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Frequency-Selective-Surface Fabrics p32

Be Smart When Choosing Optical Sensors p39

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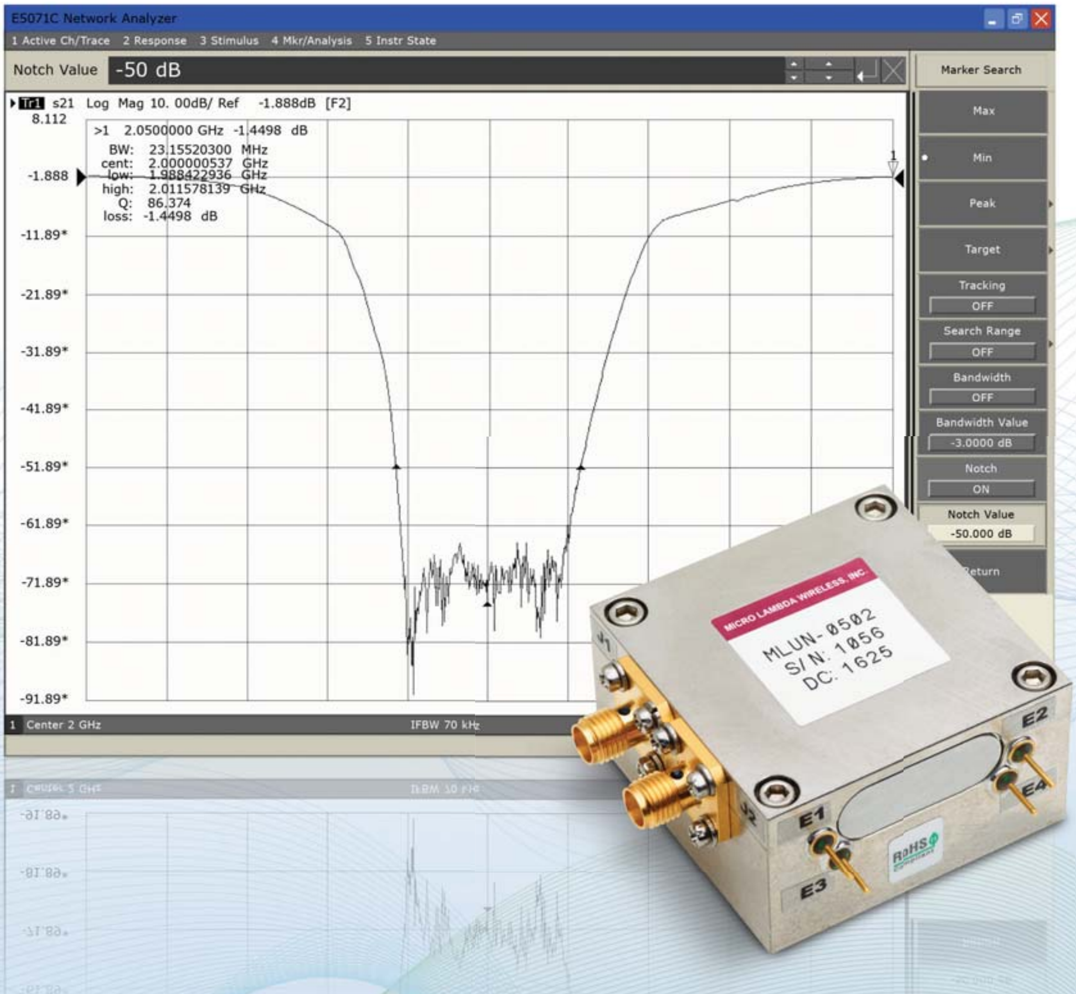

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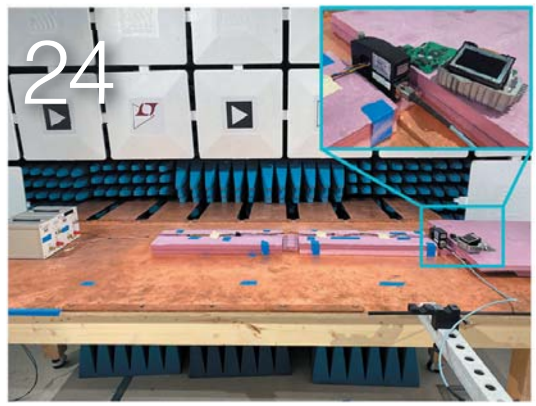

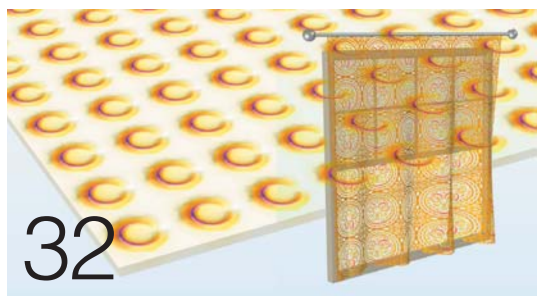

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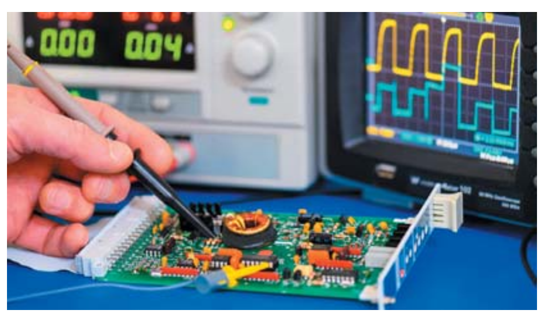

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Editorial

DAVID MALINIAK | Editor
dmaliniak@endeavorb2b.com

Where Are We with mmWave 5G?

Let's look at how mmWave 5G is coming along, how it's performing where it's been deployed, and where it's headed.

You've heard plenty about mmWave 5G already, and how it's going to usher in a utopic future of unbridled hyperfast connectivity. What's it about and what's happening with it? I had an opportunity to hear Qualcomm's perspective on mmWave 5G from Manish Tripathi, VP of engineering, and it's an exciting one.

mmWave 5G happens at frequencies of 24 GHz and higher, all the way to 100 GHz. That's a vast swath of spectrum, about 25X the amount used for 3G/4G. And that spectrum is being claimed by operators worldwide. Here in the U.S., commercial deployments are occurring in over 55 cities, mostly in the 28- and 39-GHz bands. Three FCC auctions have allocated 24, 37, and 47 GHz as well.

Whereas 4G took some time for carriers and handset makers to embrace it as mainstream, the industry is taking 5G seriously a lot earlier. If you're carrying a flagship device from any of the major cellphone makers, such as the iPhone 12, you're already set for mmWave 5G. The same goes for modules for industrial deployments, Wi-Fi hotspots, and customer premises equipment (CPE).

mmWave 5G is going to bring all sorts of opportunities to both indoor and outdoor deployments. In the U.S., more than 40 stadiums already have their infrastructures in place, ready to provide mmWave service to thousands of users at once. In fact, mmWave 5G was in use at Raymond James Stadium in Tampa, Fla. at this year's Super Bowl LV. Indoors, mmWave 5G will complement existing Wi-Fi services, bringing superior speeds and virtually unlimited capacity.

In performance field testing of commercial networks, mmWave 5G has demonstrated sustained downlink speeds of 1 Gb/s and higher in all sorts of scenarios. It doesn't matter if the device is connected to cells near, far, or in between, or if it's in a moving vehicle. Speed testing conducted with Ookla showed peak download speeds of 3 Gb/s, far better than sub-6-GHz bands or 4G LTE.

Qualcomm did some testing of mobile mmWave in an indoor enterprise use case right in its own facility. The company installed a commercial mmWave 5G site in the lobby, and the experiment has given the lie to the notion that mmWave works only on a line-of-sight basis.

In the rear of the lobby is a free-standing elevator shaft that you can get between yourself and the mmWave site. Even there, Tripathi reports, you can obtain a very usable mmWave 5G signal. That single CPE site provides solid coverage throughout the lobby, in the building's atrium, and in part of an adjacent auditorium. Some of the coverage is because mmWave signals propagate well reflectively.

mmWave 5G will significantly enhance the mobile user experience in all manner of settings: urban areas, mass transit, smart factories, and even rural regions with extended-range CPE. Enhancements are still in the works, such as optimized coverage and beam management as well as use cases beyond enhanced mobile broadband (eMBB) like industrial IoT, in Release 17+.

Deployment is progressing, although it's been slowed in some cities by painful permit processes for operators. But once enough sites are up and running, your iPhone 12 or Galaxy S21 is going to become much more fun to use. mw

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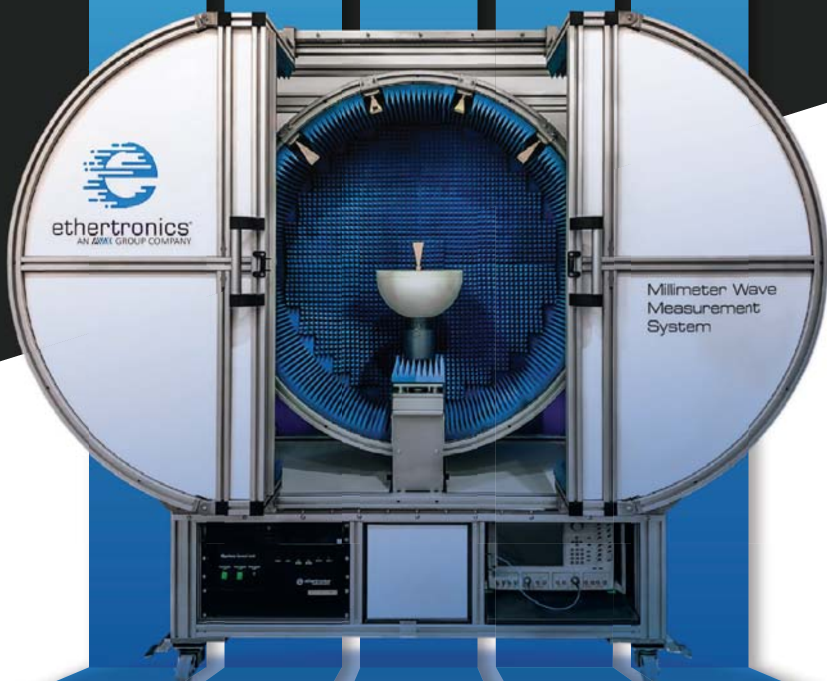
5G MMWAVE MEASUREMENT TESTING CHAMBER



TYPICAL DYNAMIC RANGE:
50db

MAXIMUM MASS OF DUT:
10kg on the mast

TECHNOLOGY:
Far-field / Spherical with oversampling

MAXIMUM SIZE OF DUT:
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FREQUENCY RANGE:
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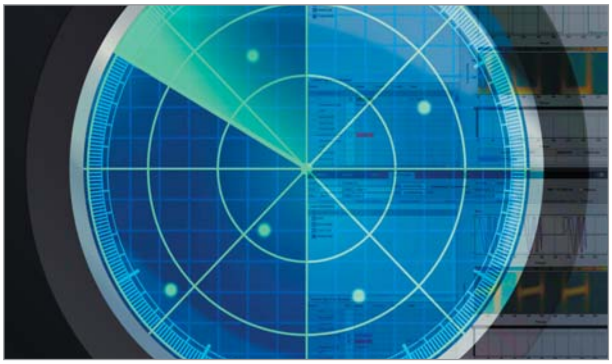
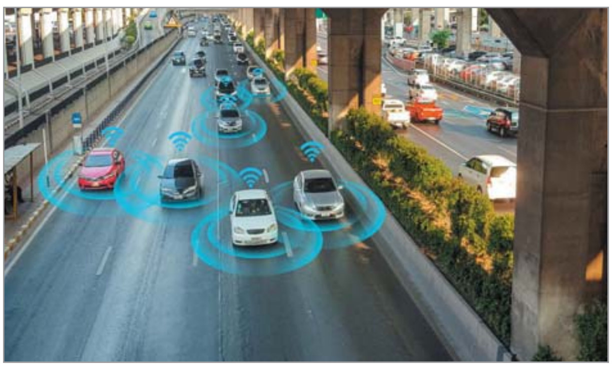


Labeling Radar and Comms Signals for Deep-Learning Apps

Previous "Algorithms to Antenna" blogs on deep learning focused on applying techniques to various radar and communications applications. Here we look at labeling the real-world data gathered from a radar, radio, or instrumentation.

