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Editorial

DAVID MALINIAK | Editor
dmaliniak@endeavorb2b.com

COPING *with the* PANDEMIC

I live in northern New Jersey, not far from the coronavirus epicenter of New York City, where the pandemic has taken its toll on my, and my family's, daily life. We've become hermits, venturing outdoors only for dog walks and studiously avoiding neighbors when we do. We rely on online shopping and grocery delivery services to further minimize interaction with others. As of now, we remain free of COVID-19, and for this, we thank God.

Our inconveniences are trivial compared to those who have been infected, not to mention the rapidly growing numbers of families who have suffered loss at the hands of this destructive disease. Sadly, things will get much worse before they even begin to improve. All of us at *Microwaves & RF* hope all of you are as well as can be and doing right by yourselves and everyone else by staying home.

The pandemic has wreaked havoc with pretty much everything, including the high-technology business at large and the wireless industry subset. According to ABI Research, the pandemic has forced a delay in the crucial standardization work that would make 5G available for enterprise use cases. The relevant standardization body, 3GPP, formally announced a deferral of this standardization until at least June 2020, which would delay commercial rollout of industrial 5G until at least 2022.

Given that most industrial enterprises are looking to upgrade their communication technology in 2021, such a delay will result in 5G missing out on at least 25% of the revenue opportunities within those enterprises. And, in turn, it will push the rollout of 5G into warehouses, shipping ports, and factory floors until at least 2022.

Back in 2003, when the SARS virus appeared in China, the Chinese economy accounted for just 4% of global GDP. Today, it's about 16%. China still is reeling from its ravaging by the coronavirus, but with the rest of the planet so heavily dependent on its manufacturing capacity, the global supply chain can't help but feel the impact. According to the procurement and supply-chain consultants at GEP, exports of electronic components from China to North America have declined by more than 50%.

As a result (again, says GEP), we can expect the global technology industry to see massive disruptions caused by the coronavirus's impact on production from China. It might not be an immediate effect, but we can be sure that it'll be felt in the coming months—just in time for the launches of major consumer technology products in the second half of 2020. Buckle up, things could get, uh, interesting. mw

Microwaves&RF **APRIL 2020**

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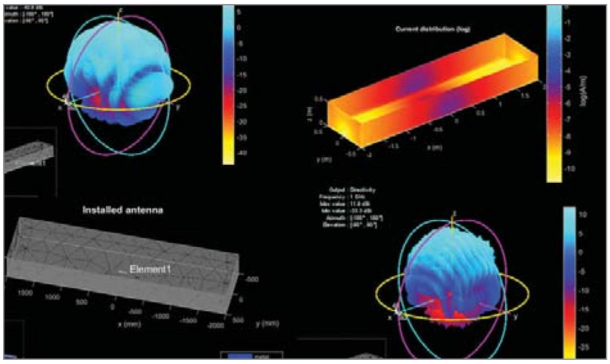

Modeling Antennas Installed in the Presence of Large Platforms

This "Algorithms to Antennas" blog describes a workflow you can use to model antennas that are mounted in the presence of platforms or structures.

https://www.mwrf.com/technologies/systems/article/21126457/algorithms-to-antenna-modeling-antennas-installed-in-the-presence-of-large-platforms

Take the Proper Steps to Flight-Test-Instrumentation Design

Real-time monitoring during test flights demands FTI equipment that provides highly accurate, comprehensive data, which means that engineers adhere to specific design parameters.

https://www.mwrf.com/technologies/test-measurement/article/21122981/take-the-proper-steps-to-flighttestinstrumentation-design

Advanced EMI Filters Cut Costs on Brush DC Motors

EMC requirements are driving up the cost of low-priced, but noisy, brush dc motors. Monolithic EMI filters reverse this trend.

https://www.mwrf.com/technologies/components/article/21123268/advanced-emi-filters-cut-costs-on-brush-dc-motors

Non-Destructive Analysis of TO-247 Structural Defects

The TO-247 is a popular electronic form factor, so doing non-destructive analysis of possible structural defects could come in handy during the design process.

https://www.mwrf.com/technologies/test-measurement/article/21125208/nondestructive-analysis-of-to247-structural-defects

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News

New Technologies Critical for SUPERIOR WEAPONS SYSTEMS

Forecasts at market research firm Frost & Sullivan point to an estimated $481 billion in spending by the U.S. Department of Defense (DoD) between 2018 and 2024 on technology development for new weapons systems. The spending projections are part of Frost & Sullivan's latest research, "US Defense Science and Technology Research Market, Forecast to 2024" (part of the firm's Aerospace and Defense Growth Partnership Service program). The study offers an overview of the science and technology (S&T) research market focused on the U.S. Armed Forces and the types of opportunities for companies serving those markets.

Referring to the DoD budget for fiscal year 2021, John Hernandez, senior industry analyst at Frost & Sullivan, explains: "According to the most recent defense budget, combined spending on research, development, testing and evaluation (RDT&E) for over 1,100 programs by defense-wide organizations is estimated to reach $106.56 billion. This wide variety of projects provides opportunities for many commercial markets to collaborate with the DoD."

As is typically the case, technological developments in military markets will eventually impact commercial markets as well, and developments in autonomous vehicles, artificial intelligence (AI) and robotics for military applications are expected to quickly make their way to the commercial sectors. "Most concepts being explored by the Armed Forces will have an impact in commercial market spaces as well," noted Hernandez. "Companies working with the DoD on RDT&E development programs will have an advantage toward the development of parallel commercial solutions."

Robotics and unmanned vehicles represent strong market areas for companies prepared to support the U.S. Armed Forces with advanced technologies. *(Courtesy: Frost & Sullivan)*

Frost & Sullivan advises companies working across the commercial and military markets to remain open to commercial-off-the-shelf (COTS) solutions in hardware and software for military customers. At the same time, those companies must make strong investments in their own R&D efforts in order to develop unique and timely solutions. Some of the technologies needed for future defense systems include robotics, AI and machine learning, as well as secure battlefield communications systems, and these technologies will be needed in extremely integrated form to serve the warfighter. ■

DSP ARCHITECTURE TARGETS 5G Endpoints and Radio Access Networks

CEVA'S NEW GEN4 CEVA-XC DSP ARCHITECTURE unifies the principles of scalar and vector processing in a powerful architecture, enabling two-times 8-way VLIW and up to 14,000 bits of data-level parallelism. It incorporates an advanced, deep pipeline architecture enabling operating speeds of 1.8 GHz at a 7-nm process node using a unique physical design architecture for a fully synthesizable design flow, and an innovative multithreading design. This allows the processors to be dynamically reconfigured as either a wide SIMD machine or divided into smaller simultaneous SIMD threads. The Gen4 CEVA-XC architecture also features a novel memory subsystem, using 2048-bit memory bandwidth, with coherent, tightly coupled memory to support efficient simultaneous multithreading and memory access.

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CEVA's Gen4 CEVA-XC DSP architecture handles highly complex parallel processing workloads required for 5G endpoints and Radio Access Networks (RAN), enterprise access points, and other multi-gigabit low-latency applications.

The first processor based on the Gen4 CEVA-XC architecture is the multicore CEVA-XC16, touted as the fastest DSP ever made. It is targeted for the rapid deployment of different form factors of 5G RAN architectures including Open RAN (O-RAN) and baseband-unit (BBU) aggregation as well as Wi-Fi and 5G enterprise access points. The CEVA-XC16 is also applicable to massive signal processing and AI workloads associated with base station operation.

The CEVA-XC16 has been specifically architected with the latest 3GPP release specifications in mind, building on the company's extensive experience partnering with leading wireless infrastructure vendors for their cellular infrastructure ASICs. The previous-generation CEVA-XC4500 and CEVA-XC12 DSPs power 4G and 5G cellular networks today, and the new CEVA-XC16 is already in design with a leading wireless vendor for its next-generation 5G ASIC.

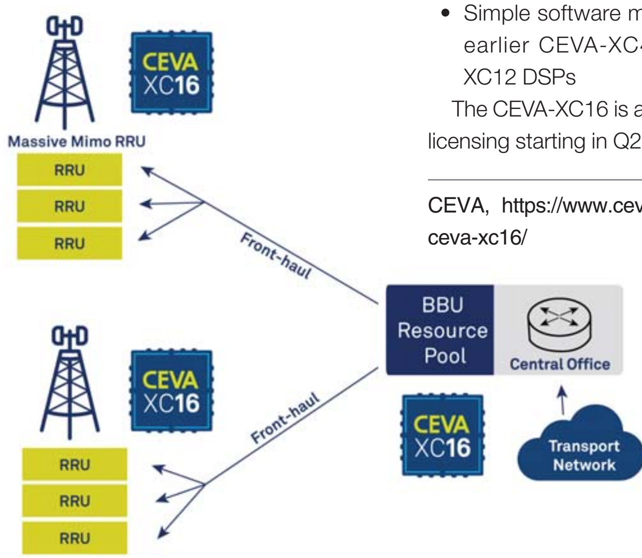
The CEVA-XC16 offers high parallelism of up to 1,600 GOPS (gigaoperations per second) that can be reconfigured as two separate parallel threads. These can run simultaneously, sharing their L1 data memory with cache coherency, which directly improves latency and performance efficiency for PHY control processing, without the need for an additional CPU. These new concepts boost the performance per square millimeter by 50% compared to a single-core/single-thread architecture when massive numbers of users are connected in a crowded area. This amounts to 35% die area savings for a large cluster of cores, as is typical for custom 5G base station silicon.

Other key features of the CEVA-XC16 include:

- Latest-generation dual CEVA-BX scalar processor units, which enable true simultaneous multithreading
- Dynamic allocation of vector units resources to processing threads, which facilitates optimal vector unit resource utilization and reduced overhead of complex flows
- Advanced scalar control architecture and tools, with 30% code size reduction from previous generations, using latest dynamic branch prediction and loop optimizations, and an LLVM based compiler
- New instruction-set architectures for FFT and FIR, resulting in 2X performance improvement
- Enhanced multiuser capabilities supporting massive bandwidth allocation of single-user as well as fine-granularity user allocations
- Simple software migration path from earlier CEVA-XC4500 and CEVA-XC12 DSPs

The CEVA-XC16 is available for general licensing starting in Q2 2020. ■

CEVA, https://www.ceva-dsp.com/product/ceva-xc16/

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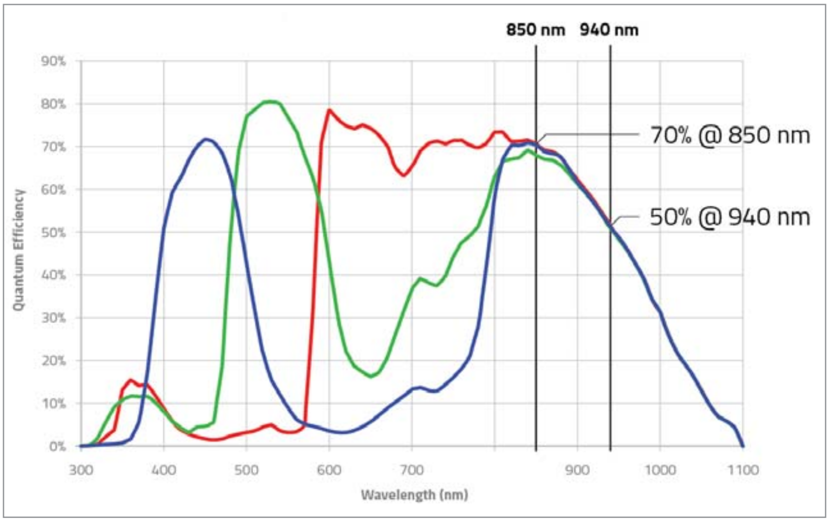
NEAR-INFRARED SENSOR TECHNOLOGY Shines in Low/No-Light Conditions Requirements



IN THE SECOND GENERATION of its near-infrared (NIR) technology for image sensors that operate in low to no ambient light conditions, OmniVision Technologies offers silicon semiconductor architectures and processes that have hit new heights in quantum efficiency. The Nyxel 2 technology provides a 25% improvement over the preceding generation in the invisible 940-nm NIR light spectrum and a 17% bump at the barely visible 850-nm NIR wavelength.

