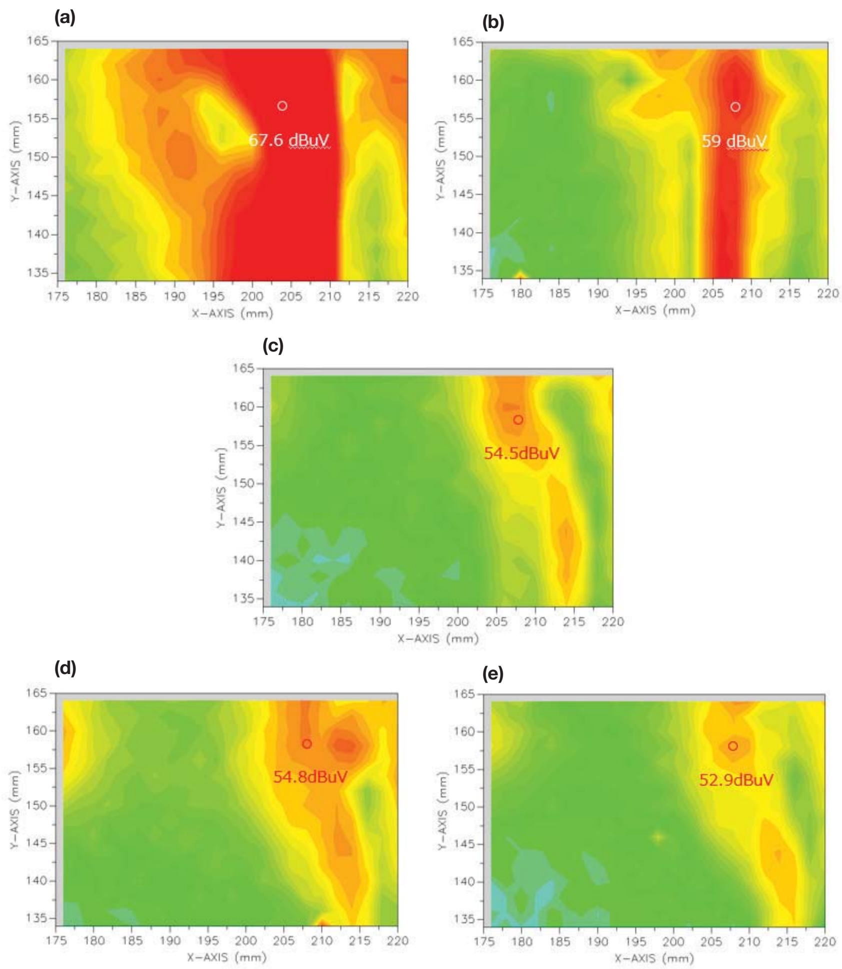
From this data, a few key points become evident. First, the magnetic material does impact the measurable E field value and, thus, attenuation level. Second, having a metal layer does help attenuate the EMI noise whether it's with ferrite or permalloy magnetic material. Finally, being able to ground the shield further improves the shielding performance.

The permalloy shields used in *Figures 5d* and *5e*, were substantially thinner, in the range of 20 µm, than all the other approaches which were in the 50- to 100-µm range. Additionally, this data is for a static frequency. When one views the attenuation over frequency, then it becomes even more obvious that many factors impact EMI noise suppression. Therefore, the choice of the magnetic material needs to be optimized for each unique application. This is shown for the two permalloy solutions in *Figure 6*.

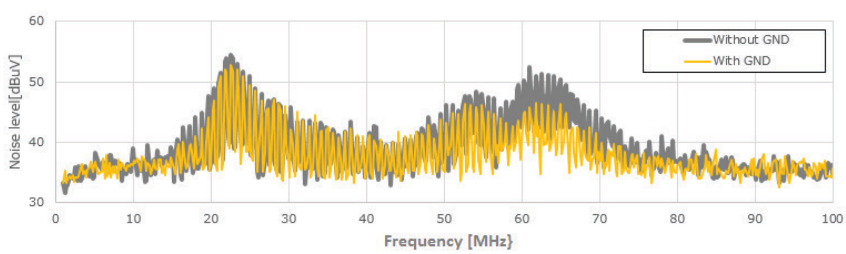
In this specific case, the noise suppression is greatly improved in the 55- to 80-MHz range. By simply grounding the magnetic shield, there's roughly a 5-dBµV noise improvement in this range. At the peak noise frequency, around 22 MHz, there is a 2-dBµV improvement. More steps should be taken to improve on this if the compliance standard requires additional attenuation. Not shown is that the no-shield and existing-shield values of *Figures 5a* and *5b* had their 67.6 dBµV and 59.0 dBµV respective noise peaks also occur at 22 MHz, which have been reduced down to 52.9 dBµV utilizing a permalloy material grounded shield.