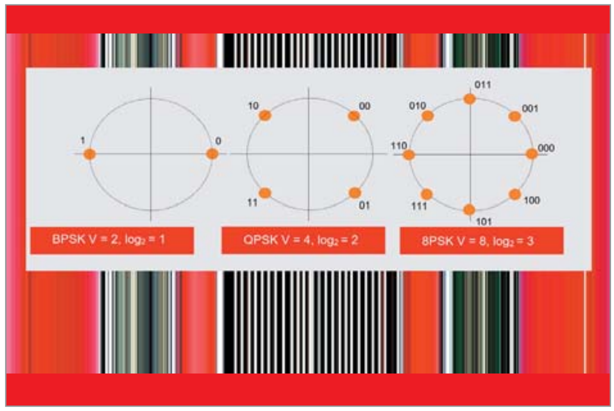
https://www.mwrf.com/technologies/systems/article/21161852/mathworks-algorithms-to-antenna-labeling-radar-and-comms-signals-for-deeplearning-apps



Automotive Radar Paves the Way to Safer Roads

Low-power radar MMICs at 24 and 77 GHz provide the electromagnetic-sensor data that combines with video cameras and LiDAR systems for reliable ADAS coverage.

https://www.mwrf.com/technologies/semiconductors/article/21159596/microwaves-rf-automotive-radar-paves-the-way-to-safer-roads



A Reminder: Pay Attention to Harry Nyquist and Claude Shannon

Many CIOs, CTOs, and architects tend to forget this telecommunications throughput issue.

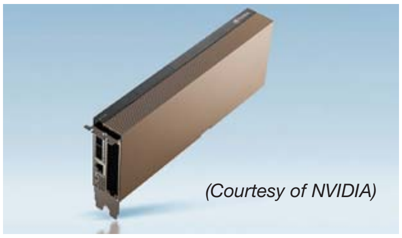
https://www.mwrf.com/technologies/systems/article/21159055/a-reminder-pay-attention-to-harry-nyquist-and-claude-shannon

Repeatable Wi-Fi Testing is Key for Device Performance Validation

This article provides a technical look at newly defined performance metrics for Wi-Fi router testing in different scenarios and explores the challenge of building repeatable Wi-Fi testing that enables validation of devices used in broadband deployments.

https://www.mwrf.com/technologies/test-measurement/article/21163158/university-of-new-hampshire-interoperability-laboratory-unhiol-repeatable-wifi-testing-is-key-for-device-performance-validation

News


(Courtesy of NVIDIA)

NVIDIA'S AI-ON-5G PLATFORM Forms Centerpiece of Smart Everything

A wide variety of service and network-infrastructure providers are preparing for an IoT economy with NVIDIA's latest platform.

Tomorrow's smart cities and factories, futuristic hospitals, and intelligent retail outlets will depend on both 5G and edge artificial intelligence (AI) computing. To that end, NVIDIA is teaming with partners such as Fujitsu, Google Cloud, Mavenir, Radisys, and Wind River to develop solutions for NVIDIA's AI-on-5G platform.

Enterprises, mobile-network operators, and cloud-service providers that deploy the platform will be able to handle both 5G and edge AI computing in a single, converged platform. The AI-on-5G platform leverages the NVIDIA Aerial software development kit with the NVIDIA BlueField-2 A100—a converged card that combines GPUs and DPUs including NVIDIA's "5T for 5G" solution. This creates high-performance 5G RAN and AI applications in an optimal platform to manage precision manufacturing robots, automated guided vehicles, drones, wireless cameras, self-checkout aisles, and hundreds of other transformational projects.

NVIDIA and several collaborators in this new AI-on-5G ecosystem are members of the O-RAN Alliance, which is developing standards for more intelligent, open, virtualized, and fully interoperable mobile networks. Such collaboration allows operators to use the same computing infrastructure required for 5G networking to provide AI services in enterprise, industrial, consumer, and residential settings.

The NVIDIA Aerial SDK, in combination with NVIDIA Metropolis, NVIDIA Isaac, and NVIDIA Clara, is an integral part of the AI-on-5G ecosystem and can be deployed on a single NVIDIA-Certified System using NVIDIA GPUs and DPUs on a single card.

A Range of Collaborations

As an example of NVIDIA's collaborative efforts to enable AI-on-5G, Mavenir is building two 5G vRAN systems based on the Aerial SDK and will target the network operator segment for public 5G and for enterprise AI with private 5G. Mavenir and NVIDIA have created a hyperconverged enterprise 5G solution to enable enterprises to implement AI-on-5G applications in a seamless and easy-to-use solution.

For its part, Fujitsu later this year plans to deliver a 5G Open RAN system for verification starting with the sub-6-GHz band. Upon the system's completion, Fujitsu and NVIDIA will be helping NTT DOCOMO and global operators with their evolution toward Open RAN in 5G, and beyond. Aerial software-defined implementation reduces time to market, speeds innovation and helps deliver AI applications to enterprises.

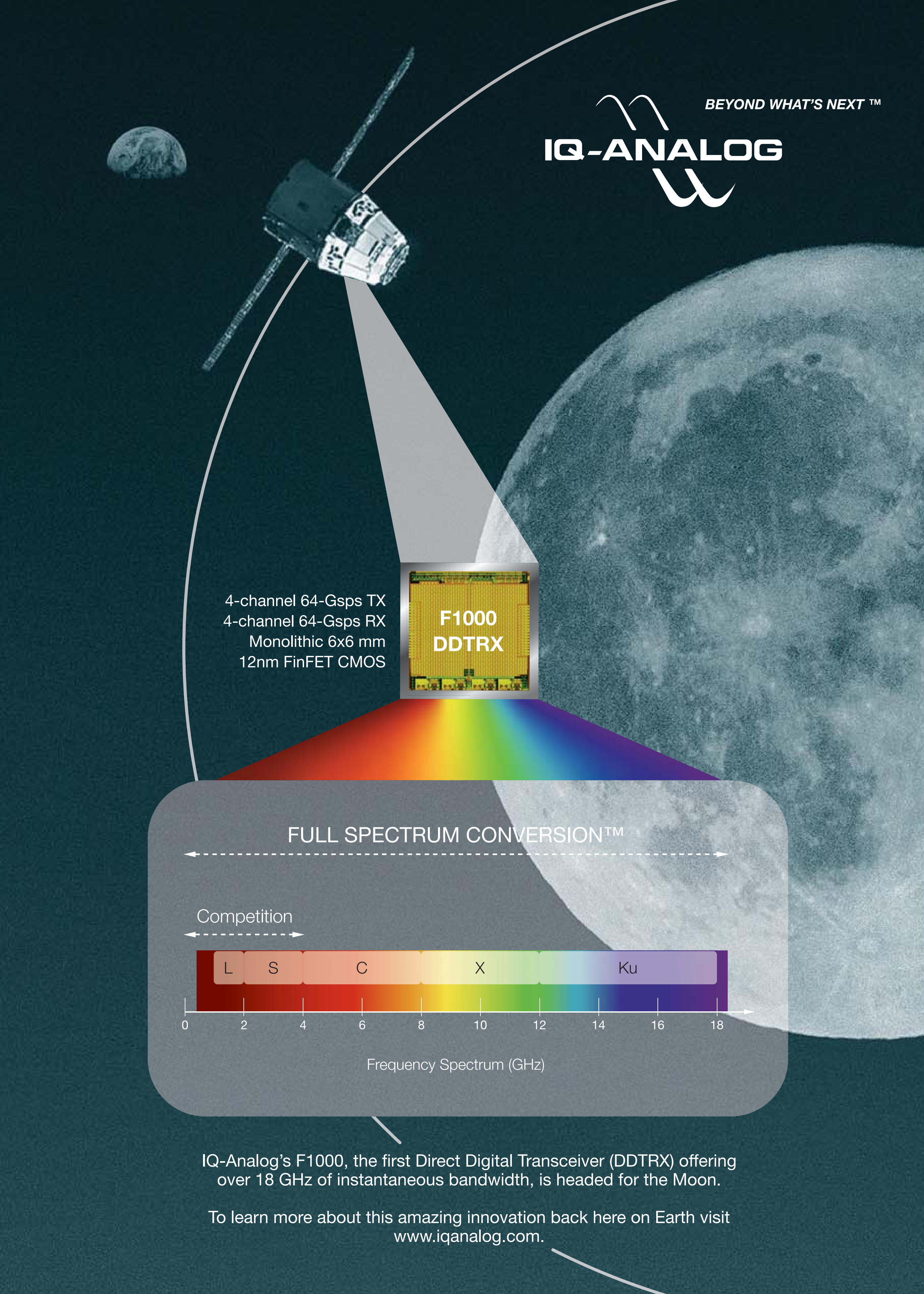
In the enterprise-deployment arena, Radisys and Wind River plan to deliver NVIDIA Aerial AI-on-5G solutions for enterprise 5G and industrial 5G networks. Over 6 million 5G cells will be deployed by 2027 to smart factories, fulfillment centers, and other enterprise, industrial, and public zones to provide localized connectivity solutions, according to ABI Research.

Google Cloud is extending the Anthos application platform to the network edge, allowing telecommunications service providers and enterprises to enable the rapid delivery of new services and applications at the 5G edge. Enterprises can turn to Google Cloud's managed services and NVIDIA for their IoT economy, and to harness data and AI to drive business performance, improve operational efficiency, and optimize safety and reliability.

AI-on-5G Data Centers

Software-defined RANs are critical for building a modern 5G infrastructure that can run a range of applications on a common platform. NVIDIA Aerial enables the best possible utilization by providing elasticity as network traffic changes throughout the day and the flexibility to offer services based on dynamic customer needs.

The NVIDIA EGX platform brings AI computing capabilities to the edge where data gets created. The NVIDIA EGX stack, which is compatible with all commercially available Kubernetes infrastructures, is an ideal platform for Aerial, enabling low-power, always-on, and high-performance devices, reshaping the telecom industry. Expanding on the platform, server makers also can pair NVIDIA GPUs and DPUs to build hyperconverged edge data centers. mw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MAVENIR, XILINX COLLABORATE on Open RAN mMIMO Portfolio

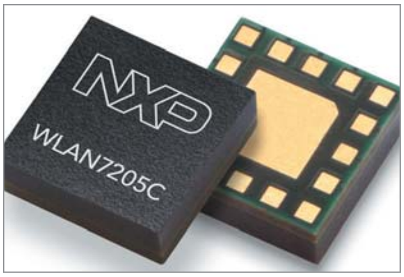
THE 5G OPEN RAN (O-RAN) ecosystem received a boost with news of Mavenir and Xilinx collaborating on a unified 4G/5G O-RAN massive MIMO (mMIMO) portfolio. The two companies have completed end-to-end integration of a first-generation mMIMO solution using O-RAN principles. The first mMIMO 64TRX joint solution is expected to be available in the fourth quarter of 2021.

The integration, which was accomplished at Mavenir's Bangalore, India lab, covered multiple deployment scenarios and was evaluated by six communications service providers (CSPs), all of which are leading global operators. Mavenir delivered the Virtualized RAN (vRAN) support for mMIMO, including Core Network, CU, and DU, with Xilinx providing the Category B O-RAN Radio Unit.

With the successful integration, the companies have reached a critical milestone in the delivery of an open and interoperable interface, which enables the deployment of mMIMO in high-density, high-mobile-traffic metropolitan areas.

With the successful integration, the companies have reached a critical milestone in the delivery of an open and interoperable interface, which enables the deployment of mMIMO in high-density, high-mobile-traffic metropolitan areas.

Together, Mavenir and Xilinx say they are developing the next generation of mMIMO products, which add up to the world's first O-RAN-compliant 64TRX mMIMO solution supporting up to 400 MHz of instantaneous bandwidth in a compact form factor. Mavenir's vRAN software supports multi-user MIMO with up to 16 layers, advanced receiver algorithms, and full digital beamforming, all running on Mavenir's open and flexible cloud-native platform, as well as on other cloud platforms. Xilinx contributes its Zynq RFSoC digital front end (DFE) and Versal AI Core for advanced beamforming, delivering a fully integrated hardware and software O-RAN-compliant mMIMO solution. ■



WI-FI 6/6E Comes to Handsets in QFN Front-End ICs

OVER THE NEXT FEW YEARS, Wi-Fi 6 and 6E technologies are poised to grab a big piece of the growing connectivity market in applications such as wireless online access, automotive, industrial/IoT, and portable devices. And NXP Semiconductors, already very well established in those markets, knows that the market will be hungry for front-end ICs (FEICs) in compact form factors like the quad-flat no-leads (QFN) package.

That's why the Netherlands-based semiconductor maker is betting on its lineup of Wi-Fi FEICs in packages including the QFN, chip-scale packages (CSPs), and RF front-end modules (RFFEs) for applications such as smartphones and computing devices.

NXP says that OnePlus has chosen its WLAN7205C QFN RFFE for Wi-Fi 6 for its latest flagship smartphone, the OnePlus 9, making that handset the industry's first to feature a Wi-Fi 6E QFN device. That device, a single-channel RFFE, packs a monolithic integrated SiGe power amplifier, switch, and low-noise amplifier to improve the range capability of the handset's Wi-Fi communications.

The WLAN7205C covers from 5.150 to 7.125 GHz, which enables it to range across the 5-GHz Wi-Fi 6 band and beyond into the 6-GHz Wi-Fi 6E (Extended) spectrum, where device OEMs can reap the rewards of uncongested frequencies that lend 5G-like performance to Wi-Fi connectivity. It features five transmit modes per band and two receive modes.

An advantage of the 2- × 2-mm QFN module is that it can be placed close to the antenna, reducing trace losses, as opposed to dual-channel, modular solutions available in the market. This improves transmission and reception, increases battery life for longer Wi-Fi usage, and enables faster data transmission for an improved user experience. The device's high level of integration is what makes the smallest QFN package possible.