These sensitivity improvements enable image sensors to see even better and farther under the same amount of light, further extending the image detection range. Nyxel 2-based camera systems also require fewer LED lights, thus reducing overall power consumption and extending battery life. These added benefits make Nyxel 2 a good candidate technology for surveillance systems, automotive in-cabin driving monitoring systems, and the burgeoning under-display sensors in mobile devices.

Machine and night vision camera applications rely on NIR technology because NIR light illuminates objects with wavelengths outside the visible spectrum, avoiding any interference with the surrounding environment. Additionally, because the night sky contains more NIR photons than visible photons, greater NIR sensitivity allows for higher-resolution image capture with fewer power-hungry LEDs, which is highly desirable for battery-powered and night vision security camera applications. Earlier NIR detection approaches fell short of the performance requirements for next-generation mobile and AR/VR products with embedded machine vision applications, as well as automotive and security cameras that require higher NIR sensitivity.

OmniVision's first image sensors with Nyxel 2 technology are expected to be available during the second half of 2020.

Competing CMOS approaches for NIR image sensing continue to rely solely on thick silicon to improve NIR sensitivity. However, this results in crosstalk and reduces the modulation transfer function (MTF). Attempts to overcome this by introducing deep-trench isolation (DTI) often lead to defects that corrupt the dark area of the image. With Nyxel 2, OmniVision has refined its approach to NIR imaging that combines thick-silicon pixel architectures with careful management of wafer surface texture to improve quantum efficiency (QE), along with extended DTI to retain the MTF levels of the first generation without affecting the sensor's dark current.

With these refinements, OmniVision's Nyxel 2 achieve 50% QE at 940 nm—a 25% improvement over the first generation, as measured using data from a 2.9-micron pixel. At the 850-nm NIR wavelength, Nyxel 2 can provide 70% QE, which is not only a 17% improvement over the first generation, but it is now on par with the QE levels of top RGB sensors that operate with visible light. The results of these Nyxel 2 technology improvements are even higher image quality, greater image detection range, and further reduction in light source requirements for even lower power consumption and extended battery life.

Nyxel 2's performance improvements provide a range of new possibilities to designers. For surveillance systems, the number of IR LEDs around security camera lenses can be further reduced to save on both cost and power consumption, or the same number can be used to increase the brightness of captures taken in total darkness. For automotive driver-monitoring systems, accuracy can be increased while placing fewer LEDs in harder-to-see places within the cabin. For smartphones, the LEDs can be reduced to aid in the never-ending quest for extended battery life, while squeezing more components into compact form factors that both enable design innovation and reduce BOM costs.

OmniVision's first image sensors with Nyxel 2 technology are expected to be available during the second half of 2020. ■

OMNIVISION TECHNOLOGIES, www.ovt.com

SIGNAL ANALYZER OFFERS 50-GHz Bandwidth, Covers 5G NR Compliance Requirements

SPORTING SUPERIOR PHASE NOISE at higher frequencies, Keysight Technologies' N9021B MXA X-Series signal analyzer provides design validation and manufacturing engineers with superior phase-noise performance at higher frequencies, and includes software that improves workflows while meeting 3GPP 5G New Radio (NR) compliance standards.

Industries from wireless to satellite communications require wider analysis bandwidth to meet demands for higher data throughput. As higher-bandwidth technologies such as 5G NR become mainstream, engineers need tools for design validation and manufacturing that offer the accuracy, speed, and bandwidth to accelerate device development.

Keysight's new signal analyzer offers an enhanced frequency-sweep algorithm for swifter test times. It performs RF and millimeter-wave analysis to address the needs of engineers designing and delivering high-frequency new-generation wireless devices.

The N9021B signal analyzer delivers a number of key capabilities; one of those is taming complex signals by combining real-time spectrum analysis with the company's PathWave 89600 vector signal-analysis software. It also captures measurement expertise and delivers repeatable results with PathWave X-Series measurement applications. Flexibility of test assets are maximized through licensing terms that enable application sharing between X-Series analyzers and PXIe instruments.

Some of the banner specs for the instrument in N9021B MXA X-Series Signal Analyzer offers the following key features:

- Frequency range of 10 Hz to 50 GHz, meeting the specification requirements for both 5G NR FR1 and FR2
- Signal detection with extended analysis bandwidth up to 510 MHz and better than 72-dB spurious-free dynamic range (SFDR)
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Keysight's N9021B MXA X-Series signal analyzer is available now starting at $105,220.00. ■

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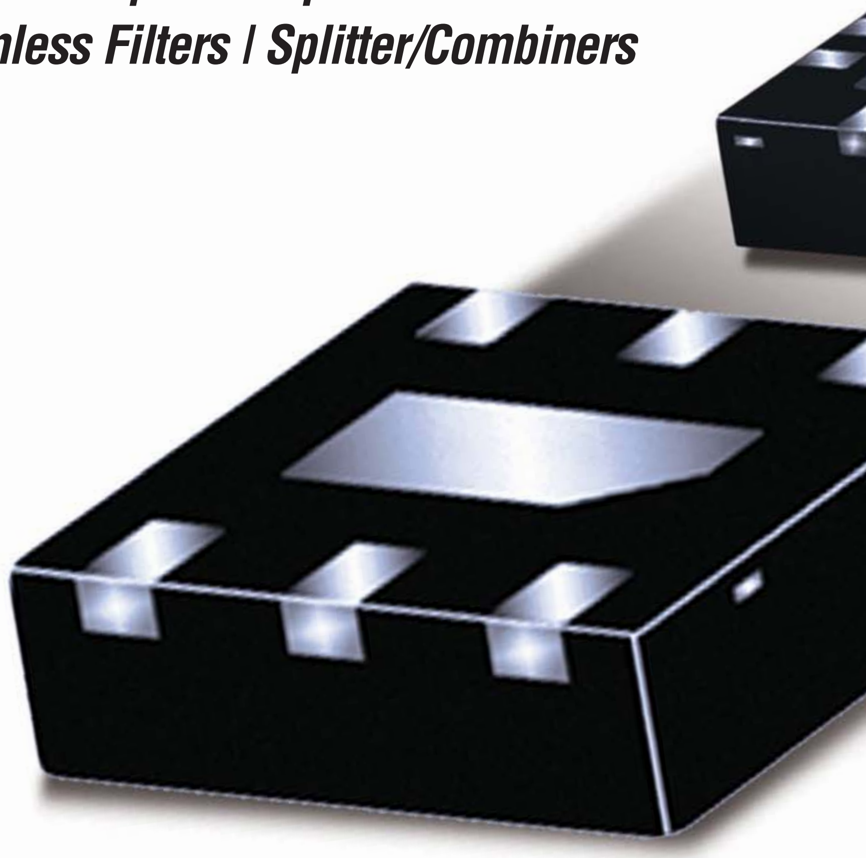

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JACK BROWNE | Technical Contributor

Bump Up Semiconductor Efficiency with GaN

GaN is a semiconductor material that's well-suited for the fabrication of high-power, high-frequency, as well as ultraviolet LED devices.

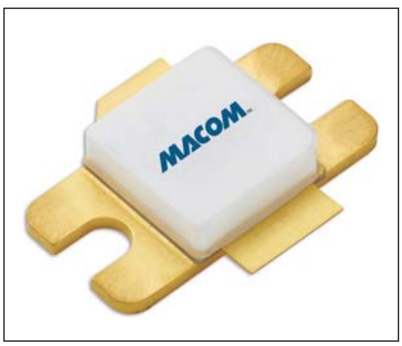
Gallium nitride (GaN) is quickly becoming the semiconductor material of choice for both RF/microwave and higher-wavelength devices. It has long been a semiconductor foundation for light-emitting diodes (LEDs) and has appeared as recently at the 2020 Consumer Electronics Show (CES) as the latest semiconductor technology for home battery chargers. The technology has perhaps its longest history in the RF/microwave industry in high-frequency semiconductor devices, where it serves as the active device replacement for traveling-wave tubes (TWTs) in high-power pulsed radar systems.

With a wide bandgap of 3.4 eV, GaN supports active devices with extremely fast switching speeds and high power levels. It features a large breakdown voltage, supporting highly efficient and compact pulsed amplifiers that achieve high output power levels in relatively small packages. In the simplest terms, GaN is capable of higher power density

1. GaN semiconductor devices for optical and RF/microwave applications are available from a wide range of suppliers, in many forms, from wafer level to packaged devices. *(Courtesy of Wolfspeed, a Cree company)* and efficiency in a smaller package than silicon (Si) or gallium-arsenide (GaAs) semiconductors.

GaN semiconductors have many advantages over legacy high-frequency, high-speed devices such as Si and GaAs. GaN is a binary compound that's formed when one atom of gallium combines with one atom of nitrogen. The resulting material handles higher breakdown voltages and power levels than Si or GaAs, with fewer variations as a result of changes in temperature. In some applications, it can reduce manufacturing costs.

GaN is available to the RF/microwave industry in a wide range of products, from die-level wafers *(Fig. 1)* to rugged high-power packaged microwave amplifiers and transistors *(Fig. 2)*. Increased interest in GaN as a starting point for optical diodes, including anti-bacterial ultraviolet (UV) lights in healthcare applications, expands potential applications for GaN transistors and semiconductor devices in automotive, consumer electronics, defense and aerospace, healthcare, and industrial power systems. GaN transistors serve as the active devices in systems ranging from wireless communications base stations to high-power pulsed military radar.



2. To make mmWave frequency semiconductors more affordable to consumers, GaN devices must be supplied in a variety of low-cost packages, including plastic packages. *(Courtesy of MACOM)*

GaN substrates are not available as a naturally occurring compound. Like GaAs, it's a semiconductor material formed in the laboratory, with properties that make it attractive for use as an electrical semiconductor substrate material. GaN substrates can conduct extremely large voltages relative to their mass, with minimal variations in electrical conductivity as a function of changes in temperature.

The thermal densities of GaN transistors are much higher than those of other semiconductor materials and device types. By creating an effective heat-flow path, such as through the base of a metal-ceramic package, a GaN high electron-mobility transistor (HEMT) can also be relied upon to generate and dissipate large amounts of power as heat. As a result, the device has become attractive to military users to generate the high-power pulsed signals of radar systems, on the ground and in the skies.

Among the problems in generating large power (and the associated heat due to losses) from a small package is the thermal dissipation and need to minimize the effects of heat on circuit performance. In addition to the transistor, the rising temperatures can also impact the performance of the circuit and its surrounding components mounted on the circuits. For that reason, many GaN devices are mounted on silicon (Si), silicon-carbide (SiC), or even silicon-germanium (SiGe) substrates to help draw heat away from the active device regions.

GaN-on-SiC AND GaN-on-Si

As an example, Qorvo *(www.qorvo.com)*, once known as the starting point for many GaAs projects, now also offers GaN-on-SiC foundry services. The firm has served a wide range of customers, from cable-television (CATV) providers to the Defense Advanced Research Projects Administration (DARPA).

Qorvo's model TGA2222, a monolithic GaN amplifier on a chip that provides 10 W output power from 32 to 38 GHz, shows how the company applies the technology to serve an expected need for 5G cellular base stations. It can be used in both pulsed and CW operation, and delivers at least 25-dB small-signal gain over that frequency range when operating at 640-mA quiescent current and 24-V pulsed voltage or 24-V CW voltage. It provides +40-dBm saturated output power over that frequency range. As an indicator of how it will be used at millimeter-wave frequencies, it's well-suited for higher-frequency 5G base stations as well as in military radar systems.

To show the capabilities of its 0.15-µm GaN-on-SiC process, Qorvo recently developed the QPM1021 high-power amplifier device for use at lower frequencies. It's designed for 10 to 12 GHz and can produce 100 W output power with 20-dB large-signal gain and better than 32% power-added efficiency. The device comes in a bolt-down ceramic package to dissipate heat. It's matched at input and output ports to 50 Ω for ease of designing surrounding circuitry.

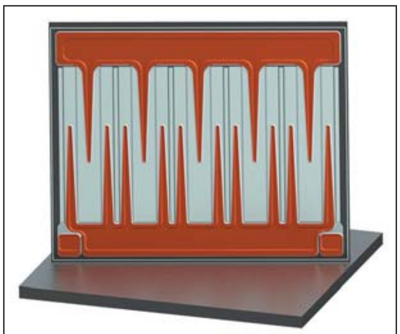
Long-time semiconductor supplier MACOM *(www.macom.com)* offers packaged GaN-on-Si power transistors rather than Si laterally diffused metal-oxide-semiconductor (LDMOS) transistors or GaN-on-SiC transistors. One example of the performance levels available from a GaN-on-Si RF transistor is the model MAPR-001011-850S00. The pulsed power transistor targeting avionics applications maintains rated output power of 850-W pulsed power from 1025 to 1150 MHz (10-µs pulse and 1% duty cycle).