TEMPERATURE IMPACT

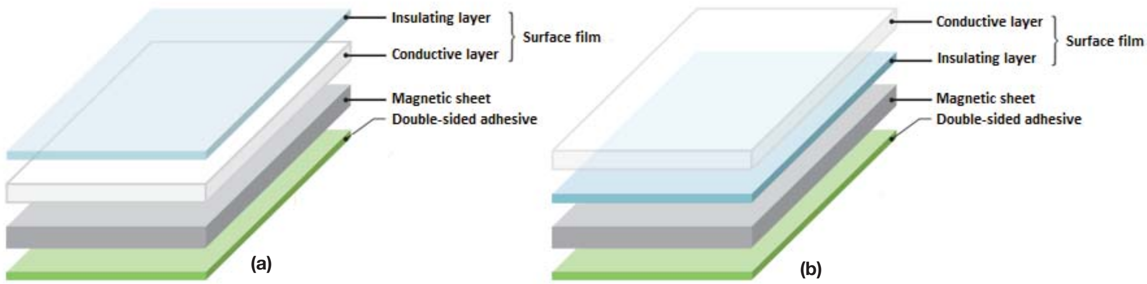
Over temperature, the behavior of the magnetic material may change. For automotive, industrial, and other similar high-temperature applications, special consideration needs to be given to the



5. Measured E-field level results are given for solutions with no shield (a), an existing shield (b), ferrite and copper (c), permalloy with no ground (d), and permalloy with ground (e).



6. Noise suppression results are given for permalloy material with and without grounding.



7. To ensure no conductive surface is exposed, a non-conductive resin layer or alternative magnetic-shield layer stack-ups are often used. Shown are an insulated top surface (a) and a conductive top surface (b).

magnetic shield's properties. Three areas of importance are μ', Bs, and the Curie temperature (Tc). μ' tends to slowly increase with temperature. However, the magnetic-flux-density value tends to decrease with temperature, which will impact how much magnetic flux can be contained within the magnetic material. If the Bs value is substantially reduced, then EMI suppression performance will be altered.

Tc can be critical if magnetic shields are used in a high ambient environment. The total shield temperature would be the ambient plus self-temperature rise due to absorption during attenuation. If the Curie temperature is exceeded, the magnetic properties of the material can be permanently lost, and performance will be severely affected.

Each material's temperature dependency is unique, and the user will need to obtain attenuation versus temperature information for any magnetic-sheet candidate based on the actual temperature environment. The user also needs to ensure the material's operating temperature is high enough to ensure the actual temperature doesn't approach the Curie temperature.

OTHER CONSIDERATIONS

Many times, designers prefer to put the EMI suppression solution right over or directly attached to some portion of the circuitry. This has been a "norm" for magnetic sheets as they're typically made of non-conductive materials (e.g. ferrite) or have a non-conductive surface. With metal cans, there has always been a clearly understood "stay clear" area and height-clearance requirement.

Now with specialty hybrid or metallized magnetic sheets, the designer must give attention to ensuring that electrical shorts aren't created by placing the EMI suppression sheet, with its conductive surface, and bridging across various components and causing failures. Many suppliers will use a non-conductive resin layer or offer alternative magnetic-shield layer stack-ups to ensure no conductive surface is exposed *(Figs. 7a and 7b)*.

If the designer needs to make electrical contact to the shield, there is an option for such an approach, especially for grounding configurations. If the shield is to be placed directly on top of the components or placed on the bottom side of a metal can, it may not have enough clearance with an added EMI suppression shield discussed above. Thus, an insulted layer shield can be used to provide protection.