What's more, the WLAN7205C includes integrated RF decoupling capacitors for all V_{CC} and control pins and requires no external matching components to gain a 50-Ω impedance into the antenna. That saves even more space within the handset. ■

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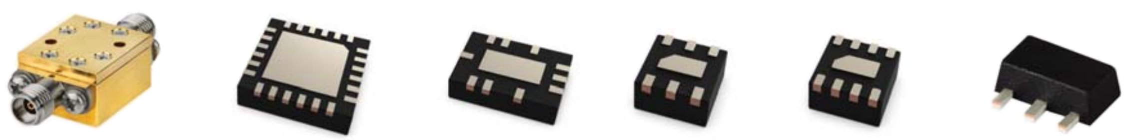
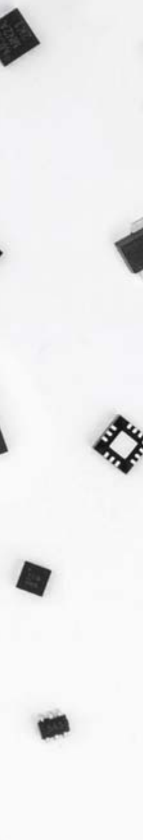
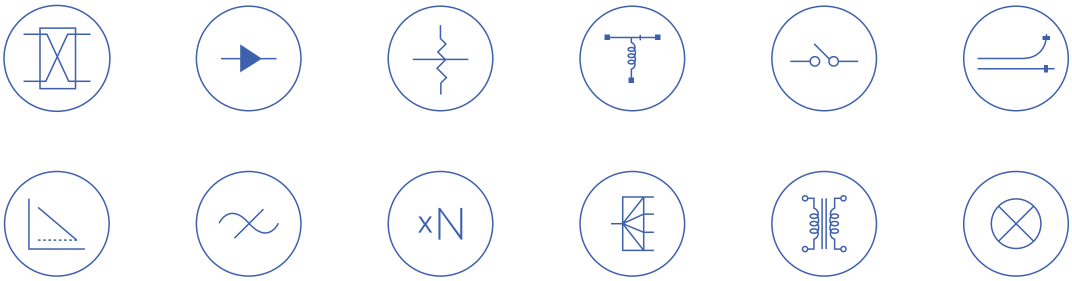
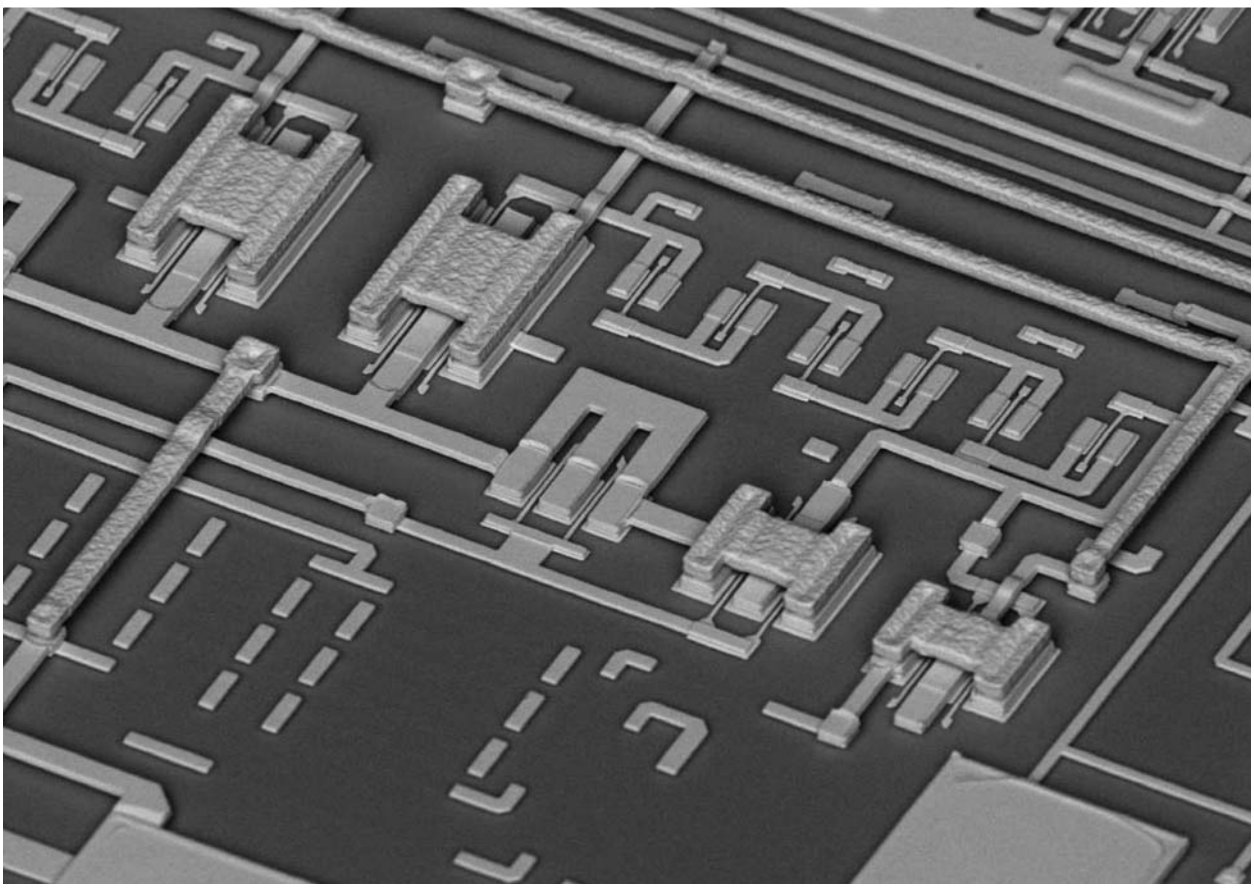








Mini-Circuits

JACK BROWNE | Technical Editor

IMS 2021 Prepares for mmWave Applications

Interest in components, circuit materials, and test solutions for millimeter-wave frequencies looms large as the RF/microwave industry readies for two versions of the annual IEEE IMS.

For the RF/microwave industry, this event is one not to forget, the largest placeholder on the calendar. In years past, the IEEE International Microwave Symposium (IMS) has been the technical conference and exhibition that brought the industry together for a week. But this isn't just any year—the pandemic caused by the COVID-19 coronavirus has forced most industries to be cautious how they do business.

However, the RF/microwave industry has always adapted to change and the way the internet is now used as a key channel of communications. The industry will support a traditional version of "Microwave Week" at the face-to-face version of the IEEE IMS 2021 Conference and Exhibition scheduled for June 7-10, 2021 at the Georgia World Congress in Atlanta, Ga. There's also an online version taking place June 20-25, 2021, wherever they have internet access.

Many companies have expressed great enthusiasm at the opportunities to meet face-to-face with customers at their exhibitor booths. But, as with many public events, attendance has been hindered by the threat of the COVID-19 virus, often reaching only 20% of expected totals.

In the hopes of meeting customers in Atlanta, the RF/microwave industry has contributed to a strong IMS show lineup of more than 300 exhibitors for the face-to-face and virtual versions of the exhibition. As usual, there's a diversified assortment of technologies and products from components, circuit materials, and multifunction assemblies through design software and test equipment.

The exhibition has always represented almost a week of constant activity, meeting new clients, and catching up with existing customers and friends. Visitors have a chance to connect with their current suppliers and find new sources of products for aerospace, commercial, defense, industrial, and medical marketplaces. In addition to the exhibition, the IMS 2021 features a strong conference of RF/microwave engineering speakers with technical lectures, white papers, and workshops.

Two Conferences in One

The first day (June 7) of the face-to-face IMS 2021 technical conference opens with a pair of plenary talks. Suresh Venkatarayalu, Chief Technology Officer of Honeywell, will welcome guests to the IMS 2021 with a special IMS keynote lecture. That same day, Dr. Ahmad Bahai, Chief Technology Officer and Senior Vice-President of Texas Instruments, will present a keynote talk introducing the 2021 IEEE Radio Frequency Integrated Circuit Symposium (RFIC 2021), co-located with the IMS 2021 technical conference in the nearby Omni Hotel.

Photo 199069016 © Billy Blume | Dreamstime.com

For those interested and involved in high-frequency, high-speed measurements, the technical portion of the face-to-face conference closes with a long-running tradition: the 97th meeting of the Automatic RF Techniques Group (ARFTG) Thursday, June 10, also in the Omni Hotel. This session will have a strong focus on mmWave measurements.

Those traveling to Atlanta can enjoy a strong primary technical conference as part of IMS 2021, with technical sessions on transmitters and power amplifiers (PAs); RF through millimeter-wave (mmWave) filtering; advances in materials, including frequency-selective materials and metasurfaces; circuit materials for mmWave frequencies; physical-layer security, including radio channel modeling; antenna arrays for wireless applications; conserving energy in low-power circuits; and advanced waveguide designs.

Later in the month, from June 20-25, the virtual technical conference features an intriguing collection of online presentations. It may not offer the same opportunities for interaction and feedback as the live event, but, if anything, covers a more widely diversified list of topics, from filter fundamentals to biomedical design issues.

The first day of technical sessions at the virtual conference (June 22) offers presentations on advanced technologies for transceivers, machine learning (ML) for computer-aided-design (CAD) tools, electromagnetic (EM) fields for security applications, and acoustic filters for communications. The following day (June 23) continues the strong focus on mmWave design, with online presentations about wireless sensor systems, frequency conversion circuits, waveguide and composite structures, instruments for biomedical measurements, and mmWave PAs. The final day of sessions (June 24) covers advances in radar systems, mmWave circuits and components, beamforming array antennas, and low-noise amplifiers (LNAs).

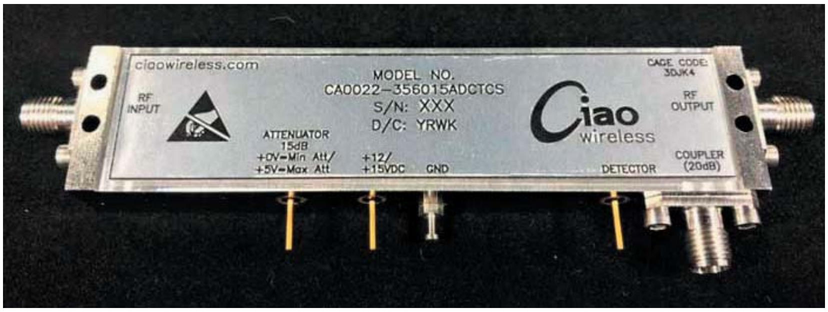
Exhibitor Showcase

The areas of interest in the face-to-face and virtual technical conferences are mirrored by the variety of products on display during both versions of the IMS 2021 exhibition. Exhibitors scheduled for the face-to-face and virtual exhibitions comprise a representative sample of the RF/microwave industry, providing products from as basic as inductors to as elaborate as "smart" signal analyzers.

With the widespread adoption of mmWave devices and modules into automotive electronic systems such as advanced driver-assistance systems (ADAS) and 5G cellular wireless networks, both show floors are expected to have "higher-frequency" feels to them at many of the booths. Attention paid to frequencies of 24 GHz and higher is expected to impact most of the product areas at the exhibitions, including active and passive components, design software, materials, semiconductors, and test equipment.

Long-time amplifier supplier **Empower RF Systems Inc. (booth 1225)** will show visitors a sampling of its high-power amplifiers (HPAs) for communications, military, radar, satcom, and test-and-measurement applications. Some of these are solid-state replacements for the oversized vacuum-tube amplifiers powering military jammers and radar systems, such as the model 2210 HPA. It provides 12-kW saturated pulsed output power from 150 to 450 MHz in a rack-mount enclosure. The 2210 consists of two amplifiers based on silicon (Si) laterally diffused metal-oxide-semiconductor (LDMOS) transistors teamed with a power converter and a power-control and combining assembly. Empower is expected to have many smaller amplifiers at its booth, with less output power at higher frequencies.

On a smaller scale, **Ciao Wireless (booth 1812)** will show broadband, high-gain, and low-noise amplifiers (LNAs) *(Fig. 1)*, with models covering total bandwidth of 1 to 40 GHz with flat



1. Broadband coaxial LNAs covering a total range of 1 to 40 GHz are available with integrated attenuators, couplers, and detectors. *(Courtesy of Ciao Wireless)*

gain levels of 20, 25, 30, or 35 dB and noise figure as low as 4 to 5 dB through 40 GHz. Well-suited for commercial and military applications, the coaxial amplifiers are available with integral power detectors, voltage-variable attenuators, and output couplers covering the full frequency range and as much as +20-dBm output power at 1-dB gain compression.

Mini-Circuits (booth 1921) will greet visitors in Atlanta with a sampling of its diversified product portfolio, including its model ZVA-24443G1 mmWave LNA, with typical noise figure of just 1.7 dB across its wide frequency range of 24.0 to 43.5 GHz *(Fig. 2)*. Designed for a single supply voltage of +9 to +15 V dc, the coaxial amplifier delivers typical output power of +20 dBm across the full bandwidth and features integrated overvoltage and reverse-voltage protection.