MACOM also supplies the MAGB-107527-270-A0P, a 50-V, 50-W-output GaN monolithic amplifier optimized for wireless cellular base stations and digital predistorted modular signals from 2.5 to

2.7 GHz. It provides better than 12 dB of gain and 44% power-added-efficiency across the full frequency range. Despite its high-power level, the depletion-mode device comes in a compact plastic package.

Microchip Technology (formerly Microsemi) *(www.microsemi.com)* is another company with GaN-on-SiC RF power semiconductors in its arsenal. The devices feature S- and L-band pulsed radar amplifier output stages capable of generating large amounts of power from small packages. For example, model 2729GN-500V is an internally matched GaN-on-SiC packaged transistor well-suited for S-band pulsed radar systems. It's capable of 500 W pulsed output power at 100% pulse width and 10% duty cycle from 2.7 to 2.9 GHz with more than 11 dB gain. The transistor and package are hermetically sealed for protection from the environment.

Wolfspeed, a Cree Co. *(www.wolfspeed.com)*, has been an early supporter of GaN-on-SiC semiconductor technology and is a SiC wafer supplier *(Fig. 3)* to major semiconductor suppliers, including STMicroelectronics *(www.st.com)*. Wolfspeed also markets its own GaN-on-SiC devices, such as the model GTRA384802FC. It's a GaN-on-SiC HEMT in a ceramic package for cellular communications applications.



3. The unique appearance of this GaN transistor is based on Island Technology cell layout technology, which results in a high yield of devices per wafer with high-current capability. *(Courtesy of GaN Systems)*

The single device delivers peak output power of 400 W and 63 W typical average power from 3.6 to 3.8 GHz while working from a +48-V dc supply. It achieves 42% efficiency with 13-dB power gain over the frequency range. With input and output ports matched to 50 Ω, the semiconductor device greatly simplifies the design of amplifier circuitry for multiple-standard cellular base stations.

The model GS66516B is among a number of enhancement-mode GaN-on-Si transistor dice and packaged devices available from GaN Systems *(www.gansystems.com)*. It's supplied in a rugged and compact metal-ceramic package that's based on the company's patented Island Technology cellular layout to achieve high current capabilities with low inductance and low thermal resistance. The device is rated for 60 A and 600 V from drain to source and features a low drain-source capacitance. It's a good fit for battery chargers, power supplies, and power converters. With low junction-to-case thermal resistance, it can dissipate the excess heat generated by high-power applications.

API Technologies *(www.apitech.com)* supplies high-power GaN amplifiers for applications in defense electronic systems. The company details the progress that GaN solid-state devices have made in recent years with a white paper, *"A GaN Solid-State Amplifier Replacement for a 1-kW Traveling Wave Tube."* The paper shows how API's model QBS-609 GaN amplifier can replace a TWT, once considered the single point of possible failure in an airborne radar system. The amplifier measures just under 12 inches in length and is a footprint-fitting replacement for a commercial TWT amplifier, with several amplifier stages in a compact metal housing.

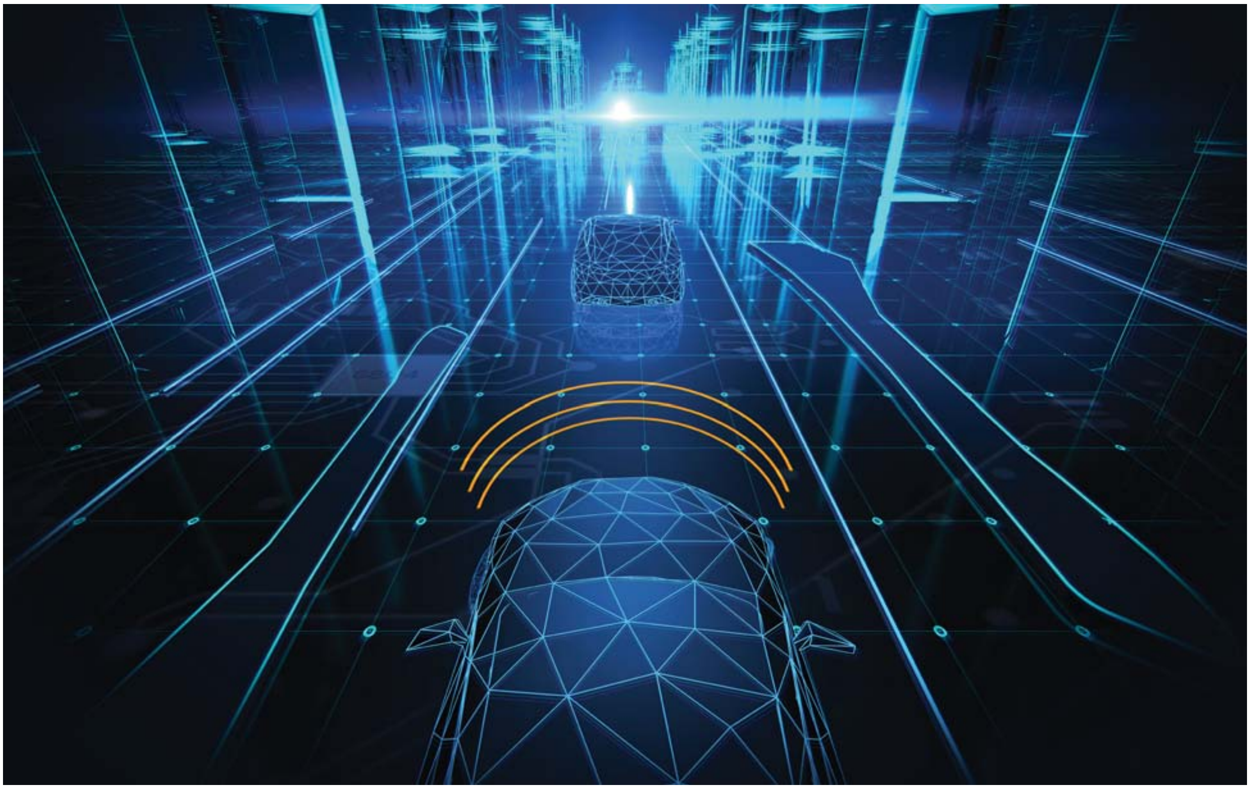
Taking integration somewhat further, NXP *(www.nxp.com)* prepared for 5G wireless communications by launching its multiple-chip power modules with integrated Doherty amplifier and input and output ports matched to 50 Ω. The monolithic multiple-input, multiple-output (MIMO) module, with Si LDMOS power modules plus GaN-on-SiGe predriver modules and receiver modules, operates from 2.3 to 3.8 GHz with output power of 3 to 5 W. The company also supplies active power devices for aerospace and defense as well as for RF energy applications. For example, model AF1C31025GN is an RF GaN power amplifier mounted on a plastic flange-mount package. The device delivers 25 W of pulsed power from 2.4 to 3.1 GHz while operating on +32 V dc.

For those seeking a head start on GaN-based amplifier design, model IGNP3135M500 is an S-band radar amplifier module based on the GaN-on-SiC power semiconductor technology from Integra Technologies *(www.integratech.com)*. It contains most of the amplifier circuitry preassembled and supplied in a compact modular-component package. The amplifier, a base-plate-cooled, pulsed RF GaN device, is designed to provide 500-W pulsed output power across a 400-MHz instantaneous bandwidth from 3.1 to 3.5 GHz. It operates at +50 V dc, achieves 50% efficiency, and can be supplied with input and output connectors as well as optional internal circuitry to monitor temperature and operating power levels (input, output, and reflected power).

If it's transistor building blocks you're looking for, the company stocks GaN-on-SiC power devices as well as legacy Si LDMOS devices. For example, for higher-frequency C-band radar systems, Integra Technologies has packaged power GaN-on-SiC transistors such as the model IGT5259CW25, which is matched to 50 Ω at input and output ports. It's capable of 25-W CW output power from 5.2 to 5.9 GHz with 12-dB typical gain and 45% power-added efficiency when operating from a +36-V dc supply.

(Continued on page 45)

MICHAEL S. GODWIN | Director, Visible LEDs, Osram Opto Semiconductors Inc.



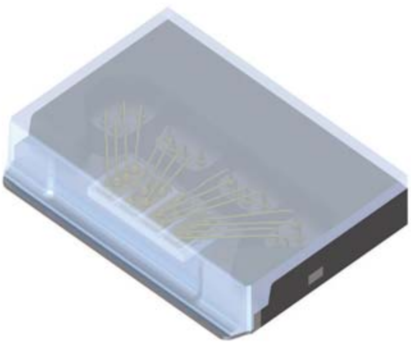
How Does High-Power SMT Help Improve LiDAR?

Osram's Michael Godwin explains the ways in which infrared high-power SMT components for LiDAR applications help systems developers meet complex safety requirements in semi-autonomous vehicles.

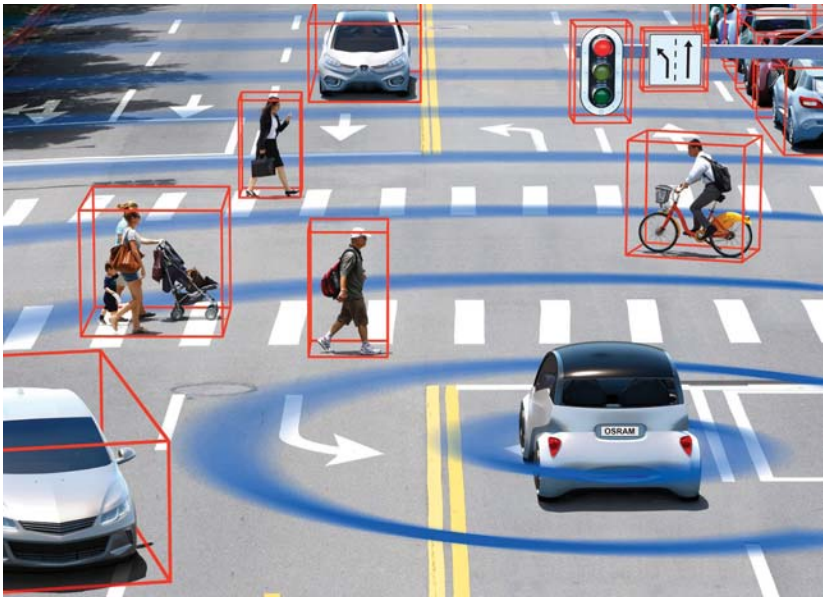
High-performance, surface-mount-technology (SMT) LEDs are critical to applications like automotive LiDAR. I recently had a chance to talk with Osram's Director of Visible LEDs, Michael Godwin.

Efficiency droop has been an issue for LEDs in the past. Wouldn't that diminish LiDAR performance?

Efficiency droop is related to blue LEDs used in visible light. The components used in LiDAR and advanced driver-assistance systems (ADAS) applications are infrared (invisible) photonics solutions. Osram produces lasers for LiDAR systems. We also offer infrared LEDs (IREDs), vertical cavity surface emitting lasers (VCSELs), or edge emitting lasers (EELs) for various driver assistant systems such as driver monitoring, gesture control, and facial recognition.



1. The SPL S4L90A_3 A01 four-channel laser is the new flagship in Osram's LiDAR laser portfolio. *(Courtesy of Osram)*



2. Multichip solutions enable even higher resolutions for the system and thus better measurement signals for the autonomous vehicle. *(Courtesy of Osram)*

What photonics technology does Osram have for the LiDAR market?

The latest addition to Osram's photonics portfolio for LiDAR applications are two new high-power SMT lasers *(Fig. 1)* including the single-channel SPL S1L90A_3 A01 and four-channel device SPL S4L90A_3 A01. With the world's first AEC-Q102-qualified four-channel and single-channel pulse laser, system developers can now choose from an even greater variety of infrared components from Osram. The two new products offer performance of 125 W per channel and an efficiency of up to 33%.