CONCLUSION

Every application's EMI issues can be unique. What worked last time may not work for the next design. With so many different magnetic materials to choose from, it's paramount to understand the frequencies and noise levels where EMI problems are prevalent, as well as understand how the materials' parameters can impact noise suppression to comply with regulatory limits.

Key areas addressed were:

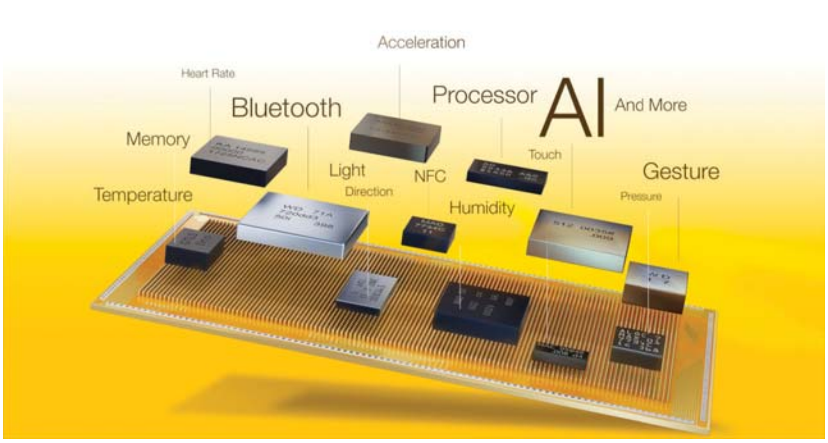
- Guidelines of choosing a lossy material rather than high Q material typically used for NFC/RFID applications
- Both a material's μ' and μ" values can be the key element in determining the right material.
- The impacts of shielding material, thickness, and the addition of metallization layers
- In the real world example provided, it was shown that using a ferrite + metal layer hybrid material improves attenuation and even more improvement can be realized by grounding the shield.
- In general, having a metallized layer will provide some level of improved attenuation, and becomes more beneficial as the frequencies approach the GHz range.

Permanent magnets, with their dc magnetic flux, can pre-saturate thin magnetic shields. Therefore, if the end product contains them, they can reduce performance if not kept some distance away. Permittivity, an important magnetic material parameter, wasn't addressed due to this being more critical for antenna performance rather than EMI suppression, but still impacts EMI shielding performance. The author hopes that, as a minimum, the reader now has a better understanding of magnetic material behavior and a better starting point in combatting their EMI woes. mw

WILLIAM WONG | Senior Editor

Building Custom Chips Just Got Easier

zGlue's ChipBuilder Pro lets designers create chips using its 2.5D chiplet Smart Fabric.

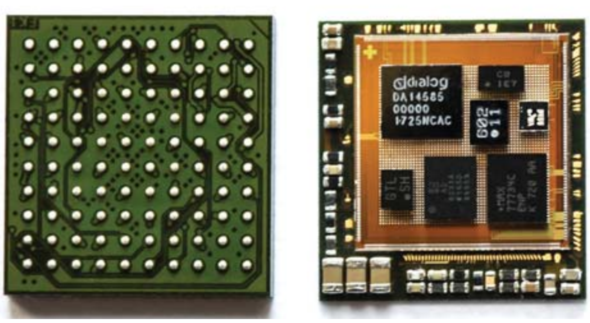


zGlue's 2.5D chiplet Smart Fabric platform *(Fig. 1)* builds chips out of chiplets that are connected with a silicon interposer layer, very similar to a chip-based printed circuit board. The chiplets are functional blocks like processors and peripherals typically found in a custom chip or in discrete components. A zGlue-based chip has the advantages of tight integration, small packaging, and power efficiency of an ASIC, but with significantly less cost. This makes it practical for smaller runs as well as creating more customized solutions quickly.