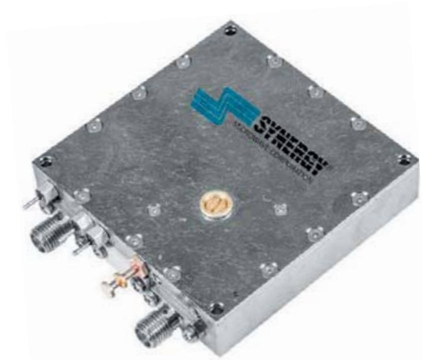
2. Model ZVA-24443G1 is a mmWave LNA with typical noise figure of just 1.7 dB from 24.0 to 43.5 GHz. *(Courtesy of Mini-Circuits)*

To satisfy a growing need for frequency conversion at mmWave frequencies, Mini-Circuits will also highlight its model MDB653H-D+ double-balanced mixer die. Well-suited to fit in the tightest PCBs, such as in SWaP applications, the frequency mixer has an RF frequency range of 20 to 65 GHz, mixing with local-oscillator (LO) signals over the same frequency range to produce intermediate-frequency (IF) signals from dc to 20 GHz for signal processing. It can also be used in the reverse direction for frequency upconversion, transforming IF signals to mmWave signals from 20 to 65 GHz at its RF port.

For those interested in some of the smallest, highest-power amplifiers at X-band frequencies but not inclined to travel, **Wolfspeed/Cree (virtual booth VO3053)** will feature its gallium-nitride-on-silicon-carbide (GaN-on-SiC) monolithic microwave integrated-circuit (MMIC) amplifiers for pulsed and CW applications. Designed for +28-V dc supplies, the tiny amplifiers fit into surface-mount-technology (SMT) packages. For example, the model CMPA901A0205 provides typical gain of 31 dB with 20-W saturated output power and 45% power added efficiency (PAE) from 9 to 10 GHz, while model CMPA80180305 offers 40-W saturated output power with 20-dB gain and 40% PAE from 7.9 to 11.0 GHz.

Also at the virtual exhibition, **Herotek (virtual booth VO3220),** in keeping with the growing interest in mmWave frequencies, will highlight its model A2640205010A LNA. It maintains 20-dB small-signal gain with typical gain flatness within ±2.5 dB from 26 to 40 GHz and maximum noise figure of 5 dB across the full frequency range. Suitable for receivers and test equipment, the amplifier also can deliver +10-dBm output power at 1-dB compression.

For signal generation, **Synergy Microwave Corp. (virtual booth VO3025)** will show visitors its KSFLOD series of phase-locked dielectric resonator oscillators (DROs), with fundamental-frequency outputs starting at 6 GHz through 15 GHz, and as high as 45 GHz when tripled. With low phase noise and spurious outputs, the compact coaxial DROs *(Fig. 3)* are well-equipped to provide LO and other signals in 5G, radar, and test systems.



3. Phase-locked DROs from the KSFLOD series offer low-noise signals from 6 to 15 GHz for system and test applications. *(Courtesy of Synergy Microwave Corp.)*

Passives

Specifiers of passive components will also find a wide variety of components at both versions of the IEEE IMS 2021, from the most basic to the most elaborate. For those in need of inductors and transformers, **Coilcraft (virtual booth VO3340)** will show examples of its extensive lines of RF and power magnetic components, including inductors and transformers for commercial, automotive, military, industrial, and space applications.

The company has developed AEC-Q200-qualified inductors for the growing number of automotive electronic applications, such as ADAS-based LiDAR and radar systems, tire-pressure monitoring systems (TPMS), and electric power-steering (EPS) circuits. The components are designed for operating temperatures from −140 to +125°C.

Ironwood Electronics (booth 2140) will show Atlanta visitors versions of its high-speed, high-frequency sockets well-

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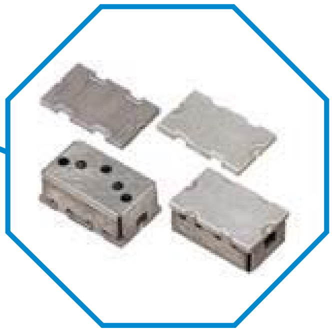

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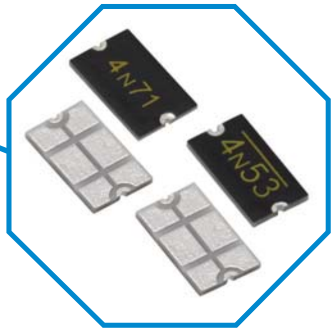

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suited for interconnections through 110 GHz. Available in standard and custom versions to replace obsolete interconnections and packaging, the sockets are designed for operating lifetimes as long as 500,000 insertions. The company will also show its Giga-snaP BGA SMT adapters for reliable interconnections to BGA SMT pads. The adapters remain attached through many solder cycles, with a fraction of the insertion force of other SMT adapters.

Mini-Circuits will be in Atlanta and at the virtual exhibition with its own collection of passive components, including miniature low-temperature cofired-ceramic (LTCC) filters, such as lowpass model LFCN-3052+. Designed to reject mmWave signals to 50 GHz, the tiny filter measures just 3.2 × 1.6 mm with low insertion loss of typically 1.2 dB across a wide passband of dc to 30.5 GHz. It delivers as much as 40-dB rejection from 41.5 to 47.0 GHz and at least 26-dB rejection across a stopband of 36.5 to 50.0 GHz.

Also on tap is its model RCDAT-30G-30 programmable attenuator, which can be simply controlled by USB or Ethernet connection to a computer. With a frequency range of 100 MHz to 30 GHz, it adjusts attenuation from 0 to 30 dB in 0.5-dB steps.

Antennas are usually passive devices, but more and more phased-array antennas with active beamforming are being considered at mmWave frequencies. For those wishing to get a "jumpstart" on a mmWave phased-array antenna, **Anokiwave (virtual booth VO3042)** will show virtual exhibition visitors its scalable active antenna kits. The kits feature phased-array antennas on PCBs, designed and constructed with the company's innovative beamforming and steering ICs. Antenna kits are available for different 5G NR frequency bands, such as the 28-GHz n257 and n261 bands. The antennas are ready for transmit and receive actions, as well as for testing with instruments such as a spectrum analyzer and test antenna.

Creating Circuits

Basic materials are a starting point for most electronic designs, whether they're semiconductors, packages, or circuits, and the growing importance of mmWave frequencies has made an impact on materials development over the last few years.

On the Atlanta exhibition floor, **Rogers Corp. (booth 1841)** will display examples of its growing lines of materials to constructed PCBs from RF through mmWave frequencies, including its RO4835T laminates *(Fig. 4)*. Designed to work with RO4835 laminates as thin inner layers for multilayer PCBs, they provide designers some control of the overall thickness of a multilayer PCB—even when stacking many circuit layers into a densely integrated design—whether for commercial, industrial, medical, or military electronic designs.

4. RO4835T laminates are low-loss, temperature circuit materials that help miniaturize multilayer PCBs through mmWave frequencies. *(Courtesy of Rogers Corp.)*

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With a dielectric constant (Dk) of 3.3, RO4835T laminates can be fabricated with the same processes used for FR-4-based PCBs. The laminates feature low loss, with dissipation factor of 0.0030 to 0.0036 depending on thickness. Thermal properties are excellent, too, with coefficient of thermal expansion (CTE) of 17 ppm/°C or less, again depending on thickness.

At the virtual exhibition, **Isola (virtual booth VO2949)** will show its Tachyon 100G circuit materials for mmWave applications to 100 GHz and high-speed digital circuits to 100 Gb/s. Also available in a wide range of thicknesses for construction of compact multilayer circuits, the materials exhibit low CTE values and excellent stability for operating temperatures from –55 to +125°C. Its spread-glass construction contributes to low jitter and reduced rise/fall times in digital circuits and its smooth copper helps minimize conductor losses.

5. The N9042B UXA signal analyzer can sweep analysis bandwidths as wide as 11 GHz across a frequency range of 2 Hz to 110 GHz. *(Courtesy of Keysight Technologies)*

Testing the Limits

Keysight Technologies recently released a handy 22-page application note on using different signal analyzers, titled "Signal Analysis Measurement Fundamentals." It provides guidance on improving the measurement accuracy of a test setup and how different settings, such as resolution bandwidth, will affect measurement speed.

In Atlanta, **Keysight (booth 1321)** will bring visitors up to speed on signal analysis, with several high-performance instruments on hand. The model N9042B UXA signal analyzer *(Fig. 5)* features a phenomenal analysis range of 2 Hz to 110 GHz and wide dynamic range. Ideal for finding and analyzing signals in 77-GHz automotive radars and short-range mmWave links in 5G wireless networks, the signal analyzer can sweep across its full frequency range with analysis bandwidth as wide as 11 GHz, to search for and find expected as well as unknown signals.

Keysight will also display its FieldFox portable microwave analyzers in Atlanta. The compact, waterproof instrument brings signal analysis to the field, in a package weighing less than 8 lbs. Models are now available with top frequencies to 54 GHz, such as the 52-GHz model N9952B with maximum analysis bandwidth of 120 MHz and dynamic range as wide as 105 dB. The portable signal analyzers are supported by test software packages such as the firm's PathWave vector-signal-analysis (VSA) software to analyze high-frequency signals with complex modulation formats, e.g. quadrature amplitude modulation (QAM).

Rohde & Schwarz (booth 1821) will be in Atlanta with an assortment of high-performance RF/microwave test equipment, including its R&S ZVA vector network analyzers (VNAs). Versions are available from 10 MHz to 26.5, 43.5, 50, and 67 GHz to characterize active and passive components for many emerging mmWave applications. The hybrid test instrument/computer and its advanced user interface has a front panel with a 12.1-in. touchscreen display that can be divided into two independent display screens for detailed analysis and control.

As part of the virtual exhibition, **FormFactor (virtual booth VO3245)** will show how it applies microelectromechanical-systems (MEMS) technology to the fabrication of its fine-pitch probe cards for semiconductor testing. As an example, its Altius vertical MEMS probe card enables high-speed, high-frequency testing of high-density interconnections on semiconductor packaging. **Anritsu (virtual booth VO3353)** will also assist mmWave testers, displaying its ME7838A4 VectorStar series of microwave/mmWave four-port VNAs, with models from 70 kHz to 110, 125, 145, and 150 GHz.

This is a small sampling of the face-to-face and virtual exhibition floors expected for the IEEE IMS 2021, but the trend toward a need for higher mmWave products is clear. Visitors to Atlanta are urged to follow all COVID-19 health and safety protocols, even when playing with some of the latest in mmWave test instruments. mw

GENGYAO LI, DONGWON KWON, KEITH SZOLUSHA | Analog Devices

MITIGATION STRATEGIES for Tricky FM Band Conducted EMI

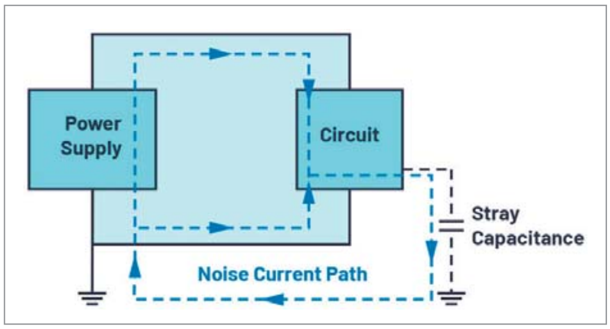
Simple techniques that can help lower this type of EMI range from using a common-mode choke or inductor orientation to reducing switch frequency or shrinking the switch-node area.

Although EMI shields and ferrite clips are often a sought-after EMI solution, they can be expensive, bulky, and sometimes insufficient. FM band EMI noise can be reduced by understanding where it's coming from and employing circuit and PCB design techniques to suppress it at the source.

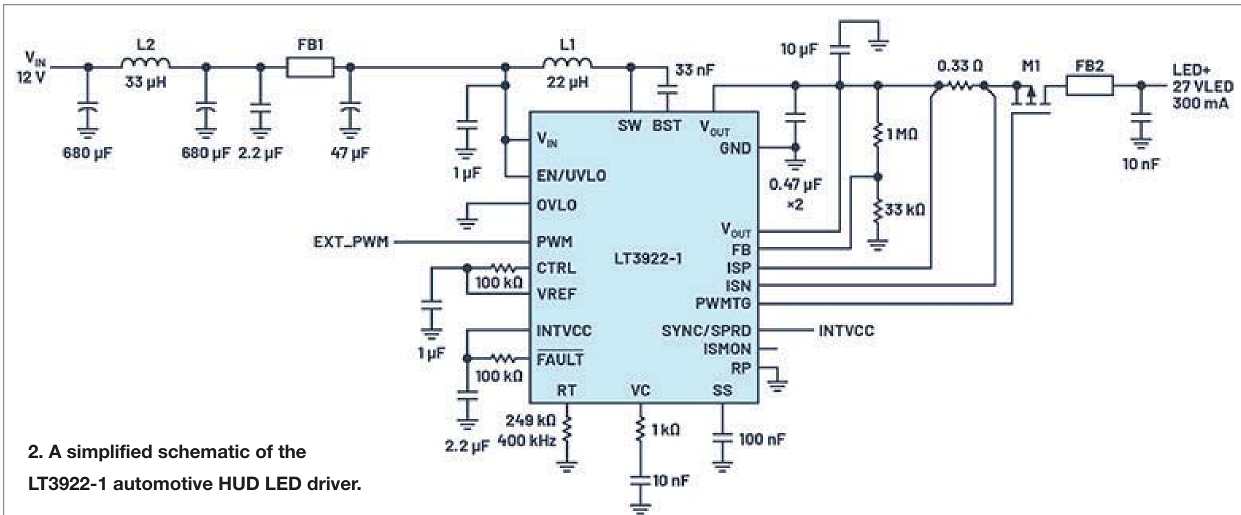
EMI performance of power-supply networks is critical in noise-sensitive systems such as automotive circuits, especially when switch-mode power supplies (SMPS) are involved. Engineers can invest significant time to reduce conducted emissions (CE) and radiated emissions (RE). In particular, when measuring CE, the FM band (76 to ~108 MHz) can be the most difficult region to achieve a passing result. Designers might need to spend significant time to do so. Why is the CE noise in the FM band so difficult to mitigate?