How do Osram's new two new infrared high-power SMT components for LiDAR applications help system developers?

The two new SMT lasers offer ease of use for the customer in their system integration because of their higher power and extended duty cycle range of up to 0.2%, allowing their customers to reach a longer detection range in the application and better resolution. Additionally, eye-safe system designs can be achieved with these high-power 905-nm products. With its sophisticated package design, the new SMTs also enable short pulse widths of around 2 ns.

Tell me a little more about Osram's photonics portfolio.

Osram is evolving into a high-tech champion of photonics. Our high-quality LEDs are used for visualization in many automotive applications such as the Osire E4633i that provides uniform color rendering across the entire color space and in dynamic light cases. Osram is also developing the second generation of Eviyos, the world's first hybrid LED with more than 25,000 pixels on a single LED. Eviyos, with its multifunctional, intelligently controllable headlamps, does more than just illuminate road ahead; it also projects HD-quality images on the ground to communicate with pedestrians and passengers.

Another great demonstration of our automotive photonics expertise is the Rinspeed microSNAP vehicle. The concept car features Osram's infrared components for 3D facial recognition, iris scanning and gesture control, and passenger monitoring that scans the interior for forgotten objects after a rider leaves the vehicle. Our technological possibilities seem virtually endless.

Why are requirements for safety systems in semi-autonomous vehicles so complex?

The requirements for safety systems in semi-autonomous vehicles are complex. They must be reliable, work in all lighting and weather conditions, and identify potential hazards and obstacles in time to take appropriate driving decisions. There is now widespread agreement that only a combination of LiDAR, camera, and radar is able to fulfill autonomous driving requirements.

How do your infrared high-power SMT components for LiDAR applications help systems developers meet these safety requirements?

A central aspect in terms of safety is the range of the used infrared light source. A powerful laser is required to be able to look as far ahead as possible. Both products showcase an output power of 125 W, 40 A per channel. Thanks to its particularly low thermal resistance of only 30K/W for the single-channel SPL S1L90A_3 A01 and 17K/W for the four-channel SPL S4L90A_3 A01, heat is easily dissipated from the component—even at high currents. Osram introduced the first 905-nm laser to the market more than 10 years ago. Today it's the most commonly used wavelength in LiDAR solutions. For instance, the 905 nm has a significant advantage compared to 1550-nm wavelength solutions, especially in terms of total system costs.

What types of applications can these new components enable?

The new components are for the LiDAR applications primarily used in autonomous driving. LiDAR can also be used in a number of other applications where 3D imaging is needed, such as agriculture, building construction, and environmental assessment *(Fig. 2)*. mw

Design Feature

BRYCE JOHNSTONE | Director of Automotive Segment Marketing, Imagination Technologies

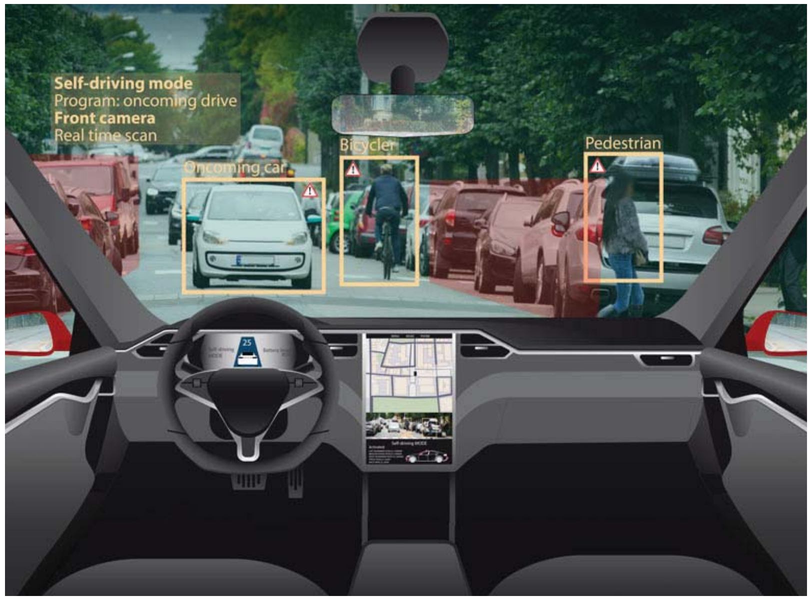
GPUs and Virtualization Boost Performance for ADAS Platforms

Rapidly advancing autonomous/ADAS technologies require more powerful GPUs to handle the load. To help mitigate costs on this front, designers are turning to virtualized GPUs to perform multiple tasks.

Over the course of decades, the graphics processing unit (GPU) has evolved from its origins as a video display adapter in arcade games to a computing powerhouse that drives artificial intelligence and machine learning, accelerating computational workloads in a wide array of fields from oil and gas exploration to natural language processing. Specifically, GPUs play an increasingly critical role in the fast-evolving technologies for autonomous driving and advanced driver-assistance systems (ADAS).

How did the GPU find its way from the video arcade to the cutting edge of scientific research and self-driving cars?

The GPU's rise as the go-to processor for Big Data workloads is due to some basic architectural differences between the traditional central processing unit (CPU) and the GPU. The GPU is a specialized type of microprocessor, originally designed for rendering visual effects and sophisticated 3D graphics for gaming, which requires intense computing power to display real-time action. To deliver that capacity, a GPU uses thousands of small and efficient cores to deliver a massively parallel architecture that can handle the processing of vast amounts of data simultaneously.



In contrast, a typical CPU consists of just few cores with abundant cache memory and is usually designed to process only a few software threads at a time. CPUs are optimized for sequential serial processing, which is sufficient for most general-purpose computing workloads. However, when it comes to simultaneous processing of vast amounts of data, the GPU wins.

A GPU with hundreds of cores to process thousands of threads in parallel has the capacity to accelerate the performance of some software by 100X compared to that of a typical CPU. And increasingly, the really challenging computational problems that we expect computers to solve for us have inherently parallel structures. Think of the enormous volumes of video-processing, image-analysis, signal-processing, and machine-learning flows that must occur reliably and in real-time to operate a self-driving vehicle. In power-constrained systems like a battery-powered electric vehicle, it's also important that a GPU typically achieves this processing speed while providing more power- and cost-efficiency than a CPU.

GPUS ARE TAILOR-MADE FOR AUTONOMOUS VEHICLES

The processing requirements of autonomous vehicles and ADAS technologies are completely within the GPU wheelhouse, especially in the areas of image analysis and parallel signal processing. Image processing is a natural problem domain for the made-for-gaming GPU. Indeed, almost any kind of computationally dense parallel computation is a good fit.

ADAS platforms can leverage the GPU's graphics compute capability to process and analyze sensor data in real-time. These discrete sensors include:

- Light detection and ranging (LiDAR), which measures the distance to a target with a pulsed laser light.
- Radio detection and ranging (radar), which is similar to LiDAR but uses radio waves instead of a laser.
- Infrared (IR) cameras systems that use thermal imaging to perceive in darkness.

These all enable ADAS to better interpret the environment and improve the system's ability to support the driver and maintain the safety of an autonomous vehicle.

As self-driving systems become more prevalent and advanced, the GPU will increase in importance—and in power. The GPU is set to be the workhorse of the autonomous vehicle, as it will be able to deliver the compute capabilities to enable cars of the future to become more aware of and responsive to their environment so that they can operate dependably, efficiently, and safely.

VIRTUALIZING THE GPU

The level of performance demanded by ADAS platforms will require increasingly larger and more powerful GPUs, thus impacting the manufacturing bills of materials for autonomous vehicles. To mitigate this expense, platform vendors will look to increase the value and functionality of the GPU by using it to perform multiple workloads in the vehicle.

Most modern vehicles already have GPUs on-board to enable driving displays and other digital dashboards, with multiple high-resolution screens to show maps, forecasts, and other visual information. 1080p resolution is now common in mid-range cars and 4K screens are increasingly specified for luxury and executive cars.

As we've already discussed, a single physical GPU is already capable of tremendous processing performance. However, virtualizing the GPU using specialized software abstracts the processing potential of a physical GPU and transforms it into multiple virtual instances. A single physical GPU is able to host multiple virtual workloads, all operating independently of each other yet emanating from the same hardware. Virtualization lets the GPU run multiple autonomous operations, without any of the virtual instances being aware of each other or in any way affecting the others.

Virtualized GPUs have obvious applicability for autonomous vehicle and ADAS scenarios, as a single GPU can power multiple applications, from visualization of maps and operations of entertainment consoles to the processing of environmental sensor data to identify roadway obstacles.

However, enabling multiple virtual operations from a single GPU in automotive applications is only safe and effective if the GPU has rock-solid support for hardware-accelerated virtualization.

Virtualization software is most dependable when hardware enforces entirely separate managed address spaces for each virtual instance, and enables the restart, or flushing, of an instance that's not operating correctly. This workload isolation is key to allowing shared use of the GPU, while keeping critical software, such as driver-assistance systems, from being corrupted by any other process.

Imagine a situation where a problem with the dashboard software was able to affect the correct operation of the drive-assistance system—it would have disastrous consequences. Hardware-supported virtualization for GPUs provides protected execution contexts to ensure that this situation doesn't arise.

From an ADAS platform developer's point of view, hardware-based virtualization offers another additional benefit. It enables a safer environment to deliver various applications and services without any concerns about the electronics systems being taken down by a rogue piece of software. It also means that rather than a traditional

Imagine a situation where a problem with the dashboard software was able to affect the correct operation of the drive-assistance system—it would have disastrous consequences. Hardware-supported virtualization for GPUs provides protected execution contexts to ensure that this situation doesn't arise.

hardware box with fixed software for the infotainment and engine management systems, the car becomes a flexible, configurable software platform that can be updated over-the-air. It enables OEMs to swap paid-for services in and out easily, without disrupting the car's operation, thus offering potential new revenue streams.

IMAGINATION'S GPU SOLUTIONS

PowerVR GPUs developed by Imagination address the data processing and trusted architecture challenges that face developers of autonomous-vehicle platforms. PowerVR GPUs support full hardware virtualization, completely isolating virtual instances that share the GPU. They also provide the muscle required to manage and prioritize these virtual operations to effectively power the ADAS platform architecture, with the performance bandwidth demanded to achieve safe, dependable outcomes.

Lower power consumption is also critical for autonomous vehicles, as most self-driving cars will be electric and operate on batteries. Lower power requirements for the vehicle control computing platform help lead to improved overall vehicle performance.

The core compute architecture inside PowerVR GPUs was designed from the ground up to offer fast performance and low power consumption through reduced-precision computation, especially half-precision floating point (FP16). Running at lower precision (where lower is usually classed as less than 32 bits) is one of the best ways to reduce power dissipation in an embedded GPU without significant loss of accuracy.

Imagination designed the FP16 hardware as a separate data path from the full-precision FP32 hardware. Though shared data-path designs are common since they're simpler in many ways, having discrete hardware for each pathway enables the company to offer the best possible power consumption and efficiency as each data path accepts fewer design compromises to do what it needs to do.

Imagination also offers a toolset to support the development, optimization, and deployment of neural networks across GPU and AI accelerators. The design environment provides a single unified tool-chain that lets developers take multiple frameworks and multiple network types and bring them into a format that allows them to be deployed on:

- The GPU as a compute engine.
- The PowerVR Series2NX and Series3NX neural networks accelerators.
- A mixture of the above two, where the flexibility of the GPU to implement a new network layer can be complemented by running the remaining layers on a highly optimized, high-performance dedicated convolutional-neural-network (CNN) accelerator.

According to Imagination, ADAS platform designers can trust PowerVR GPU as a proven component in the overall system architecture of the autonomous vehicle, with best-in-class power efficiency and memory bandwidth usage, as well as a balanced GPU design that fits well with the car's technology needs. These include improved performance for the systems that the driver and passengers interact with most—on larger and higher-resolution displays—and with a design that lends itself to safer, more dependable next-generation ADAS applications. mw

BRYCE JOHNSTONE is responsible for relationships and marketing throughout the automotive value chain in support of defining IP requirements for the rapidly changing car market. Previously at Imagination, he was in charge of the Developer Ecosystem, largely working with mobile games companies throughout the world. Johnstone holds a BSC in Electrical and Electronic Engineering from the University of Edinburgh and an MBA from the Open University.