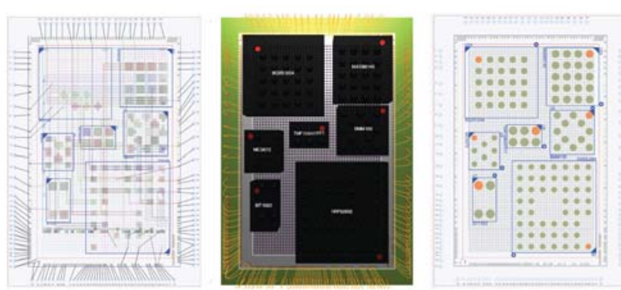
ChipBuilder Pro *(Fig. 2)* is the latest tool being shown at this year's Consumer Electronics Show, where the product was a CES 2020 Innovation Awards Honoree. The visual zGlue Integrated Platform (ZIP) allows developers to select from 1500 chiplets to include in their designs. This includes chiplets like Cypress Semiconductor's PSoC and Wi-Fi chiplets. Custom chiplets can be added to the list by working with zGlue. The zGlue ChipletStore also has 60 Quick-start Templates. The software provides design and release management plus versioning support.

zGlue sells the ChipBuilder Pro and provides the ChipBuilder 3.0 Community Edition for free. ChipBuilder Pro has a yearly subscription price of $25,000 that includes 10 chips of one new design every year. An additional 100 chips run $25,000.

The yearly subscription includes 40 hours of engineering support as well as parasitic net extraction and system verification. Security features include IP protection and visibility into account activity. This approach also supports system reconfiguration during the hardware debug process. As a result, developers can fix bugs without the need for remanufacturing. mw



1. zGlue's Smart Fabric silicon interposer technology allows chiplets to be mounted within a chip to deliver compact, custom chips.



2. ChipBuilder Pro provides an easy-to-use, visual interface for designing with chiplets.

PATRICK WORFOLK | CTO, Synaptics

4 Predictions for the First Year of the Ambient Computing Decade

In 2020, key technology building blocks in ambient computing will be ready for broader adoption and start to appear in consumer products.

Straddling the border between two decades, it's now clear that the most impactful technological development of the past 10 years was the evolution of the smartphone into the most widely used computing platform in the world. Looking forward, the next decade will be marked by ubiquitous ambient computing, with sensors, displays, processors, and communications capabilities embedded throughout the physical environment.

In 2020, a couple of technologies that are essential building blocks in ambient computing will be ready for broader adoption and will start popping up in consumer products. Here are the four emerging developments I think will have the biggest impact:

1. Edge processors with artificial-intelligence engines

Putting processors with powerful neural-network compute accelerators in smart speakers, smart displays, security cameras, and other Internet of Things (IoT) devices will make them faster, more reliable, and more private. Right now, if you ask Alexa to turn on the living-room lamp, the trigger word will be detected in your device and then your voice will be streamed to a data center in the cloud for speech recognition and interpretation. Subsequently, a message is typically sent to a second cloud facility that will communicate instructions back to the lightbulb.

New, efficient neural-network compute technology and new methods to compress hugely complex neural networks will give these devices the power to recognize speech, interpret images, and identify patterns without sending data to the cloud. Thus, video and audio of every intimate moment at your home will stay in your home, rather than being transmitted to an unknown data center in the cloud.

Many high-end smartphones already contain chips with specialized circuitry to efficiently process the huge computations required for computing using neural-network algorithms. Advances in this technology now allow it to be implemented in processors that are economical to deploy in devices that retail for less than $100.

2. Perception through computer vision

Thanks to the combination of low-cost, high-performance image sensors and advances in computer vision through the use of deep-learning algorithms, a multitude of devices now can interpret images, not just capture them. Your doorbell will have different sounds for your neighbor, the UPS carrier, and a stranger, as well as recognizing different vehicles in your driveway.

Instead of simply receiving a stream of motion events that may or may not contain anything interesting, you will only get notified when a meaningful event occurs. Furthermore, the AI engine technology previously mentioned will allow these compute-vision algorithms to be run in edge devices, maintaining your privacy while perceiving the world around them.

In addition to working on live camera streams, computer-vision technology can be applied to video. Your streaming video box will be able to skip or select scenes based on their content. Imagine, for example, watching the highlights of a baseball game using a computer-vision system that zooms past everything but plays where the ball is hit. Alternatively, perhaps you want to just watch clips of the game that include your favorite

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player. Your smart video device will be able to create an endless assortment of personalized, individual highlight reels.

3. Proactive interaction with devices

Today, to interact with a smart device, you need to wake it and issue an explicit command. "Hey Siri, show me the video from the baby monitor." Increasingly, the technology will be able to take the initiative, handling some tasks automatically and alerting you only when necessary. You won't have to check on the baby every 10 minutes; the computer-vision system will notify you if she wakes up.