Low-frequency (AM band) CE is dominated by differential-mode (DM) noise. High-frequency (FM band) CE is dominated by common-mode (CM) noise.[1] Common-mode noise current is generated by nodes with changing voltages on the PCB. The current leaks through stray capacitance to reference ground and back to input plus and minus cables *(Fig. 1)*. Due to the complexity of stray capacitance around the PCB, it's not practical to simulate stray capacitance and estimate FM band conducted EMI. Rather, it's best to test the board in an EMI chamber.

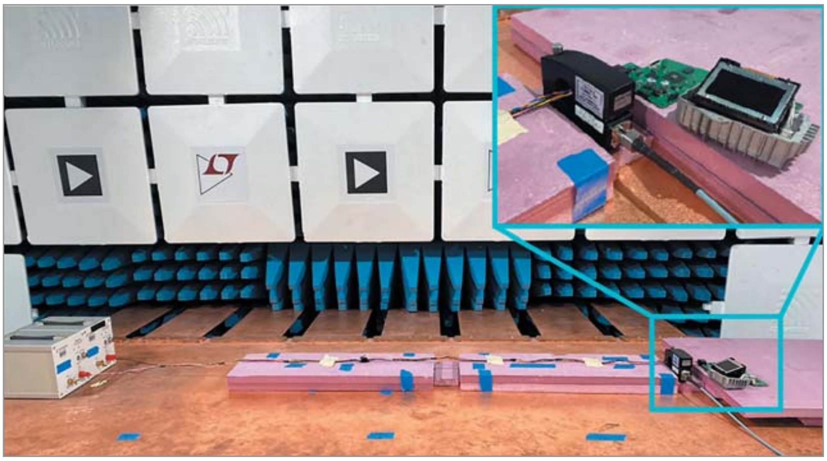
There are proven methods in the lab that effectively reduce FM band EMI, including changing switching frequency, switching slew rate, switch node layout, hot-loop layout, inductors, and even the location of input cables and load. The efficacy of each method could vary from board to board.



1. A conducted emission, common-mode noise current path.



2. A simplified schematic of the LT3922-1 automotive HUD LED driver.



3. CISPR 25 current-probe conducted emissions (CE) setup in an EMI testing chamber (50 mm).

This article examines a number of simple, low-cost ways to reduce FM band conducted EMI on a board—without using ferrite clips or shields. The results are verified by performing current-probe CE tests, in a certified EMI chamber, on a board featuring the LT3922-1 in an automotive HUD LED driver *(Fig. 2)*.

In this test, CE is measured with a current-probe method in a CISPR 25 EMI setup *(Fig. 3)*. CE can be tested by either the voltage-probe method or current-probe method, but the current-probe method standard is generally considered the stricter of the two.

Instead of measuring the voltage output from the line-impedance stabilization networks (LISNs), the current CE method utilizes a high-bandwidth current probe to measure CM noise signals propagating through the power cord or harness, at distances of 50 mm and 750 mm from the DUT. Peak and average CE data is collected at each sweep and compared against published standards limits.

For the current-probe method, FM band average CE limits described in CISPR 25 Class 5 are as low as −16 dBμA. Here, we present several effective approaches to improving results in the FM band under current probe testing for CE. Many of these methods can be applied to improve results in voltage method CE testing as well.

All of the tests in this study feature spread-spectrum frequency modulation (SSFM) enabled, unless otherwise specified. SSFM reduces EMI spikes at the switching frequency as well as its harmonics.

There are proven methods in the lab that effectively reduce FM band EMI, including changing switching frequency, switching slew rate, switch node layout, hot-loop layout, inductors, and even the location of input cables and load.

Common-Mode Choke Suppresses FM Band EMI Noise

CM noise current, which is generated during switching, leaks into the reference ground through stray capacitance and comes back through input supply and return paths in the same direction. By increasing the common-mode impedance in the loop with a CM choke, unwanted CM noise can be suppressed.

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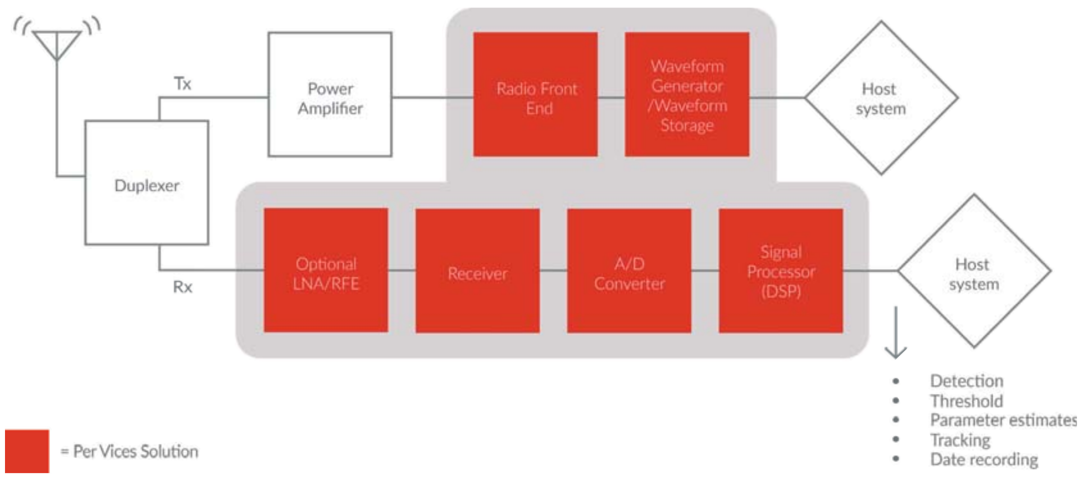

PRODUCT FEATURE/TECH SPECS

For the most demanding radio applications, engineers choose Per Vices' Cyan. Cyan SDR offers an all-in-one solution that seamlessly integrates into new and legacy systems. With both transmit and receive capabilities, Cyan provides up to 16 independent radio chains each with 1GHz of RF bandwidth and operation from DC to 18GHz. It offers a 0-20GHz tuning range, 16 bits converter resolution, 160-400 Gbps digital backhaul bandwidth, an FPGA size of 2,735k, and 1-4 DSP chains per radio chain. A fully customizable solution, Cyan has been deployed to meet the strictest performance requirements for industry leaders across radar, MRI, GNSS, low latency links, and test and measurement markets.

WHY PER VICES

Per Vices SDRs replace the need for costly, complex, inflexible dedicated hardware, with one integrated, flexible wireless platform driven by software. Traditional, hardware based RF systems rely on hundreds of discrete parts, vendors, and years in costly and uncertain research and development. The block diagram (above) highlights all the sections of a traditional radar system that are encompassed in a Per Vices SDR. Per Vices simplifies technical and supply chain complexity for wireless system manufacturers across industries, saving time and budget without sacrificing performance.

APPLICATIONS

- Radar
- Medical Imaging
- GNSS
- Low Latency Links
- Test and Measurement
- Spectrum Monitoring

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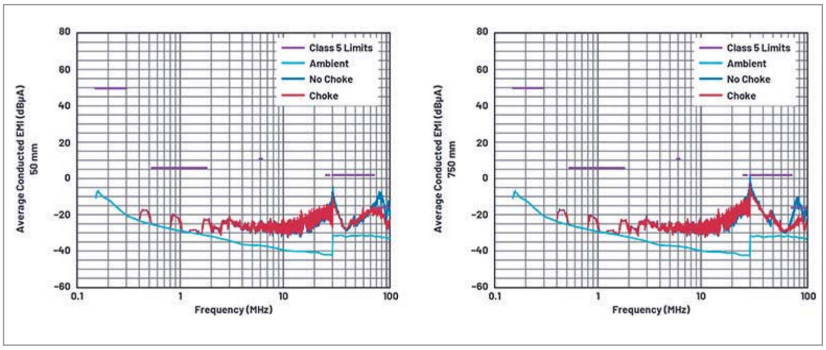
FM Band EMI

Figure 4 shows 50- and 750-mm average current-probe CE results, comparing the original circuit without the choke and with the choke installed before the LED driver circuit. The ambient noise floor is also shown for reference. FM band CE (76 to ~108 MHz) was reduced by more than 8 dBµA.

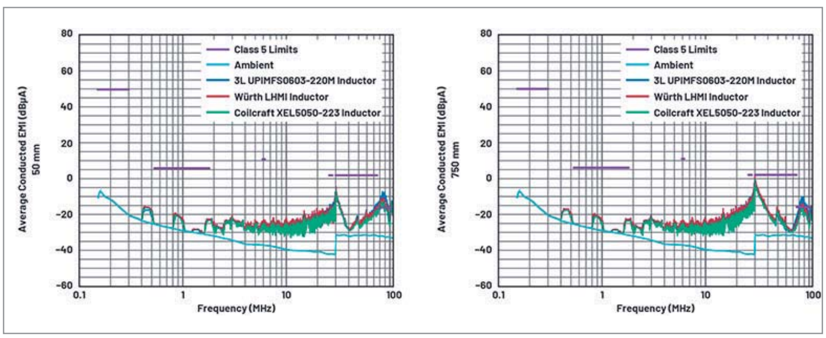
Inductors Make a Difference

Fast changing voltages and currents are applied to the main inductor, making it an electromagnetic antenna. Therefore, inductors could be a source for the FM band CE noise. EMI test results can be improved through a number of inductor-related methods. For instance, the assembly orientation of the inductor can make a difference.[2]

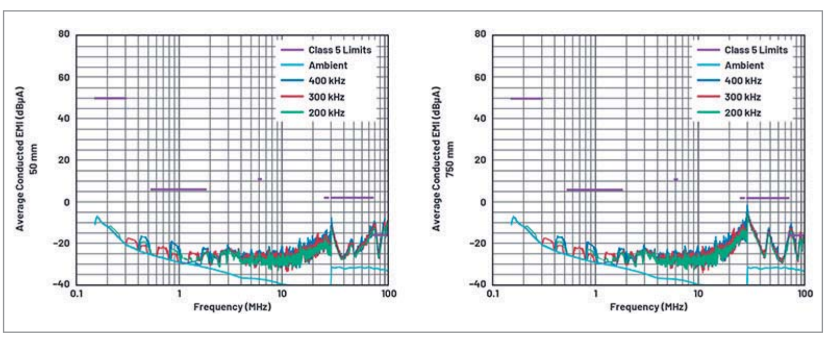
Shielded inductors usually have lower emissions than unshielded ones, and some core materials limit H-field and E-field radiation more than others. For example, iron powder and metal alloy powder inductors have less E-field shielding effectiveness at frequencies above 1 MHz.



4. Current-probe CE shows that emissions are lower in the FM band when a common-mode choke is used.



5. Current-probe CE inductor comparison.



6. Current-probe CE comparison of switching frequencies.

Specs Comparison of Inductors Tested

Part number	3L UPIMFS0603-220M	Würth 74437346220	Coilcraft XEL5050-223
Magnetically shielded	Yes	Yes	Yes
Pad exposure	Exposed	Exposed	Hidden
Core material	Metal dust	Iron powder	Composite

MnZn and NiZn perform better at higher switching frequencies.[2,3] Inductors with exposed pads perform worse than hidden pad inductors. Connecting the long lead of the inner coil winding to the high dV/dt (switch) node can increase E-field radiation dramatically.

Three 22-µH shielded inductors were tested *(see table above)*. EMI was evaluated in the same circuit without a CM choke, and each inductor was assembled in its best performing orientation. The results are compared in *Figure 5*. In this study, the Coilcraft XEL inductor yields the best FM band performance, reducing FM band EMI by 5.1 dB compared to a 3L inductor.