DAVID HOLLANDER | Senior Director, Marketing, Bluetooth SIG
http://bluetooth.com/

What's the Difference Between Bluetooth LE and Bluetooth Classic Audio—and How Will It Impact HEARING AIDS?

Bluetooth LE Audio improves upon Classic Audio in a number of ways, and the opportunities for developers are exciting. Check out some potential use cases for the new audio standard.

The theme for World Hearing Day 2020 was simple: "Don't let hearing loss limit you."

This is sometimes easier said than done for the 455 million people worldwide that have disabling levels of hearing loss, and the number will rise to 900 million by 2050. Though hearing aids and hearing-loss prevention and treatment techniques have improved over the years, people with hearing loss may still feel restricted in certain situations, like when trying to engage in a conversation with several people talking over each other or watching a video without subtitles.

AUDIO IS BLUE: A NEW WAY TO EXPERIENCE HEARING

This year's World Hearing Day focused on encouraging people with hearing loss to continue participating in public and social life. And the Bluetooth Special Interest Group (SIG) has worked closely with the hearing aid industry to define and introduce LE Audio, the next generation of Bluetooth wireless audio, to help advance this mission.

> Far too often [those affected with hearing loss] withdraw from their social and professional environment. This does not have to happen. LE Audio will be one of the most significant advancements for hearing aid and hearing implant users."

LE Audio, announced in January, is a new Bluetooth audio standard that improves Bluetooth audio for all, including the growing number of people with hearing loss. Thanks to its low energy consumption, high sound quality, and multi-stream audio functionality, LE Audio will help enable a more seamless integration of hearing aids and other audio technology.

Dr. Stefan Zimmer, Chairman of the Board of the German Hearing Aid Industry Association (BHVI), believes the new audio standard will positively impact people across the world.

"Far too often [those affected with hearing loss] withdraw from their social and professional environment. This does not have to happen," says Zimmer. "LE Audio will be one of the most significant advancements for hearing aid and hearing implant users."

HOW DOES LE AUDIO DIFFER FROM CLASSIC AUDIO?

With the introduction of LE Audio, Bluetooth audio will support two modes of operation, the current mode, now referred to as Classic Audio, and LE Audio. As the names suggest, Classic Audio operates on the Bluetooth Classic radio (also referred to as Bluetooth BR/EDR), while LE Audio operates on the Bluetooth Low Energy (LE) radio. LE Audio will improve the performance of the same audio products and use cases supported by Classic Audio, including wireless calling, listening, and watching.

Significantly, LE Audio will also support the development of standard Bluetooth Hearing Aids. In addition, it will introduce exciting features that will enhance their performance as well as an entirely new use case—Bluetooth Audio Sharing—which is expected to enable the next generation of Assistive Listening Systems (ALS). This will make hearing assistance not only more accessible, but the places we go and the world around us will be more friendly to hearing aid users.

THE IMPORTANCE OF STANDARDIZATION

Support for Bluetooth technology in hearing aids to date has been based on proprietary implementations. As a result, relatively few hearing aids include Bluetooth technology and compatibility is limited. By standardizing support for Bluetooth technology within hearing aids, LE Audio will lead to the availability of more Bluetooth hearing aids and enable true global interoperability.

Thanks to the standardization that LE Audio will enable, people with hearing loss will be able to realize the same benefits of Bluetooth audio enjoyed by users of standard Bluetooth headphones and earbuds.

AUDIO SHARING

While current Assistive Listening Systems, such as inductive loops, have provided tremendous benefit to people with hearing loss, they suffer from a number of challenges that have limited deployment, including quality, cost, spill-over, interference from other devices, and privacy issues. In addition, telecoil systems are optimized for speech, which means music can sound distorted. They're often most effective at a certain angle, too, which may require the user to hold a device (like a telephone) in a way that could be awkward or uncomfortable.

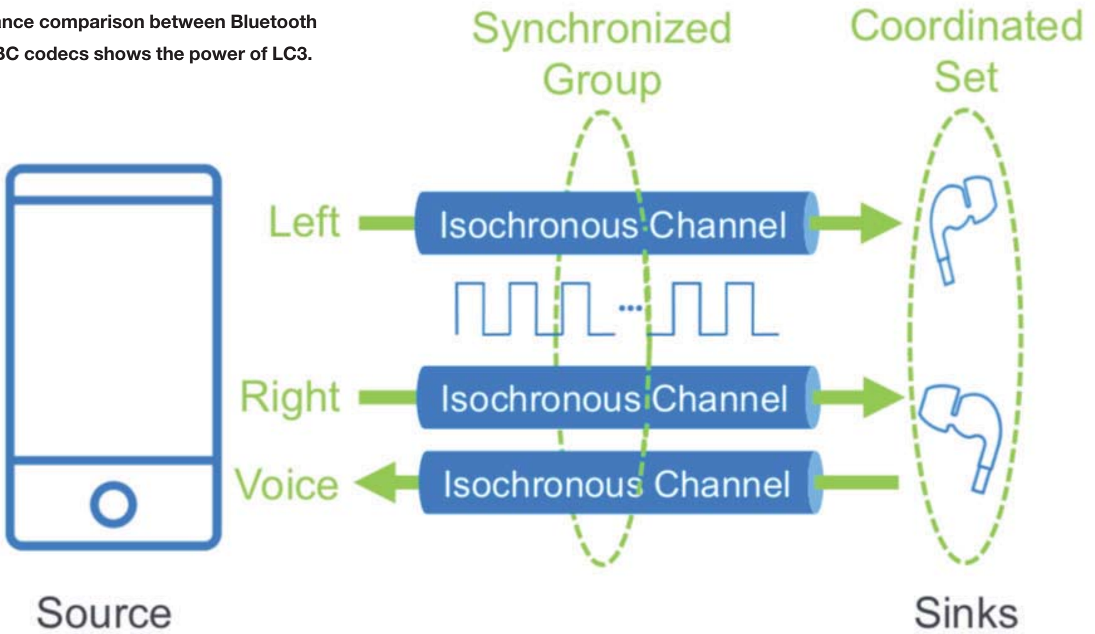
Bluetooth Audio Sharing will enable an advanced new type of ALS with higher audio quality and greater privacy that avoids spill-over challenges. It will also be significantly easier and cost less to deploy.

Here are just some of the ways you might see Bluetooth Audio Sharing in action in the future:

- At a movie theater, the audio track would send audio directly to hearing aids.
- Hearing aid users will be able to receive direct announcements at public venues like train stations or airports via their hearing aids.
- Multiple friends will enjoy music played on a smartphone through their Bluetooth headphones and hearing aids at the same time, helping hearing aid users tune in and be part of a shared music experience.
- Audio from home TVs or public TVs, such as those in waiting rooms, terminals, and sports bars, could be streamed directly to hearing aids or earbuds.

CES 2020 provided a glimpse of the future, as Nuheara unveiled its IQstream TV, a hardware accessory device that connects directly to a television. The user can then balance the volume of the TV sound with ambient sounds and conversations or simply focus on the TV itself.

These actions are all controlled independently from anyone else in the room. The user can give themselves as



A performance comparison between Bluetooth LC3 and SBC codecs shows the power of LC3.

immersive an experience as they'd like. For example, if other people in the room were talking too loudly during an episode of *Schitt's Creek*, you could isolate the broadcast without disrupting their conversation. Indeed, when one of us shines, we all shine.

In the future, LE Audio will make this more mainstream. The technology could work with a more extensive amount of Bluetooth-enabled products and also be installed directly into a TV, rather than an external device.

"Location-based Audio Sharing holds the potential to change the way we experience the world around us," says Peter Liu, Architect, Wearables Systems, Bose Corp. "For example, people will be able to select the audio being broadcast by silent TVs in public venues, and places like theaters and lecture halls will be able to share audio to assist visitors with hearing loss as well as provide audio in multiple languages."

REMOVING THE STIGMA OF HEARING LOSS

On average, people with some degree of hearing loss wait seven years before seeking help. Spending nearly a decade without the full ability to hear is partly a result of the stigma around hearing loss.

The introduction of LE Audio also brings a new, high-quality, low-power audio codec called LC3 (Low Complexity Communications Codec). LC3 offers lots of possibilities for hearing aid manufacturers and users. Listening tests have shown that LC3 provides superior audio quality over the subband codec (SBC) included with Classic Audio, even at a 50% lower bit rate *(see figure above)*. Developers and hearing aid manufacturers can leverage the power savings provided by LE Audio to design products that provide longer battery life or, in cases where current battery life is enough, reduce the form factor by using a smaller battery.

In this way, LE Audio will assist hearing aid manufacturers in designing devices that are more discreet or that more closely resemble earbuds that have become increasingly mainstream. Both trends have the potential to help remove some of the stigma around wearing a device in our ears and reduce the time it takes for people experiencing hearing loss to take action.

AUDIO FOR ALL, WITH NO LIMITATIONS

A big theme of World Hearing Day 2020—and, by extension, for the World Health Organization and Bluetooth effort—is inclusivity, reminding all of us that being hard of hearing shouldn't limit anyone. Hearing aids can significantly improve how people with hearing loss engage with the world. LE Audio's standardization of Bluetooth Hearing Aids and its introduction of Bluetooth Audio Sharing have the potential to further improve the quality of life for hearing aid users, remove limits, and empower people with hearing loss to feel more confident and connected in their daily lives. mw

DAVID HOLLANDER is the Senior Director of Marketing for the Bluetooth SIG. His team is dedicated to raising awareness of the expanding capabilities of Bluetooth in the IoT and advancing the interests of Bluetooth creators and users across the globe.

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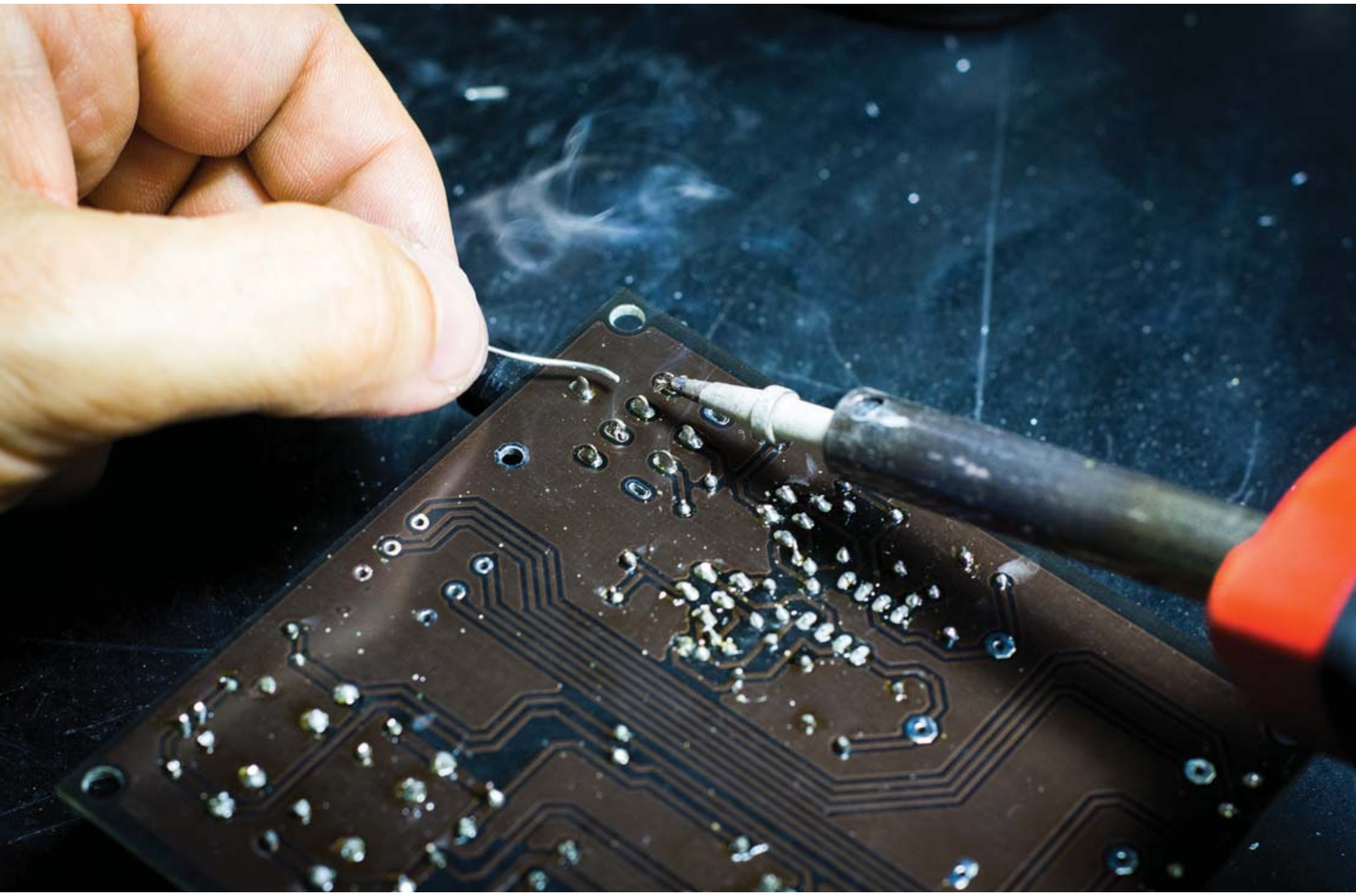


Common PCB Soldering Problems TO AVOID

Soldering can make or break a PCB, both figuratively and literally. This article offers basic tips and nine specific problems/mistakes to look out for when doing a soldering job.