Your tea kettle might notice a pattern when you come home from work and ask you, "Would you like to heat water every weekday afternoon when the garage door is opened?" These proactive capabilities are enabled by advances in computer vision and the ability to run the algorithms in the edge devices.

4. Ambient computing at work

Most of the innovation in the IoT has been around the development of smart-home devices. Workplaces already have security, communications, and computing infrastructures, using older generations of technology. This year expect to see more companies deploying sensor, voice interface, and edge processing technology to embed connected intelligence into the physical environment of their offices.

Think about the time you'd save if you didn't have to set up the slides and video conference for a presentation. As soon as you walked into the meeting room, your face will be recognized, the people on the invite list will be connected, and your presentation will appear on the screen. If you need to change something, just ask. "Office assistant, connect to Chris in accounting and bring up the third-quarter sales projection."

In 2010, you could already see the rapid evolution of smartphones with touchscreen interfaces, selfie and world-facing cameras, and always-connected data. Nevertheless, few could imagine all of the ways those technologies would be woven together and applied. This leads me to one final prediction: Prepare to be surprised by what the IoT does for you over the next year.

We're at an exciting point in time when lower costs and higher performance enable widespread deployment of smart connected sensors and interface devices. We're also learning a great deal about how to build useful applications, many employing artificial intelligence, that take advantage of these technologies. As much as these four developments are going to impress people in 2020, remember that the decade of ambient computing is only just beginning. mw

Model Your Way to Project-Level Success

In this Q&A, Rick Gentile from MathWorks discusses his goal for his current blog series along with topics like hybrid beamforming and RF and antenna modeling.

Many have already seen your name thanks to the *Algorithms to Antenna* blogs. What do you want readers to gain from them?

MATLAB and Simulink are used by a large and diverse customer base. As a result, we see firsthand how much modeling improves the likelihood of project-level success, especially as system complexity increases. 5G, radar, and electronic-warfare (EW) systems span multiple signal domains, so many technical disciplines must come together to design and field a system.

We see areas where the 5G community leverages phased-array antenna, RF, and signal-processing technology previously developed for aerospace and defense applications. We also see the convergence of applications in the form of multifunction RF apertures, where the system alternates between surveillance, communications, interference management, and even weather-related functions. With the availability of commercial software-defined radios and radars, the number of applications continues to grow rapidly. This means new communications and radar engineers enter the field and need to ramp up quickly.

Each of these trends adds complexity to new projects. Our goal with the blog series is to share examples and techniques where simulation can be applied to reduce risk. Hopefully, readers gain insights into the full signal chain at the early phases of development where they have the greatest flexibility to make the most intelligent design choices. They also can gain confidence in their design before they field it.

Can you tell us some of the ways that MathWorks *(www.mathworks.com)* supports the needs of both commercial wireless and aerospace/defense applications?

There's a great mix of wireless and aerospace/defense engineers that use our platform products, MATLAB and Simulink, as the basis for simulation. We have continued to expand the number of focused tools that are application-specific.

For example, in wireless, this includes products that are focused on 5G along with other standards-based wireless. In addition, we have built up specific tools that focus on each part of the system. This has also helped to bring large development teams together. For example, the RF and antenna engineers on a project can integrate with their signal-processing and system-level colleagues.

We also support smaller teams by enabling broader workflows. This could be where system engineers can get an idea of how changes in subsystems impact overall performance. It also can be helpful for engineers responsible for a specific subsystem to see how design choices impact other subsystems. We have connected workflows across the different technical disciplines, too. This helps downstream when systems are integrated.

The other good news is that with the advent of the multifunction RF aperture, technology cross-pollination across industries is accelerated. In addition, we continue to expand our modeling capabilities so that different levels of abstraction can be used depending on what's needed during specific project phases. As projects mature, higher-fidelity capabilities can be applied when they make the most sense.

The 5G Toolbox was launched last year. What's been the reception to that?

The reception has been very positive. It's been great to see such a rapid adoption of a new product. It really speaks to the timeliness of having the 5G Toolbox so close to the standard approval.

We see two main areas of adoption: teams that want to ramp up on the standard quickly and teams that are already experts but need a framework to develop algorithms on. One very well received aspect of 5G Toolbox is that it's all written in MATLAB. Anyone that has the toolbox also has the code for all of the algorithms and building blocks. This gives our customers great insight into all aspects of 5G.