Lower Switching Frequency Results in a Quieter FM Band

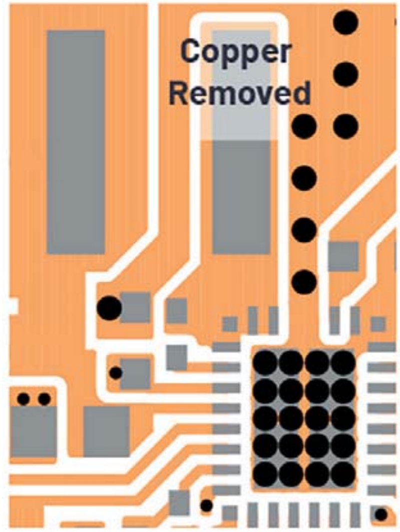
Reducing the switching frequency (f_{SW}) lowers the emissions energy at a given high frequency. In *Figure 6*, current probe CE is tested without a CM choke and compared at 200-, 300-, and 400-kHz switching frequencies. All of the components other than RT were kept the same. The 200-kHz test shows the lowest EMI in the FM band, with emissions 3.2 dB lower than the 400-kHz case.

Shrink Your Noise Antenna by Reducing Switch-Node Area

The high dV/dt switching node is a noise source that generates capacitive coupling and increases CM EMI noise in CE. It also works as an antenna, which radiates electromagnetic noise into the space, affecting radiated EMI as well. Therefore, a minimized switching-node area on the PCB layout improves EMI performance.

To test this on a PCB, the switching node area was reduced by cutting off some copper and moving the inductor closer to the IC *(Fig. 7)*. EMI was tested before and after the copper removal *(Fig. 8 on page 30)*.

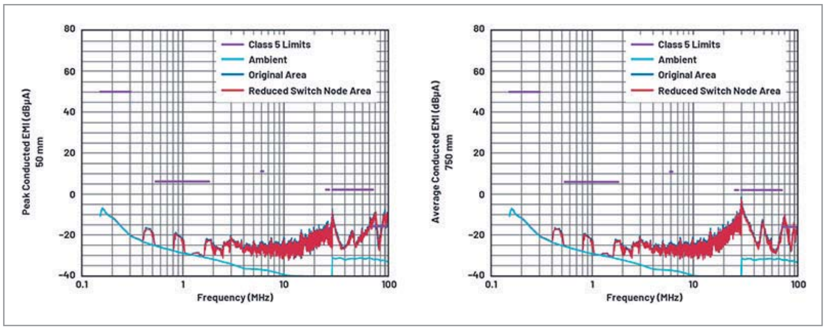
The 50-mm current-probe CE test decreases 1 dB at 105 MHz, while the 750-mm test doesn't show obvious improvement. This result indicates the copper area isn't the main contributing factor to FM band EMI for this application. Still, it's worth trying to reduce switch-node area as much as possible to achieve a low-EMI PCB layout, or during EMI mitigation.



7. Switch-node cutoff area.

Conclusion

A power supply's EMI performance depends foremost on the performance of the power-supply IC, but even a high-performance IC can only deliver low EMI



8. Current-probe CE comparing switch-node areas.

> **It's difficult to estimate which inductor is best by looking exclusively at specs, but comparisons can be made in the EMI lab. The assembly orientation of inductors on the PCB is also important.**

with proper selection of components and effective PCB layout. In this article, we explored several methods of mitigating conducted emissions in the FM band.

Applying a CM choke on positive and negative input lines increases impedance in the common-mode noise current loop. Different inductors with different core materials, core constructions, and coil constructions yield a range of EMI performance results. It's difficult to estimate which inductor is best by looking exclusively at specs, but comparisons can be made in the EMI lab. The assembly orientation of inductors on the PCB is also important.

Reducing switching frequency and reducing switching-node copper area can help lower FM band CE. If the DUT is a switching-regulator circuit using a controller part (external MOSFETs), FM band EMI can be further shrunk by reducing switching slew rates and minimizing hot loop areas. mw

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JIYOUN MUNN | Technical Product Manager, COMSOL Inc.

Pulling Back the Curtain on FREQUENCY-SELECTIVE-SURFACE FABRICS

As more wireless devices populate densely populated areas, unwanted EMI becomes an increasingly persistent problem. One way to diminish or eliminate EMI altogether is via frequency-selective surfaces.

Demand for broadband high-data-rate communication continues to escalate. Our use of mobile devices and wireless internet applications for work and entertainment adds fuel to that fire, as does the increasing number of devices interconnected via Wi-Fi, Bluetooth, and the Internet of Things (IoT).

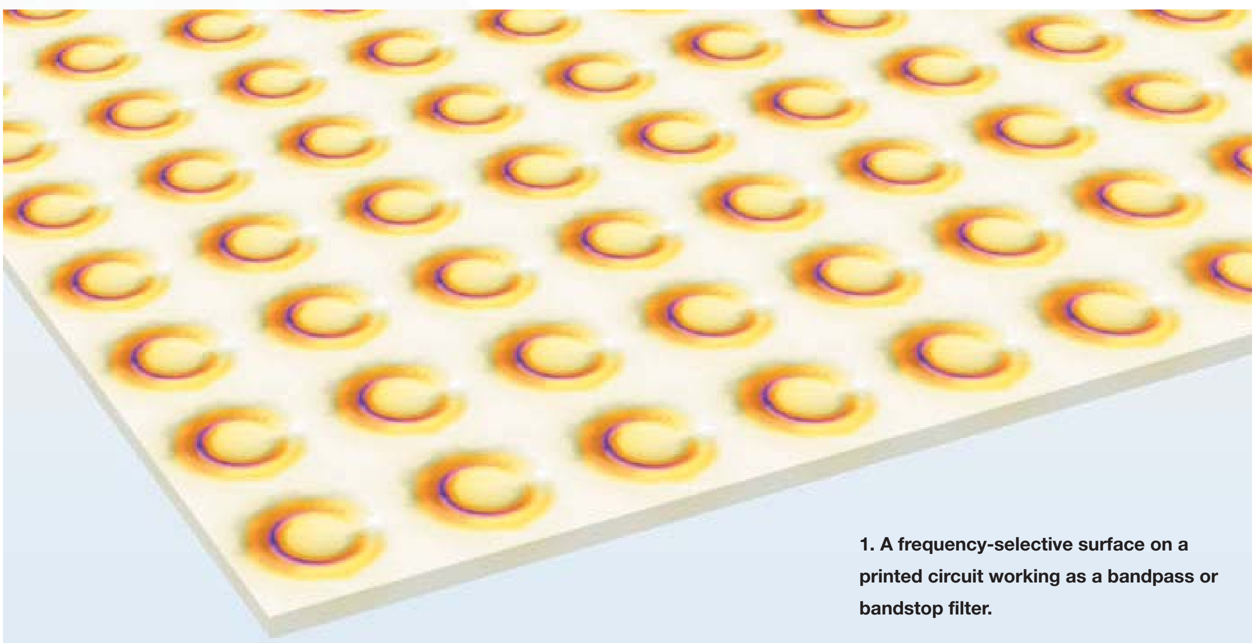
When wireless communication devices must operate in a physically crowded area, such as an apartment complex with multiple households streaming media and working from home, signals become more vulnerable to unwanted electromagnetic interference (EMI) from other devices and wireless systems. Invisible electromagnetic waves from your neighbors may "trespass" into your home, interfere with your systems, and congest the signals.

Such unwanted radiation reduces the signal-to-noise ratio of your wirelessly connected devices, resulting in degraded performance. To get better reception, your wireless router may need to be reconfigured to use a different channel frequency, which can be an inconvenient task.

A better solution to these problems is to make small but clever changes to living spaces and work environments. Just as indoor environments are protected from excessive heat, cold, and moisture, they also can be protected from EMI. In fact, you can treat a space in a way that selectively blocks undesirable signals and only lets the wanted signals through—and it can even be done in a way that's aesthetically pleasing.

EMI Protection with Frequency-Selective Surfaces

To achieve shielding from EMI, we can utilize frequency-selective surfaces composed of periodic structures *(Fig. 1)*.



1. A frequency-selective surface on a printed circuit working as a bandpass or bandstop filter.

Such periodic structures have been studied extensively for military applications with the goal of reducing the radar cross section (RCS) of scatterers like radomes, vehicles, and airplanes.

Recently, periodic structures have been the subject of research as a means of enhancing the performance of antenna arrays by suppressing surface waves and improving bandwidth. Researchers also have investigated periodic structures as a way of manufacturing engineered materials, or so-called "metamaterials." They have permittivity and permeability properties at the macroscopic level that can't be achieved using traditional materials. Now let's look at how future applications of frequency-selective surfaces may improve everyday life.

It's possible to make wearable RF and microwave devices and antennas from conductive fabrics. They can be designed to perform reasonably well, even when applied to clothing, where the surface of the component is warped. Frequency-selective surfaces can be woven using fabric and threads like that of regular fabric but made from a conductive material.

If a conductive pattern is printed on the walls, ceiling, or floor of a room, then it's also able to serve as a bandpass filter or Faraday cage, selectively shielding incoming and outgoing radiation. Similarly, a conductive fabric used as a curtain would be able to (selectively) shield a window.

Avoiding RF Performance Degradation

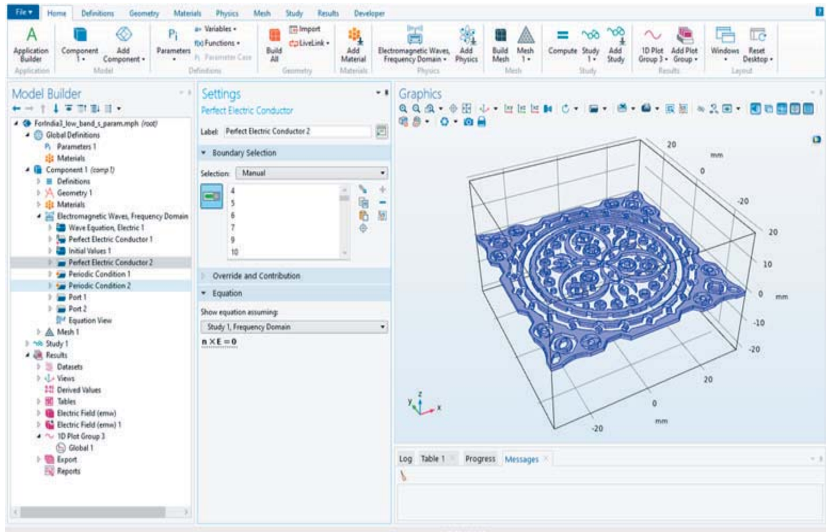
The biggest challenge when using flexible wearable components (for example, a printed flexible RFID tag) is that it's hard to maintain the RF performance when the dominant polarization is parallel to the printed surface. Due to the electromagnetic boundary conditions according to Maxwell's equations, the electric field is canceled out when the polarization is parallel to an adjacent conductive body. The device doesn't perform as in free space unless it's properly designed with a ground plane and a phase-compensating structure, like a thick, high-permittivity material.

However, when the frequency-selective surface is oriented approximately perpendicular to the direction of incident-wave propagation and matched to the given polarization without being surrounded by RF-opaque materials (e.g., a curtain covering a window), the RF performance problem is no longer significant.

If we assume that the walls in a house are built with metal beams, and that there's a lossy material finish on the surfaces of the walls with a high dielectric constant, then this structure would be an efficient electromagnetic shield. Incoming waves would, in this scenario, propagate only through the windows. A window is the most appropriate place to hang a frequency-selective-surface fabric because it would simultaneously block sunlight and unwanted electromagnetic signals *(Fig. 2)*.

A window is quite a small portion of most houses. Yet, it's an electrically large object in terms of the number of wavelengths covered. Numerical analysis of an electrically large device is very computationally intensive both in terms of time and memory. Fortunately, typical frequency-selective surfaces

2. Shown is an imaginary view of a frequency-selective-surface curtain hanging in front of a window; this view was created using the COMSOL Multiphysics software.



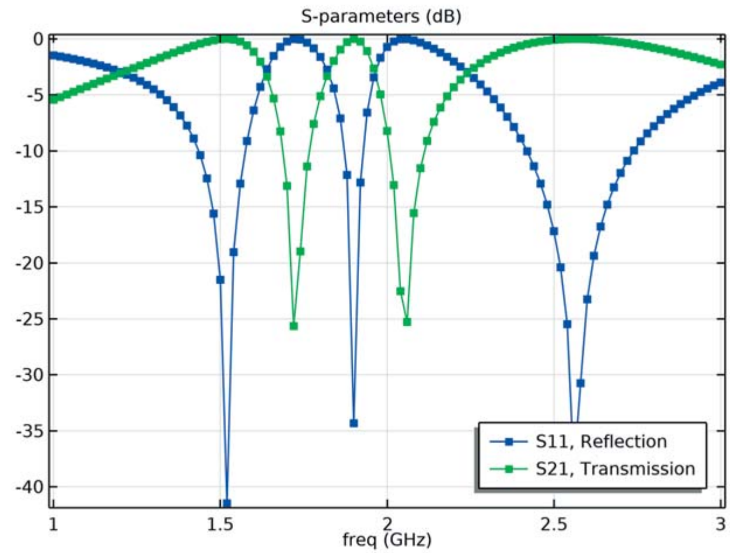
3. This image illustrates geometry and physics settings in the COMSOL Multiphysics software.

have a repeating pattern that can be exploited to reduce the computational burden.