The quality of the soldering has a tremendous impact on the overall quality of the PCB. Through soldering, different parts of the PCB are connected to other electrical components to make a PCB function properly and serve its purpose. When industry professionals are evaluating the quality of electronic components and devices, one of the most prominent factors in their assessment is the caliber of the soldering work.

To be sure, soldering is quite straightforward. But it does take practice to master. As the saying goes, "practice makes perfect." Even a complete novice can make functional solders. But for the overall longevity and functionality of the device, a clean and professional soldering job is the way to go.

In this guide, we've highlighted some of the most common problems that can happen during soldering. If you would like to know more about what it takes to make perfect solders that last, this is the guide for you.

WHAT IS THE PERFECT SOLDER JOINT?

It's difficult to encompass all types of solder joints into one comprehensive definition. Depending on the type of solder, PCB used, or component connected to the PCB, the ideal solder joints might vary drastically. Still, most of the perfect solder joints have:

- Complete, solid wetting
- A smooth and shiny surface
- A neat concave fillet

To achieve an ideal solder joint, regardless of whether it's an SMD solder joint or a through-hole solder joint, it's necessary to use the right amount of solder, an appropriate solder iron tip heated to an accurate temperature, and a prepped PCB contact with a removed oxide layer.

Here are nine of the most common problems and mistakes that can happen on solders, usually when soldered by an inexperienced worker:

1. Solder Bridges

PCBs and electronic components are becoming smaller and smaller, making it difficult to maneuver around the PCB, especially when trying to solder. If you're using a solder iron tip that's too large for the PCB, you might create unwanted solder bridges.

A solder bridge is when soldering material connects two or more PCB connectors. This is quite dangerous and, if undetected, can cause the board to short circuit and burn out. Make sure to always use the right size of soldering iron tip to prevent solder bridges.

2. Too Much Solder

Novices and beginners tend to use too much solder when soldering, and a large bubble-like solder ball forms at the solder joint. Besides looking like a weird growth on the PCB, it can also be difficult to spot if the solder joint is functional. There's plenty of room for mistakes under that ball of solder.

The best practice is to be use solder conservatively and, if necessary, add more if the joint needs it. Strive for a clean solder with a nice concave fillet.

3. Cold Joints

Cold joints occur when the soldering iron is at a lower-than-optimal temperature, or the duration of the heating of the joint was too short. Cold joints have a dull, messy, pock-marked appearance. In addition, they have a shorter lifespan and are less reliable. It's also difficult to assess whether a cold joint will perform well under current or limit the functionality of the PCB.

4. Burnt Joints

Burnt joints are the complete opposite of cold joints. It's obvious that the soldering iron operated at a higher-than-optimal temperature, the solder joint exposed the PCB to heat way too long, or a layer of oxide was still present on the PCB, preventing optimal heat transfer. The joint has a burnt appearance, and if the pads have lifted at the joints, the PCB might be damaged beyond repair.

To be sure, soldering is quite straightforward. But it does take practice to master. As the saying goes, "practice makes perfect."

5. Tombstones

Tombstones often occur when trying to connect electronic components such as transistors and capacitors to the PCB. If all sides of the component are properly connected to the pads and soldered, the component will be straight.

Failing to achieve the necessary temperature for the soldering process might cause one or more sides to lift, making a tombstone-like appearance. Tombstoning affects the longevity of the solder joint and might negatively affect the thermal performance of the PCB.

One of the most frequent problems that's causing tombstoning during the reflow soldering process is the uneven heating in the reflow oven, which can cause premature wetting of the solder in some areas of the PCB versus other areas. The uneven heating issue usually occurs for home-made reflow ovens. That's why we recommend acquiring professional equipment.

6. Insufficient Wetting

One of the most common mistakes by beginners and novices is the lack of wetting of the solder joints. A badly wetted joint has less solder than necessary to make a proper connection between the PCB soldering pads and the electronic components attached to the PCB by solder.

Poorly wetted joints will almost certainly limit or impair the performance of the electrical device, suffer from poor reliability and longevity, and might even cause a short that could fatally damage the PCB. They also often occur when solder used in the process is insufficient.

7. Skips

Solder skips can occur in the factory where the robots solder components to PCBs or at the hands of an inexperienced solder. It might occur due to a lack of concentration on the part of a human operator. Likewise, poorly configured robots can easily skip a joint—or one part of the joint.

This leaves the circuit open and renders certain areas or the whole PCB non-functional. Take your time and make sure to inspect all the solder joints carefully.

8. Lifted Pads

Lifted pads on the solder joints occur due to either excessive force or excessive heat applied to the PCB during soldering. The pad lifts off the surface of the PCB and is a potential short-circuit hazard that could ruin the whole board. Always make sure to reattach the pads back to the PCB and then solder the components on.

9. Webbing and Splashes

Webbing and splashes on the PCB occur when either the board is contaminated by pollutants that affect the soldering process or by insufficient use of the fluxing agent. Besides the messy appearance of the PCB, webbing and splashes are a huge short-circuit hazard that could potentially damage the board.

CONCLUSION

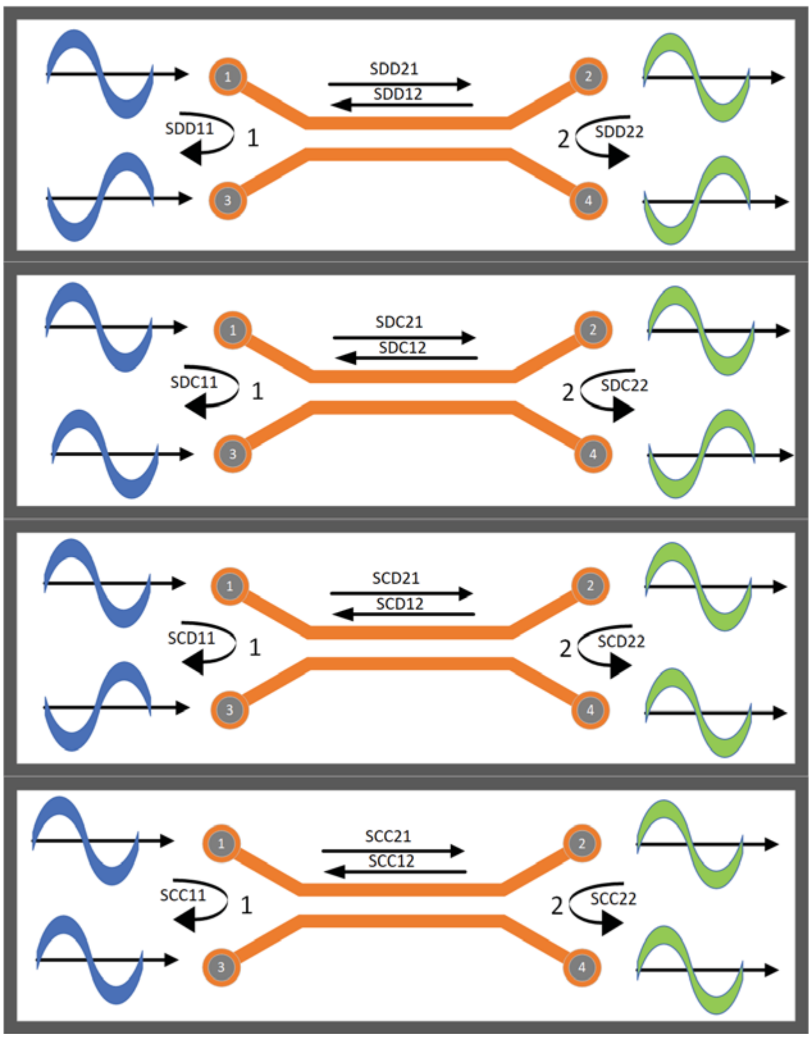
We hope that you find this guide useful and informative. If you see yourself making any of these soldering mistakes, don't get discouraged; it happens to the best. Being an expert at soldering takes time and practice, and everyone makes mistakes.

There's no sure-fire method to perfect soldering, but following these tips might help:

- Always inspect and familiarize yourself with the PCB before soldering.
- Make sure that the pads and joints are clean, free of pollutants, and ready for soldering.
- Keep your soldering iron in perfect shape, especially paying attention to the tip.
- Take your time.
- Practice, practice, practice. mw

STEVE ELLIS | Senior Product Manager, Fairview Microwave
https://www.fairviewmicrowave.com

Why Skew-Matched Coaxial Cables Matter to Signal-Integrity Test and Measurement



1. The diagram shows mixed-mode S-parameters based on a common/differential input or output.

This article explores some common measurement parameters and how skew-matched coaxial assemblies can augment a test setup to boost the accuracy of the overall differential-signal characterization process.

Phase stability means reliable performance in specific test-and-measurement applications that call for a close match in frequency and phase between cables with low relative drift over temperature, vibration, and flexure. Yet, phase stability may not be adequate in cases where tighter skew tolerances are needed for a more synchronized distributed clock chain.

Skew-matched coaxial cables are specifically designed to service the growing data-rate demand in differential-signaling applications. This article explores some common measurement parameters and how skew-matched coaxial assemblies can augment a test setup to lend more accuracy to the overall differential-signal characterization process.

HIGH-SPEED DIFFERENTIAL-SIGNAL DEVICE CHARACTERIZATION

Differential signaling is often used in high-speed digital (multi-gigabit) applications because any noise will equally affect both lines if they're coupled closely together (with adequate conductor width for desired differential impedance). Thus, it's often much easier to filter noise than in single-ended lines and may reduce transmit-power requirements on the transmission lines.

The common-mode noise introduced by non-ideal devices can be rejected at the receiver. There is, however, cross-mode conversion (common-to-differential mode, differential-to-common mode) that invariably results from manufacturing imperfections that cause device asymmetries. As with any design, prototype, and testing process, all electrical anomalies must be adequately discerned and evaluated before production. While signal-integrity (SI) engineers have numerous tools at their disposal to characterize a differential device, mixed-mode S-parameters are among the more basic and necessary tools for understanding high-speed differential systems.

Typically measured with a vector network analyzer (VNA), S-parameters are an extremely useful modeling and measurement tool for the design and analysis of both single-ended unbalanced and differential balanced passive high-frequency systems. However, a single-ended, two-port device under test (DUT) in RF applications would require a 2×2 S-parameter matrix for analysis, whereas a two-port differential DUT would leverage a 4×4 S-parameter matrix. *Figure 1 (on page 35)* depicts the various mixed-mode S-parameters based on a common/differential input or output.

Two-port, single-ended S-parameters reveal insertion loss/attenuation/gain data (S21) as well as return loss/voltage standing-wave ratio (VSWR) data (S11). Differential S-parameters offer insight into the performance of a system with differential return loss (e.g., SDD11), insertion loss (e.g., SDD21), near-end crosstalk (NEXT) (SDD31, SCC31, SCD31), far-end crosstalk (FEXT) (SDD41, SCC41), and differential-to-common mode conversion (SCDxx). *Table 1* provides general definitions for the 16 different mixed-mode S-parameters while *Figure 2* illuminates some more specific parameters utilized in a mixed-mode analysis.