You've spoken a great deal about hybrid beamforming. Why is this significant?

It's been a popular topic from our customers. We receive a lot of requests to help with system modeling and more specifically system-level partitioning. It's one of the areas in a large system where the disciplines meet. Antenna array meets RF chain meets signal processing. The results of making the right architectural choices in this area translate to lower system cost and at required performance levels. Even as systems evolve to fully digital beamforming, this is an area that continues to be of high interest.

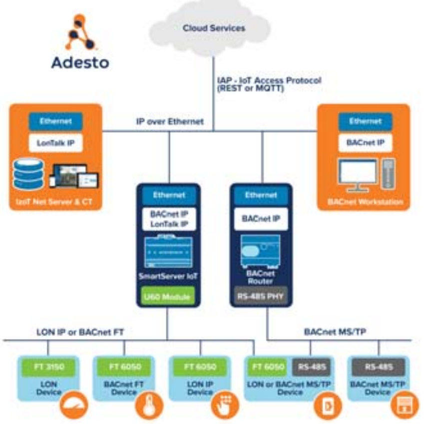
In the early part of 2020, we will include several new blog posts on integrating higher-fidelity models for antenna elements and RF components, along with 5G waveforms.

Can you explain how MathWorks is diving deeper into RF and antenna modeling?

We have continued to expand our antenna and RF modeling to respond to customer requirements. This includes more complex antenna designs and structures. It also includes support for more RF analysis and architectures. Our RF and antenna element libraries continue to grow. It's easy to solve for your own structures as well.

With our RF and antenna tools, we always try to help customers balance options for fidelity with simulation time. The other area we spend a lot of time thinking about is ease of use. This is helpful to seasoned veterans in the field, but it's also great for others getting started or expanding their work focus. Finally, as I mentioned earlier, we ensure that the results of RF and antenna modeling can be directly integrated into system-level models. mw

Smart Transceiver Supports New Protocols



THE FT 6050 smart transceiver system-on-chip from Adesto is designed to help consolidate smart control networks. It includes a quad-core processor that accepts a 10-MHz input clock and can be configured to run at 5 to 80 MHz. On-chip memory includes 64 kB of RAM and 16 kB of ROM. There's support for 254 network variables and 127 aliases, along with 254 address table entries. New protocol support for the FT 6050 includes native BACnet and LON router and network managers. Additional support for open-system products includes izoT Net Server, a platform for creating and managing devices, and izoT Commissioning Tool, a front-end graphical user interface. Overall, compatibility is possible with thousands of LON and BACnet devices, in addition to IP access to any FT 6050-based device.

ADESTO TECHNOLOGIES, 3600 Peterson Way, Santa Clara, CA 95054; (408) 400-0578; www.adestotech.com

3U VPX Dual RF Transceiver Delivers 70-MHz to 6-GHz TDD, FDD

VADATECH'S VPX571 DUAL RF agile transceiver is based around the AD9364 from Analog Devices and Xilinx's UltraScale+ ZCXU15EG MPSoC. As a result, the module supports time division duplexing (TDD) and frequency division duplexing (FDD) from 70 MHz to 6 GHz and channel bandwidths from 200 kHz to 56 MHz. The module includes a 64-bit-wide DDR4 memory channel for supporting large datasets. The Xilinx FPGA features 3528 DSP slices and 746k logic cells. It also houses a quad-core Arm application processor, dual-core Arm real-time processor, Mali graphics processor unit, as well as block RAM and UltraRAM. Onboard memory includes 64 GB of flash, 128 MB of boot flash, and a slot for an SD card connection. For interfacing, the module has options for SERDES, dual GbE, and eight LVDS connections.

VADATECH, 198 N. Gibson Rd., Henderson, NV 89014; (702) 896-3337; www.vadatech.com

Prototyping for Cellular IoT with the "Thingy:91"

NORDIC SEMICONDUCTOR'S THINGY:91 prototyping platform targets cellular IoT applications. It's powered from a 1440-mAh Li-ion battery that's rechargeable through an onboard USB connector. The heart of the board is an nRF9160 system-in-package (SiP) that incorporates an Arm Cortex-M33 application processor, an LTE modem, GPS, and an RF front-end system. In addition, the platform is certified for global low-power, long-range LTE-M/NB-IoT use, which allows developers to operate worry-free throughout many of the world's frequency bands. A major feature of the development board is the wide array of sensors available, including temperature, humidity, air quality, air pressure, color and light, and G-force accelerometers. The kit comes preloaded with application tracking software.