When a repeating pattern can be identified in an electromagnetic analysis, such as in this case, the whole curtain doesn't have to be analyzed when calculating its reflection and transmission characteristics. Using the RF Module, an add-on to the COMSOL Multiphysics simulation software, only a unit cell needs to be modeled using so-called Floquet periodic boundary conditions. It includes the interaction between adjacent unit cells and can be used to represent a pattern corresponding to an infinite array of unit cells.

Analyzing Electromagnetics

Now let's look at a basic electromagnetic analysis of a model that represents only waves with normal incidence to the periodic pattern *(Fig. 3)*. The reflection and transmission characteristics in the frequency domain are, in this case, computed using port boundary conditions. These excite or terminate the simulation domain with a field consisting of a user-defined plane-wave mode. Perfectly matched layers, which are used to absorb any higher-order modes, support the port boundary conditions.



4. An S-parameter plot from 1 to 3 GHz shows the suggested frequency-selective surface's reflection and transmission characteristics.

All metallic patterns are modeled as perfect electric conductors, since the loss is expected to be negligible in the simulated frequency range. The shape of the frequency-selective surface pattern is then tuned to transmit only the desired GPS signals, specific band of a cellphone spectrum, Wi-Fi, and Bluetooth frequency ranges. Let's assume that the frequency-domain study is performed between 1 and 3 GHz.

A plot of the computed S-parameters *(Fig. 4)* shows the bandpass character around GPS, Wi-Fi, Bluetooth, and partial cellphone bands for UMTS and LTE. The frequency-selective-surface curtain permits the signals in these frequency bands to pass through while reflecting electromagnetic waves for other undesired frequencies.

This simulation prototype demonstrates the feasibility of utilizing a frequency-selective-surface fabric in a living space. There's plenty of room for improvement, especially with respect to shielding in other frequency bands, which isn't addressed in this prototype model.

At each frequency band of interest, a certain part of the conductive pattern acts like a resonator. A resonant part is shown in visualizations as an electrically "hot area" in terms of the electric-field magnitude *(Fig. 5)*. Once identified, such an area of the design can be further tuned to enhance the frequency-spectra performance. In addition, the model can be extended for obliquely incident waves as well as for warped fabrics.

5. Shown is the electric-field distribution on the unit cell of the frequency-selective surface at 1.9 GHz.

AUTHOR'S NOTE: During my career as a simulation engineer, I long held this idea about modeling a frequency-selective-surface fabric, but it wasn't realized until I had a chance to visit India. Before traveling to India for the COMSOL Conference and other presentations, I visited several famous cultural heritage sites. In the end, it was an Indian trellis pattern that inspired the frequency-selective-surface model featured in this article.

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SERGEY KOMAROV | Business Development Engineer, TT Electronics

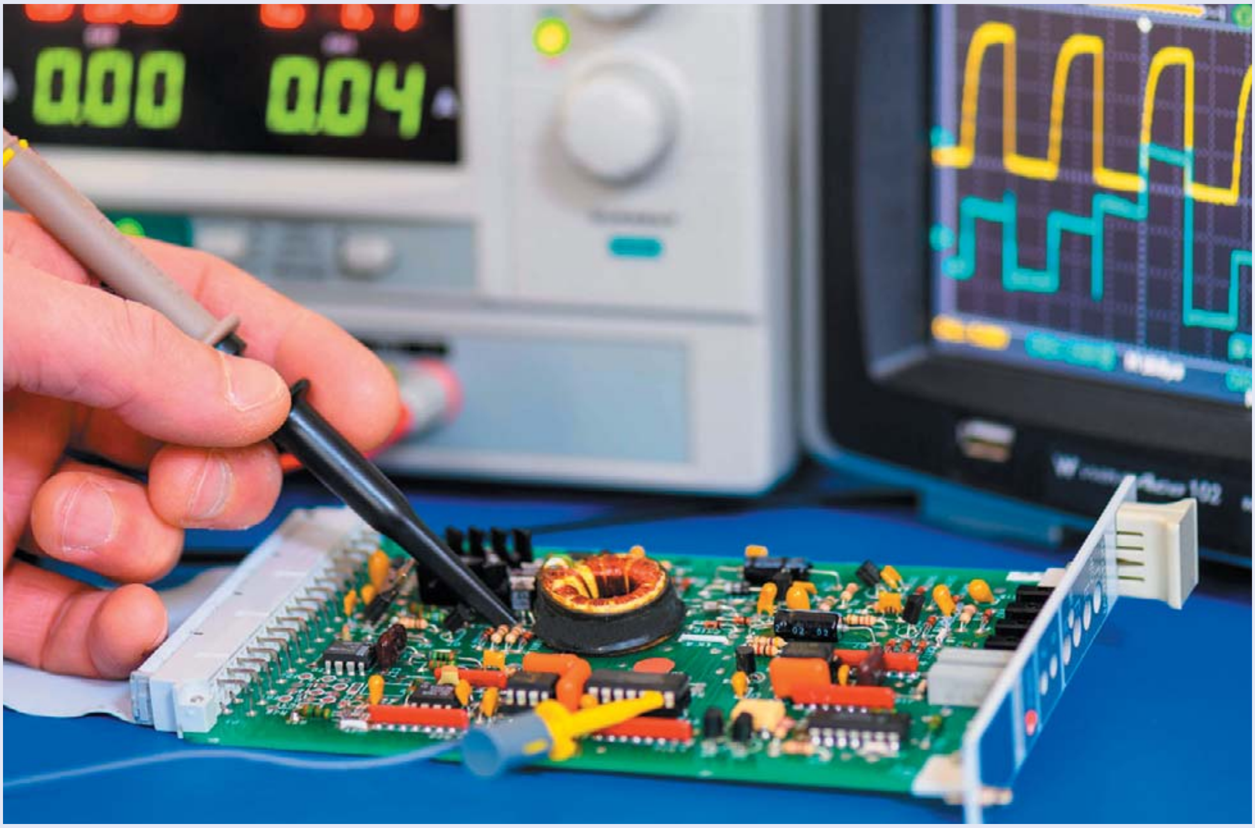
OPTICAL SENSORS:

Apply Reliability Strategies to Drive Smart Component Selection

MTBF/FIT studies provide a framework for determining component-level reliability—a key concern for organizations the world over.

FOR DESIGNERS OF engineered electronics powering our most critical applications and devices, reliability is a common goal. At the same time, a design engineer or purchasing manager must have the ability to quantify reliability of the parts selected—a delicate balance between performance and dependability—to optimize total cost of ownership. On this landscape, a greater understanding of mean time between failure (MTBF) considerations can improve *both* reliability and costs.

Purchasing professionals at such organizations are all too familiar with budgets and the steps required for correlated selection and sourcing. Still, they may have limited insight into how to evaluate reliability reports, how to ensure statistically similar comparison among sources and options, and how these factors may affect their



product design and development. Will a commercial-off-the-shelf (COTS) part suffice, or is S-Level (space-rated) required? Are all parts designated for a particular level the same amongst suppliers? And is MTBF data inherently reported in similar fashion from study to study and vendor to vendor?

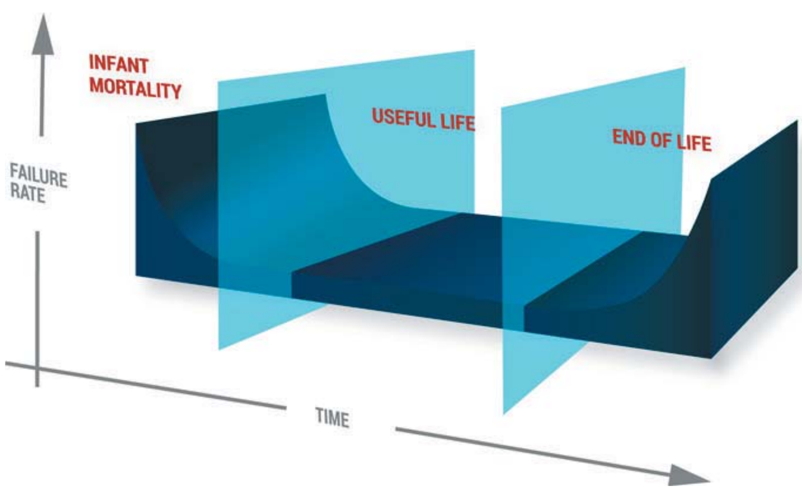
These and other concerns represent deeper intelligence about how MTBF impacts product design, performance, and longevity. By clarifying how reliability data is obtained, measured, calculated, and interpreted, purchasing pros can evaluate options more consistently and successfully.

Screening Levels

TT Electronics

Process	TX	TXV	B	S	ESA
Ball bond	100%	100%	100%	100%	100%
Die/bond shear	Sample	Sample	Sample	Sample	Sample
Pre-cap visual @ 30X	Sample	100%	100%	100%	100%
Pre-cap visual @ 100X	N/A	N/A	N/A	100%	100%
Electrical test	100%	100%	100%	100%	100%
High temp. storage	Optional	Optional	Optional	Optional	100%
Temp. cycle	100%	100%	100%	100%	100%
Constant Acceleration	100%	100%	100%	100%	100%
Visual inspect	N/A	100%	100%	100%	100%
PIND	N/A	N/A	N/A	100%	100%
Fine & gross leak	100%	100%	100%	100%	100%
Sterilization	N/A	N/A	N/A	100%	100%
HTRB	100%	100%	100%	100%	100%
Burn-in & test	100%	100%	100%	100%	100%
X-ray	N/A	N/A	N/A	100%	100%
External visual	100%	100%	100%	100%	100%
Lot Acceptance	Yes	Yes	Yes	Yes	Yes
Group A/B/C/D	Required	Required	Required	Required	Required
Paperwork	Specified	Specified	Specified	Specified	Specified

1. This chart illustrates the broad range of reliability ratings, helping designers environmentally screen their options to meet a design's unique circumstances and facilitate collaboration with their purchasing managers.



2. After screening out "infant mortality" cases, remaining units in a population are expected to function through their useful life and eventually fail due to end-of-life wear out. The period of useful "normal" life is characterized by the lowest (albeit non-zero) rate coupled with relatively constant failure rate.

Defining Key Considerations in MTBF

The universal cross-industry reliability term, often expressed as MTBF, represents a projected number of operating hours before the first failure and between all subsequent failures. FIT (failure in time) is the expected number of failures in one billion hours. FIT is simply another way of reporting MTBF = 1E9/(FIT).

To optimize MTBF and its impact on overall design, the component selection process should answer the following questions:

- What's the optimum level of screening versus cost required for my application? For example, can ideal performance be achieved using parts designated as standard COTS, military (TX, TXV ratings), space (S rating), or a customized version of one of these standard offerings?
- Which stress tests are performed on the selected parts to weed out "infant mortality" cases?
- What is the target MTBF/FIT value?

Purchasers must request reliability reports from all potential suppliers and compare not just the MTBF/FIT values, but also the total operating hours, which are based on test conditions (accelerating factors) and number of units used in each study.

MTBF Strategies Feature a Range of Reliability Options

Industrial and commercial electronics that are particularly sensitive to price and time-to-market competition tend to favor COTS components. This is due to their lower price and significantly shorter lead times versus high-reliability (HiRel) alternatives. For the same reasons, buyers in markets such as military, aerospace, and more specifically, space, occasionally choose commercial rather than HiRel parts.

Even though HiRel is more frequently desired due to the performance-critical nature of applications in these mar-

kets, commercial components may still be selected. The MIL-PRF-38535 and MIL-PRF-19500 specifications outline screening requirements and stipulate which validating tests must be applied to microelectronics circuits (ICs) and discrete components, respectively.

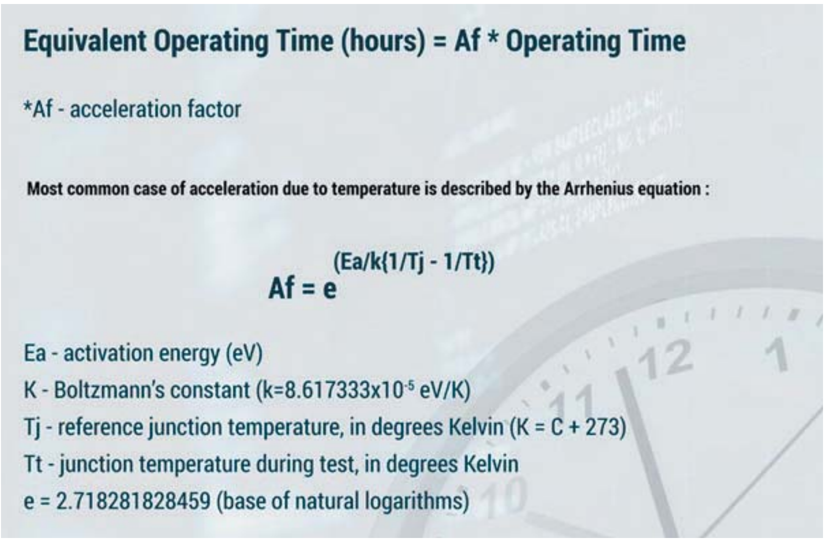
As a result, MIL-PRF-19500 would guide screening tests for LEDs, VCSELs, photodiodes, phototransistors, and photodarlingtons, while photologic sensors, optical encoders, and Hall-effect ICs would be screened using the MIL-PRF-38535 spec. Further, the MIL-STD-883 specification states the actual tests conditions required for class level "B" and level "S" (space) parts *(Fig. 1)*.