GENERAL DEFINITIONS FOR THE 16 DIFFERENT MIXED-MODE S-PARAMETERS

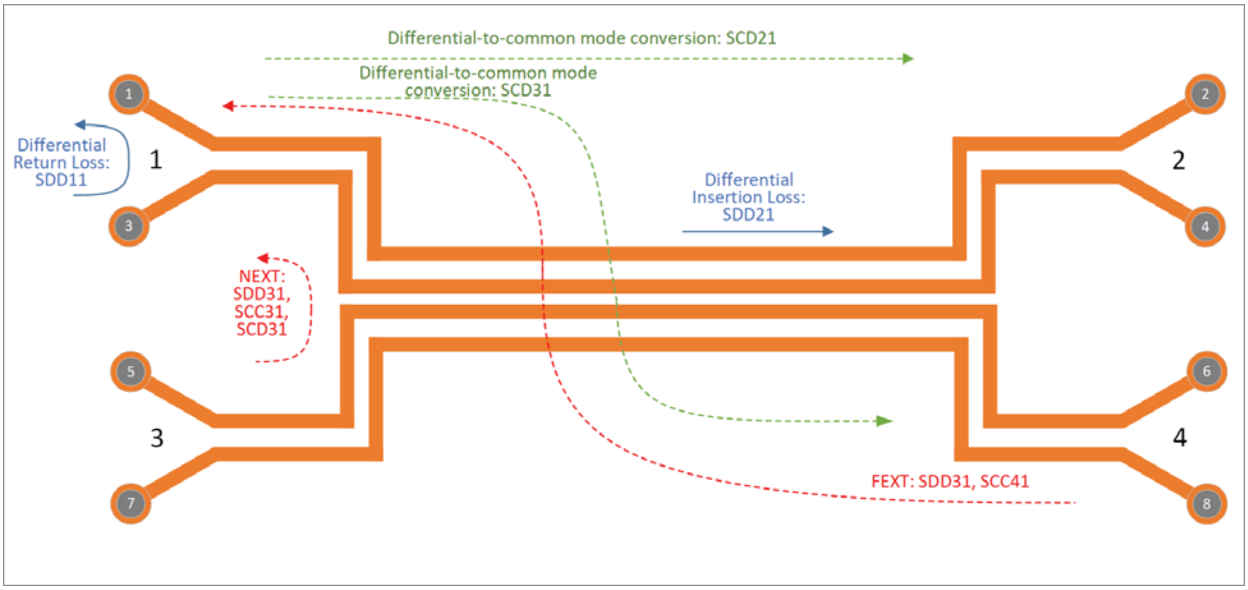
Input	Output	Mixed-mode S-parameter	Description
Differential	Differential	SDD11	Reflected differential signal measured at port 1 driven with a differential signal at port 1
		SDD12	Transmitted differential signal measured at port 1 driven with a differential signal at port 2
		SDD21	Transmitted differential signal measured at port 2 driven with a differential signal at port 1
		SDD22	Reflected differential signal measured at port 2 driven with a differential signal at port 2
Differential	Common	SCD11	Reflected differential signal measured at port 1 driven with a differential signal at port 1
		SCD12	Transmitted differential signal measured at port 1 driven with a common signal at port 2
		SCD21	Transmitted common signal measured at port 2 driven with a differential signal at port 1
		SCD22	Reflected common signal measured at port 2 driven with a common signal at port 2
Common	Differential	SDC11	Reflected common signal measured at port 1 driven with a common signal at port 1
		SDC12	Transmitted common signal measured at port 1 driven with a differential signal at port 2
		SDC21	Transmitted differential signal measured at port 2 driven with a common signal at port 1
		SDC22	Reflected differential signal measured at port 2 driven with a differential signal at port 2

Time-domain transmission (TDDxx) parameters are also vital in the characterization process, particularly for jitter analysis (eye diagrams) and crosstalk. Multi-domain test templates are popular for testing multi-gigabit digital standards such as USB 3.0, Ethernet, and serializer/deserializer (SERDES) applications.

It's important to note that a single-ended NxN S-parameter matrix isn't directly related to the mixed-mode NxN S-parameter matrix *(Fig. 3 on page 38)*. Aside from using a mixed-mode VNA kit, the mixed-mode S-parameters can be derived mathematically from a traditional VNA Touchstone (SnP) file via adequate mode-conversion matrices.[1]

TIME-DOMAIN ANALYSIS (JITTER, BIT ERROR RATE)

Time-domain analysis can either be performed with an oscilloscope (in TDR mode), a bit-error-rate tester (BERT), or a VNA that performs an inverse discrete Fourier transform (DFT) to convert from the frequency domain (SDD21) to the time domain (TDD21). Where mixed-mode S-parameters are useful for characterizing a differential channel in the frequency domain (crosstalk, noise, insertion loss, and so on), eye diagrams are useful tools in evaluating clock jitter or the BER of the signal; these reveal jitter, interference, and signal attenu-



2. Some important measurement parameters can be derived from the mixed-mode S-parameters. Note: NEXT and FEXT parameters listed are in the condition where ports 1/2 are the victim ports and ports 3/4 are the aggressor ports.

ation problems. Other time-domain tools, such as single-pulse response, can reveal intersymbol interference (ISI), or the interference of a symbol on a subsequent chain of symbols, which is often caused by clock jitter, noise, and crosstalk.

Jitter testing is of particular importance as data rates and clock frequencies rise, causing eye openings to shrink and leaving far less room for noise, crosstalk, and the various manufacturing flaws that cause jitter. Moreover, shorter rise/fall times, in turn, increase the amount of high-frequency spectral content so that there's still often considerable energy up to the fifth harmonic. For instance, a 20-Gb/s data rate would correlate to a 10-GHz clock frequency, which would require a bandwidth (BW) of 50 GHz to reveal fifth-harmonic content (and thus increase the resolution in the time domain).

For exceptionally high data-rate applications, the equation for bandwidth (Equation 1) frequently enables successful recreation of the rising/falling edge of the signal. This significantly reduces the bandwidth and dynamic range requirements for test equipment.

$$BW = \frac{0.35}{\tau_R} \quad (1)$$

where BW is bandwidth, and τ_R is rise time.

In these cases, a VNA can become an all-in-one tool for multi-domain analysis and more straightforward channel characterization. However, utilizing precision coaxial components, particularly skew-matched coaxial sets with an adequate method for eliminating the errors caused by the test fixtures, increases the likelihood of obtaining the most accurate measurements that the test equipment is capable of.

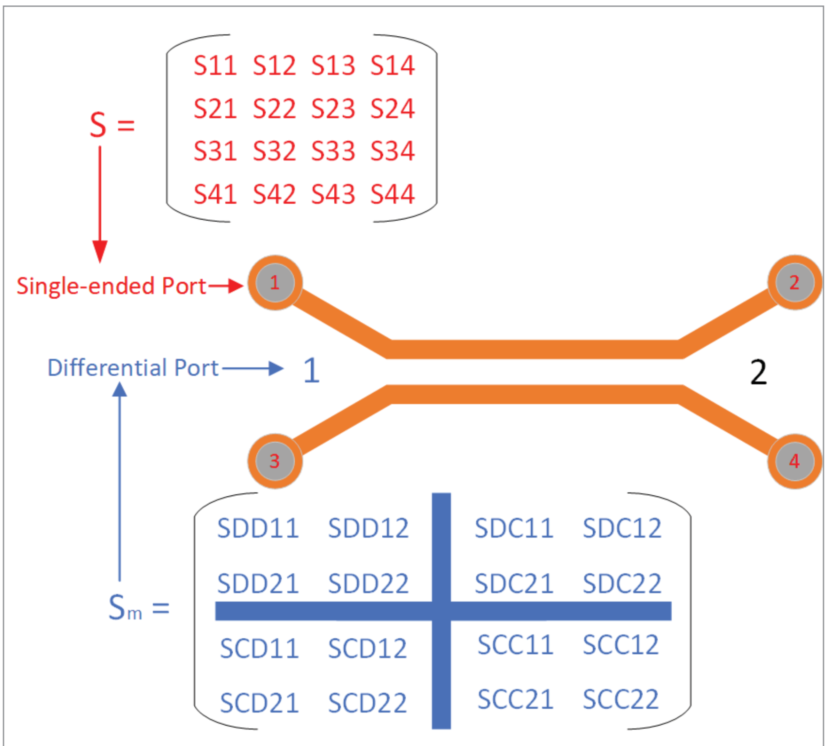
USE CASES FOR DELAY-MATCHED COAX CABLES

Modern high-speed digital communication systems rely on the precise timing of signals to and from a transmitter or receiver. Examples include SERDES for high-speed I/O signal transmission as well as generalized differential measurements found in high-speed interfaces such as USB 3.1, multi-gigabit Ethernet, and PCI Express.

Measuring channel signal integrity

Generating timing margins is often done at the design and simulation level by characterizing the crosstalk, jitter, skew, and electromagnetic simulation of "flight time" (interconnect delays). However, physical measurements using test instruments may also be necessary to gain a more accurate assessment of channel loss. Flaws, or "pathologies," within the system can carefully be revealed for better design and margin optimization.

Test benches naturally require the use of additional test fixtures and cables/connectors to reach the test equipment. If these additional components have poor signal-integrity (SI) characteristics, it can convolute the process of isolating the source(s) of jitter, skew, or crosstalk. Such problems are typically only discerned by introducing structures with good SI qualities. This includes the use of skew-matched cables to mitigate the sources of skew within the differential test system.



3. Single-ended S-parameters can be converted to mixed-mode S-parameters via mode conversion matrices.[1]

Error correction and fixture/cable removal techniques

The IEEE P370 task force's mission was to create an industry standard for the characterization of high-frequency electrical interconnects up to 50 GHz. This has been realized, to some extent, through a list of recommended practices that prevent inaccurate de-embedding of test fixtures and cabling from the DUT, which in turn leads to inaccurate S-parameter measurements. These inaccurate measurements can unknowingly be distributed where there's no IEEE standard to check the quality of the S-parameters prior to publishing that data.[3]

Typical calibration for a single-ended system would require a short, open, load, and (one) thru to bring the measurement plane to the DUT (pre-measurement error correction). In a DUT utilizing differential signaling, the PG370 standard for pre-measurement error correction requires the 2X-thru to be customized to the test fixture (i.e., same PCB panel, layer, layer transitions, PCB orientation, and electrical length). Even with more accurate post-measurement custom proprietary algorithms for de-embedding, test-fixture removal adds error to the measurement, harming timing margins and optimization of the DUT.

The procedure for the S-parameter de-embedding itself relies heavily on the accuracy of the S-parameter behavioral model.[5] For instance, time-domain measurements such as jitter characterization can be less consistent across measurements without skew-matched coaxial cables, as jitter metrics can be directly affected by the mismatch in delay between the cable assemblies.

> Often, test fixtures for high-speed, differential components will include short lengths of mini coax or semi-rigid cables that guarantee a level of delay match. However, such cables frequently hinder test capabilities due to inflexibility or the lack of length needed to reach test equipment.

NEED FOR SKEW-MATCHED COAXIAL CABLES

Often, test fixtures for high-speed, differential components will include short lengths of mini coax or semi-rigid cables that guarantee a level of delay match. However, such cables frequently hinder test capabilities due to inflexibility or the lack of length needed to reach test equipment.

Unfortunately, a simple replacement/extension of two seemingly identical coaxial assemblies of the same length can't reliably accomplish a skew match down to the order of picoseconds. This remains true even when there's phase tracking, or a controlled manufacturing with consistent materials, fabrication methods, and temperature conditioning to maintain nearly uniform performance across a production line of coaxial cables. Skew-matched coaxial cables require more intentional care with a precise cut and connector attachment as well as respective testing to achieve high accuracies.

While highly effective and often critically important, phase-stable coaxial cables are more frequently used for single-ended port systems. The problem of delay mismatch is only exacerbated in cases where:

- Measurements are performed at wavelengths up to millimeter waves
- Measurements are performed with longer lengths of skew-matched coax
- Cables undergo semi-frequent flexure for T&M purposes

CONSIDERATIONS IN MAKING SKEW-MATCHED ASSEMBLIES

Phase-stable coax

A set of skew-matched coaxial cables must each be individually phase-stable to be able to maintain a delay on the order of picoseconds between the two assemblies. Coaxial cables will invariably exhibit insertion loss (S21) due to intrinsic sources of loss (e.g., dielectric loss tangent, dielectric conduction, metallic losses).