NORDIC SEMICONDUCTOR, Karenslyst Allé 5, 0278 Oslo, Norway; phone: +47 22 54 84 60; www.nordicsemi.com

K/Ka-Band Transceiver Built for Satellites

ARRALIS ANNOUNCED THE launch of a new K/Ka-band transceiver for satellite applications. The LE-KaTR-102 transceiver is a fully populated PCB designed to fit within a 1U CubeSat profile (100 × 100 × 100 mm). Frequency coverage will include 27 to 30.5 GHz for uplink communications and 17 to 21.2 GHz for downlink communications. The design is based off the company's Leonis plug-and-play chipsets. The chipset includes a 17- to 21-GHz transmitter, 27- to 31-GHz receiver, phase-locked loop (PLL), and 24-GHz VCO. The devices feature direct IQ inputs and outputs to support high-data-rate complex modulations.

ARRALIS LTD., Tierney Building UL, Castletroy, Limerick, Ireland; phone: +353 61 748 264; www.arralis.com

Multi-Radio Mezzanine Cards Handle Multiple Access Points

THE GATEWORKS NEWPORT GW640x and GW630x are single-board computers (SBCs) designed to implement multiple radio access points. The boards can support three Mini-PCIe radios individually and up to 21 additional Mini-PCIe-based radios via a PCIe expansion connector. This is also made possible thanks to the integrated Octeon Tx SoC, which features an ARMv8 core that's capable of processing up to 11 million packets per second. Applications that can benefit from its use include dual-band Wi-Fi with additional frequency band support, Wi-Fi monitor and sniffer applications covering simultaneous channels, mesh networks, and other networks that integrate several wireless technologies.

GATEWORKS CORP., 3026 South Higuera St., San Luis Obispo, CA 93401; +1 805-781-2000; www.gateworks.com

5G 2020 Forecast

(Continued from page 19)

However, technical issues must be considered in the utilization of mmWave. For example, mmWave frequencies travel relatively small distances and don't easily penetrate obstacles such as walls. Plus, they consume a considerable amount of transmit power, providing additional challenges for battery-operated devices. Even the sub-6-GHz versions have technical issues in that the 5G target "air time" latency is 1 to 4 ms.

Unfortunately, the equipment currently shipping (2019) is testing at 8- to 12-ms latency. Some providers report that the latency is really around 30 ms when the server latency is added to the "air time" latency, leaving mmWave-compatible products to still be developed.

Given the evolving standards and the technical questions surrounding mmWave (and even sub-6-GHz), what's the status of the chipsets/components required to build a 5G product? As expected, the typical RF component suppliers are all providing 5G solutions: Avago/Broadcom, Huawei, MediaTek, Murata/pSemi (previously known as Peregrine), Qualcomm, Qorvo, Samsung, and Skyworks. However, as of this writing, they all appear to be providing components that focus only(?) on the sub-6-GHz frequency bands.

The geopolitical situation relative to 5G also adds confusion to the 5G timeline. Some countries have totally accepted 5G, its standards, and its implementers. Other counties haven't accepted the 5G standards and/or the implementers, while others are still in the "deciding" stage. It could be interesting "driving" your autonomous vehicle from a country that supports 5G to one that doesn't support all providers.

Several 5G market analyzers place the current worldwide market at approximately $40B (USD) and growing by a 57% CAGR to over $1T (USD) by 2025. With the standards still evolving, what are the likely changes that will occur by 2025?

So, when would you be willing to spend ±1,000 dollars for a 5G ONLY smartphone or commit your manufacturing floor to 5G mmWave connectivity? 2020?

Would you like to see what components are shipping in the current set of 5G devices? Are those devices really using 5G or falling back to 4G/LTE?

What 5G stocks would you like to invest in? What would "Motley Fool" recommend? mw

TED SCARDAMALIA'S background ranges from being a Senior Manager in a Fortune 50 company to raising $15.6M in Venture Capital for an eight-person startup.

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