The purpose of environmental screening (burn-in, temperature cycling) is to accelerate failures due to latent defects in the "infant mortality" stage of the bathtub curve to screen weak components before they're shipped and assembled into products. Failure analysis (FA) performed on each failing unit identifies the root cause associated with design, process, or material weakness. The goal of all these activities is to drive the dppm (defective parts per million) level to as close to zero as possible.

Once "infant mortality" cases are screened out, the remaining units in population are expected to function through their useful life and eventually fail due to end-of-life wear out. The useful "normal" life period is characterized by the lowest (albeit non-zero) rate and relatively constant failure rate *(Fig. 2)*.

All parts operating in the intended application could be considered an ongoing MTBF/FIT study. Obviously, it's not practical to let all manufactured parts operate for indefinite periods of time to observe the *actual* FIT rate. But, by applying accelerated stress conditions (heat, humidity, temperature cycling, vibration, load, and others) on a statistically significant sample size (usually more than 100 parts), the experiment time could be substantially shortened to expediently obtain MTBF/FIT values.

Comparing MTBF/FIT values from different suppliers for similar components without knowing actual study conditions could be misleading. Statistical by nature,



3. MTBF varies with operating conditions. Instead of performing separate MTBF studies for each stress level (i.e., different temperature), substitute actual Operating Time with Equivalent Operating Time, which is calculated based on the various well-known life acceleration factors for different stress conditions.

4. TT's OPB350 is used in medical applications such as a hemodialysis system.

The purpose of environmental screening (burn-in, temperature cycling) is to accelerate failures due to latent defects in the "infant mortality" stage of the bathtub curve to screen weak components before they're shipped and assembled into products.

Stress Results

TT Electronics

Test	Samples	Test Conditions	Total Device Hours	Failures
High temperature operating life	300	T_A @ 70°C, I_F @ 34 mA, V_{CE} @ 22.5 V	302,400	0

Projected product life of OPB350, operated at 20 mA and 5 V DC

Ambient Temperature	60% Confidence		90% Confidence	
	MTBF	FIT	MTBF	FIT
(°C)	(hours)	(per 10^9 Hours)	(hours)	(per 10^9 Hours)
70	521,178	1,919	208,019	4,807
60	840,880	1,189	334,622	2,980
50	1,380,554	724	551,024	1,815
40	2,312,440	432	922,970	1,083
30	2,964,194	252	1,582,238	632
20	6,981,063	143	2,786,368	359

5. This table reveals the stress results for TT's OPB350 tube liquid sensor.

MTBF/FIT values vary greatly with the number of samples used and the length of time these parts have been in operation.

To hit the target, the manufacturer must understand the customer's minimum required MTBF value prior to designing their MTBF study. A larger study sample size and a longer operating time would produce higher a MTBF value with all other parameters being equal, including stress test conditions and number of failures. To provide an "apples to apples" comparison, the reliability report must include the number of units and hours of operation under specific test condition; these could be unified under a single term: "Total Device Hours."

Total Device Hours is simply the number of parts used in MTBF/FIT study multiplied by their Operating Time:

*Total Device Hours = Number of units in a study * Operating Time (hours)*

Under different operating conditions, the MTBF value would change. But rather than performing a separate MTBF study for each stress level (such as different temperature), we can simply substitute actual Operating Time with Equivalent Operating Time, a calculation based on the well-known life acceleration factors for different stress conditions *(Fig. 3)*.

For example, the reliability study for TT Electronics' OPB350 (a tube liquid sensor for medical applications including hemodialysis) used 300 units operating at

70°C for 1008 hours, resulting in 302,400 Total Device Hours *(Fig. 4)*.

From the results presented in *Figure 5*, the worst-case scenario for MTBF is 208,019 hours or 23.7 years with the device operating at 70°C with 90% confidence.

A claim of 90% confidence means virtual certainty, while 60% corresponds to a lower degree of certainty and higher uncertainty. Evaluation of MTBF at 90% confidence is recommended, understanding that the difference between two MTBF values at 90% and 60% confidence provides appreciation for the deployed performance time range.

For MTBF = 208,019, we can calculate FIT = 1E9/MTBF = 4,807 failures in one billion hours.

The accelerated life test performed for 1,008 hours of actual Operating Time at 70°C (158°F) corresponds to much longer Equivalent Operating Time at lower temperatures, resulting in significantly larger MTBF values at those temperatures. Using the Arrhenius relationship to determine Equivalent Operating Time at 20°C (68°F), the MTBF value with 90% confidence is 2,786,368 or 318 years (up to 797 years with 60% confidence), which is well outside the intended operating life of the device.

Create Synergy Between Design and Purchasing

MTBF/FIT studies provide a framework for determining component-level reliability, but not all component manufacturers offer this data. To rest assured that your design is based on reliable components that will perform for the long haul, it's critical to obtain and understand an MTBF/FIT study for each part sourced. From discrete components and slotted switches to reflective sensors and Hall-effect ICs, reliability studies give you the upper hand and competitive advantage.

Knowing the optimum screening level versus cost required for your application is step one—standard COTS, military, space, or a customized version of one of these options. Step two involves determining which stress tests to conduct to eliminate infant mortality cases; be sure this is validated by accelerated testing on a statistically significant sample. And finally, by requesting reliability reports from all potential suppliers, you can readily compare values for MTBF/FIT and Total Operating Hours; keep in mind these can vary and must be supported with insight into actual study conditions.

With such valuable data in hand, design engineers and purchasing managers can be on the same page when selecting the right components for performance and longevity.

Monolithic Amplifier Die Delivers Flat Gain from DC to 50 GHz

Mini-Circuits' model LTA-M1109-D+ is a broadband monolithic distributed amplifier die with flat gain and a low noise figure from dc to 50 GHz. When biased at +5 V dc and 160 mA, the tiny chip amplifier is capable of 17.3 dB gain at 100 MHz, 16.1 dB gain at 20 GHz, 17.4 dB at 30 GHz, and 17.4 dB at 40 GHz. With better than ±2.2-dB gain flatness from 0.1 to 40.0 GHz and a wide bandwidth extending to 50 GHz, the distributed amplifier die is ideal for 5G networks, commercial and military radios, and instrumentation applications. The typical noise figure is 3.1 dB at 10 GHz, 4.0 dBm at 20 GHz, 5.5 dB at 30 GHz, 7.8 dB at 40 GHz, and 11.8 dB at 50 GHz. The typical output power at 1-dB compression is +20.0 dBm at 10 GHz, +19.3 dBm at 20 GHz, +17.9 dBm at 30 GHz, and +17.0 dBm at 40 GHz. Based on pseudomorphic high-electron-mobility-transistor (pHEMT) semiconductor technology, the RoHS-compliant amplifier is well matched to 50 Ω and designed for maximum operating voltage of +7.5 V dc and maximum RF input power of +17 dBm. It has an operating temperature range of -40 to +85°C.

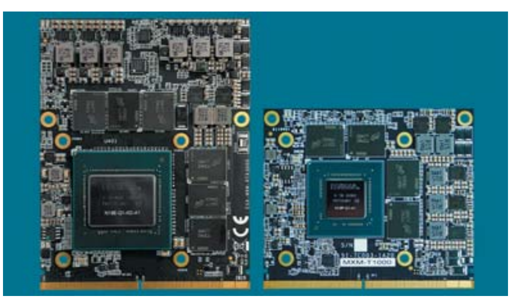
MINI-CIRCUITS, www.minicircuits.com

Ultrasonic Sensors Offered in a Range of Tx/Rx Options

CUI Devices recently announced the addition of new ultrasonic sensors to its product portfolio, which are offered with a range of transmitters, receivers, and transceivers with analog outputs. The analog sensors feature distance ratings from 0.2 up to 18 meters and beam angles of 75° or 80°. The sensor models are also housed in compact aluminum or plastic cases with through-hole mounting styles, making them easy to fit into many designs. The sensors provide carrying-frequency ratings from 23 to 40 kHz, peak-to-peak voltage ratings from 80 to 180 V, and operating temperature ranges from -30° up to 85°C. The sensors can handle sound pressure levels from 105 to 115 dB and sensitivity ratings from -75 to -68 dBV.

CUI DEVICES, www.cuidevices.com

Machine-Vision Modules Target Smart Factories



Cincoze has expanded its GM-1000 machine-vision module lineup with a pair of Quadro MXM GPU boards. The new MXM-RTX3000 and MXM-T1000 pack the additional GPU capacity for rapid adoption of machine vision in smart factories, which engender environmental-perception applications such as positioning, measurement, identification, and more. Both MXM GPU modules use the NVIDIA Quadro Turing GPU architecture based on the latest 12-nm process technology. The MXM-RTX3000 packs 1920 CUDA cores, 5.3 TFLOPS peak FP32 high-end computing power, parallel integer execution, AI-computing Tensor core, and specialized RT cores for ray tracing. The MXM-T1000 offers 896 CUDA cores and 2.6 TFLOPS peak FP32 computing power while consuming only 50 W for power-conscious, high-speed computing. Both models support GDDR6 memory, with the MXM-RTX3000 featuring a single card capacity of up to 6 GB and 336-GB/s memory bandwidth, while the MXM-T1000 has 4-GB capacity and 192-GB/s memory bandwidth. Both modules also have different form factors, with the MXM-RTX3000 sporting an MXM 3.1 Type B form factor, while the MXM-T1000 has a Type A form factor.

CINCOZE, www.cincoze.com

Active Noise-Cancelling Sensors Reduce Driver Fatigue

Molex's new accelerometer-based road noise-cancelling (RNC) sensor reduces low-frequency sounds that increase driver fatigue for safer driving. Instead of installing sound-absorbing insulation materials in vehicles for excessive noise, the sensor can be installed in-chassis for accurate and efficient active noise cancellation (ANC). Molex's series of ANC accelerometer and microphone sensors use Analog Devices' Automotive Audio Bus (A2B) technology, allowing the sensors to capture and isolate soundwaves, reducing road-based and engine noise. That noise is isolated through a vehicle's suspension, which provides optimal cancel timing.

MOLEX, www.molex.com/molex/products/family/road_noise_cancellation_sensors

BLE SoC Facilitates Efficient Indoor Asset-Tracking Design

ON Semiconductor has added Quuppa's Intelligent Locating System to its RLS 10 Radio SoC, which allows manufacturers to design ultra-low-power indoor asset-tracking applications with direction-finding features and advanced angle-of-arrival (AoA) technology. The Quuppa ILS is a platform for location-based services and applications and utilizes positioning algorithms to enable real-time tracking of tags and devices with centimeter-level accuracy. The RLS 10 takes advantage of that technology to garner positioning updates up to 50 times per second. The radio SoC offers the Eclipse-based ON Semiconductor IDE plus support for Keil µVision and IAR Embedded Workbench, packs a complete BLE protocol stack, and offers mesh networking with an iOS app.

ON SEMICONDUCTOR, www.onsemi.com

Microwave and RF Antennas Handle Satcom Testing

Atlantic Microwave has launched a series of microwave and RF antennas for satcom testing and measurement. The range includes horn, patch, and spiral antennas that can transmit signals at frequencies that range from 0.5 GHz up to 40 GHz. These antennas are ideal for applications where cabling testing and signal distribution are not practical or possible with cable or fiber. The new antenna range coincides with the ever-increasing demand for connectivity in all areas, including land, sea, and air.

ATLANTIC MICROWAVE, www.atlanticmicrowave.com/catalogue/rf-components/antennas

Waveguide Components Boost RF Performance

Fairview Microwave now offers a line of double-ridge waveguide components designed for radar, wireless and satellite communications, and test and instrumentation. The new line features 28 models with straight sections, bends, and twist configurations. The transmission-line components take advantage of broader frequency bands, deliver increased RF performance, and offer lower cut-off frequencies than conventional rectangular waveguides. Additionally, double-ridge waveguide-to-coax adapters are available in WRD-180, WRD-650, and WRD-750 waveguide sizes. They also feature SMA, N-type and 2.92mm connectors, UG-style square cover flanges, and typical VSWR performance down to 1.5:1.

FAIRVIEW MICROWAVE, www.fairviewmicrowave.com/rf-products/double-ridge-waveguide-components.html

Module Powers CCP Measurement Microphones

GRAS Sound & Vibration has introduced its GRAS 12BA and 12BB microphone power modules. The devices are designed for engineers who need to power constant-current-power (CCP) measurement microphones with seamless integration of sensitivity data via Transducer Electronic Data Sheet (TEDS). The single-channel (12BA) and four-channel (12BB) USB-powered modules offer integrated TEDS support and are ideal for production test applications, saving time during setup and configuration. The power modules can be used with any audio analyzer, with TEDS data accessed in two ways: When paired with Audio Precision's APx audio analyzers, TEDS can be read directly via the APx500 software; for use with other analyzers, TEDS data is available through the Mic Power Module App with a command-line interface for data output.

GRAS SOUND & VIBRATION, www.grasacoustics.com

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