The phase/time delay (related to phase (S21)), on the other hand, intrinsically depends on the physical length of the cable as well as the dielectric constant, or relative permittivity (ε_r), of the dielectric material, both of which are temperature-dependent (Equation 2). The linear coefficient of thermal expansion (CTE) will generally increase with temperature as the dielectric constant decreases. Cable length is generally fixed by the metallic materials due to its hardness in comparison to the insulating material, so the CTE of the inner and outer conductors is more relevant to understanding the changes in length over temperature.

$$\tau = \frac{l\sqrt{\varepsilon_r}}{c} \quad (2)$$

The design of phase-stable coaxial cables is a science unto itself, with a particular focus on the use of stable dielectric materials. Many of the techniques involve introducing air into the dielectric. Low-density and foamed materials exhibit lower insertion loss and more phase stability over temperature, which boosts the velocity of propagation (V_p) to 75% to 80%. However, such materials provide less overall mechanical strength and a less consistent dielectric constant over the length of the material, which means a balancing act between material strength (elastic modulus) and relative permittivity. Phase stability also increases with less overall mechanical strain on the coax.

Highly phase-stable coaxial cable will often be relatively thin to mitigate the bending forces perpendicular to the cable during flexure. Moreover, strain-relief boots are typically added between the connector and the transmission line to buffer the forces from a hard connector ferrule and the softer coax during a bend *(Fig. 4 on page 42)*. To maintain phase tracking over a lot of phase-stable cables, temperature conditioning or aging mitigates the risk of a divergence in phase during temperature fluctuations over the operational lifetime of the coax.

Making two nearly "identical" cables

Creating a pair of cables that experience near-identical delays means maintaining similar V_p values between the two dielectric materials and adjusting length for the minor (1 to 2%) variations between them. This, naturally, gets trickier as cables grow longer, because greater length widens the window for variations between the two cables. The dielectric constant also decreases with increasing frequency.

Millimeter-wave, skew-matched pairs have a much wider bandwidth to closely match dielectric-constant behavior and thus time delay. The precision of a delay- or skew-matched pair of coax depends on the quality of the cut, attachment of the connectors, and the care put into optimizing each individual set for phase stability. Most importantly, batch testing likely would not suffice for consistently achieving a channel-to-channel delay match of, say, 1 to 5 ps. Each set of cables must therefore be 100% tested for reliable performance across a production line of skew-matched coax.

4. Shown is a pair of skew-matched coaxial cables.

CONCLUSION

Skew-matched cable assemblies are particularly useful in characterization of high-data-rate, differential-signaling applications. Along with the large repertoire of test equipment, probes, and fixtures, the passive transmission lines connected to the test equipment can either add to or remove from the integrity of a test setup. Significant design considerations are necessary to ensure a tight skew match between two coaxial transmission lines, thus making channel-to-channel delay matching less straightforward than it may seem. mw

STEVE ELLIS, senior product manager for RF interconnects at Fairview Microwave, has been involved in the RF and microwave industry for over 35 years, including extensive work in the areas of microwave component test and measurement and radar and communication systems. He currently oversees the development and growth of Fairview Microwave's line of RF, microwave, and millimeter-wave interconnect products.

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Signal-Recording System Scans, Documents RF Spectrum

PENTEK'S LATEST ADDITION to its family of Talon signal-recording and playback systems is the Talon RTR 2654 26.5-GHz RF Sentinel Intelligent Signal Scanning rackmount recorder. The RTR 2654 provides automated, continuous real-time monitoring from 800 MHz to 26.5 GHz and can record bandwidths up to 500 MHz. The system is built on a Windows workstation with an Intel Core i7 processor; users may install post-processing and analysis software tools like MATLAB. A 4U 19-in. chassis features front-panel USB ports and rear-panel I/O connectors. Front-panel, hot-swappable SSDs are available in configurations from 7.6 to 245.7 TB, supporting RAID levels 0, 5 or 6. Starting at $125,000, the ARO for all models is 16 weeks.

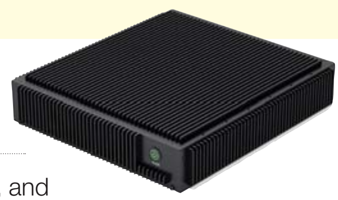
PENTEK, www.pentek.com

Cellular Modem and Router Move M2M and NB-IoT Communications

MULTI-TECH SYSTEMS has launched its Dragonfly embedded cellular modem and the MultiConnect rCell 100 series of intelligent cellular routers. The Dragonfly embedded cellular modems feature an onboard Arm Cortex-M4 processor, are fully industry certified, and are ready to integrate system-on-modules that can be configured and managed with the MultiTech Connection Manager software. The rCell 100 Series routers are targeted toward M2M (machine-to-machine) and NB-IoT communications. They are built into ruggedized enclosures (-40°C to 85°C operating range) and feature over-the-air upgrades, WAN failover, secure software updates, and certificate management, and are now available with LTE Category 4 capability for Europe. The mPower Edge firmware's cloud-based device management platform and an intuitive user interface allow for quick configuration.

MULTI-TECH SYSTEMS, www.multitech.com

Multiple Industries Gain from Rugged Server and Coprocessor Pair



NEW FROM GENERAL MICRO SYSTEMS (GMS) is the fully sealed, ruggedized, and conduction-cooled Thunder S422 server and Lightning X422 GPGPU coprocessor. Intended to be run in tandem, the pair is also fully capable of being deployed individually as part of custom systems. The S422 server (pictured) is based on an Intel 22-core Xeon E5 server CPU and features ECC-protected RAM and removable storage, four 40/100-Gb Fiber Ethernet ports, 30 10-Gb Ethernet ports with power-over-Ethernet (PoE) support, and expandable I/O options. The X422 is built around two Nvidia V100 Tesla Tensor core GPUs. Two internal PCIe slots allow coprocessing to be offloaded to AMD GPGPUs, Altera or Xilinx FPGA modules, DSP cards, and more. The duo has already been selected for two new military development programs.

GENERAL MICRO SYSTEMS, www.gms4sbc.com

Highly Integrated Transceiver Cuts Base-Station Parts Count

A RECENT ADDITION to Analog Devices' RadioVerse ecosystem, the ADRV9026 highly-integrated, wideband, and software-defined RF transceiver, supports both frequency-division duplex (FDD) and time-division duplex (TDD) standards. Available in a 14- × 14-mm BGA package, the new IC serves applications in 3G/4G/5G macrocell base stations, massive MIMO (M-MIMO) and small cell systems, as well as O-RAN small cell designs. Key features include quad-channel transmitters and receivers with up to 200 MHz of receiver/transmitter bandwidth. This includes coverage of all bands from 650 MHz to 6 GHz. Also integrated into the IC are dual-channel observation receivers (maximum bandwidth synthesis of 450 MHz) and multichip phase synchronization for all local oscillators and baseband clocks. Samples, software, and design resources, including simulation tools and development kits are available.

ANALOG DEVICES, www.analog.com/ADVR9026

(Continued from page 18)

MORE GaN OPTIONS

With respect to its development efforts on GaN devices, Analog Devices *(www.analog.com)* expects to eventually reach beyond 50 GHz in producing gain and solid-state output power. The company plans to support semiconductor devices well into the millimeter-wave frequency range for such applications as 5G base stations and automotive safety systems, although its devices are presently reaching much lower upper-frequency ranges.

As an example, the model HMC1087 die is a GaN chip transistor MMIC power amplifier that can produce +39 dBm saturated output power with 11-dB small-signal gain from 2 to 20 GHz. The device input and output ports are matched to 50 Ω for ease of corresponding amplifier circuit design. The MMIC amplifier is a good fit for radar and communications systems in its frequency range.

To strengthen its position in GaN semiconductor technology, Swiss-based STMicroelectronics *(www.st.com)* recently divulged its plans to acquire a majority stake in the French GaN epitaxial specialist Exagan. Of the acquisition, Jean-Marc Chery, the company's president and CEO said, "ST has built strong momentum in silicon carbide and is now expanding in another very promising compound material, gallium nitride, to drive adoption of the power products based on GaN by customers across the automotive, industrial and consumer markets.

"The acquisition of a majority stake in Exagan is another step forward in strengthening our global technology leadership in power semiconductors and our long-term GaN roadmap, ecosystem and business," added Chery. "It comes in addition to ongoing developments with CEA-Leti in Tours, France, and the recently announced collaboration with TSMC."

STMicroelectronics already has a well-developed GaN semiconductor fabrication process in which a two-degree, high-electron-mobility gas layer is formed between an aluminum-gallium-nitride (AlGaN) buffer layer and the GaN substrate. The company serves a variety of markets, including power and safety, with products such as millimeter-wave (mmWave) automotive radar transceivers for advanced driver-assistance system (ADAS) applications at 24 and 76 GHz.

These monolithic chirp radar ICs, which come in miniature multilead plastic packages, can be used as the foundations for complete automotive radar safety systems. As an example, the company's model STRADA770M is a radar transceiver in a transistor package with integrated frequency-modulated continuous-wave (FMCW) chirp modulator and a profiles-based sequencer for use in the 76- to 77-GHz and 77- to 81-GHz bands. Depending on the voltages supplied to it, the device can generate additional voltages as needed using integrated low-dropout (LDO) regulators.

This, of course, is just a sampling of commercial GaN devices currently on the market. With the automotive market quickly adopting ADAS radar systems and 5G requiring more bandwidth than currently available, semiconductor suppliers are being asked to make these active devices affordable at mmWave frequencies, and GaN is currently the semiconductor material of choice at those higher frequencies. mw

ROLLING YOUR OWN GaN DEVICES

FOR THOSE WHO KNOW what kind of GaN device they want to make, several foundries are available to fashion custom ICs and discrete devices. For example, Raytheon Co. (Woburn, Mass.) is a Category 1A Trusted Foundry for the U.S. Defense Department for both GaN and GaAs.

The foundry fabricates GaN high-electron-mobility transistors, pseudomorphic GaN (pGaN), and metamorphic GaN (nGaN) devices. Raytheon's Andover, Mass. facility also provides all of the services associated with a semiconductor foundry, including circuit design, layout, modeling, fabrication, test, and module design for the fabricated ICs.

BAE Systems (Nashua, N.H.), another DoD-accredited partner, also provides GaN and GaAs foundries for industry use, backed by 6-in.wafer production runs. The foundry provides GaN-HEMT-based foundry services *(see figure)* to the U.S. Department of Defense (DoD) and the design community at large for monolithic microwave integrated circuits (MMICs) from 1 to over 200 GHz. For those who prefer a variation, the foundry services from Wolfspeed are based on 100-mm-diameter, GaN-on-SiC IC technology backed by design and testing capabilities. ■

GaN and GaAs 6-in. diameter semiconductor wafers are part of a foundry that serves both military and commercial customers. *(Courtesy of BAE Systems)*

Join Us in the Pits

This shot is of the crew working on the #81 at the Sebring, Fla. racetrack.

You might have read about our sponsorship of DragonSpeed, one of the NTT IndyCar Series competitors. *Microwaves & RF/ Electronic Design* and *Machine Design* Senior Content Directors Bill Wong and Bob Vavra will be covering all the action from the pits at the Indianapolis 500 at the Indianapolis Motor Speedway (IMS) in Speedway, Indiana on August 23, 2020. We will be cheering on Ben Henley and the DragonSpeed crew.

If you're into this type of racing, then we have a treat for you! We are running a contest called **Join Us in the Pits**. Find the link on the *Microwaves & RF* website *(www.mwrf.com)* or go to the entry page at *https://design.endeavorb2b.com/2020-DragonSpeed-IndyCar-Drawing*. We have two grandstand tickets to give away! The winner also receives a three-night stay in Indy and a three-day pass that provides staff access to the track entry, pit, and garage areas. A $1,000 travel voucher rounds out the prize package.

One entry per day is allowed. Contest only valid for residents of the United States. It's a WIN-WIN deal exclusively for *Microwaves & RF, Electronic Design* and *Machine Design* Community Members!

Not a member? Join by subscribing to one of our newsletters: *mwrf.com/ subscribe, electronicdesign.com/subscribe* or *machinedesign.com/subscribe*. mw

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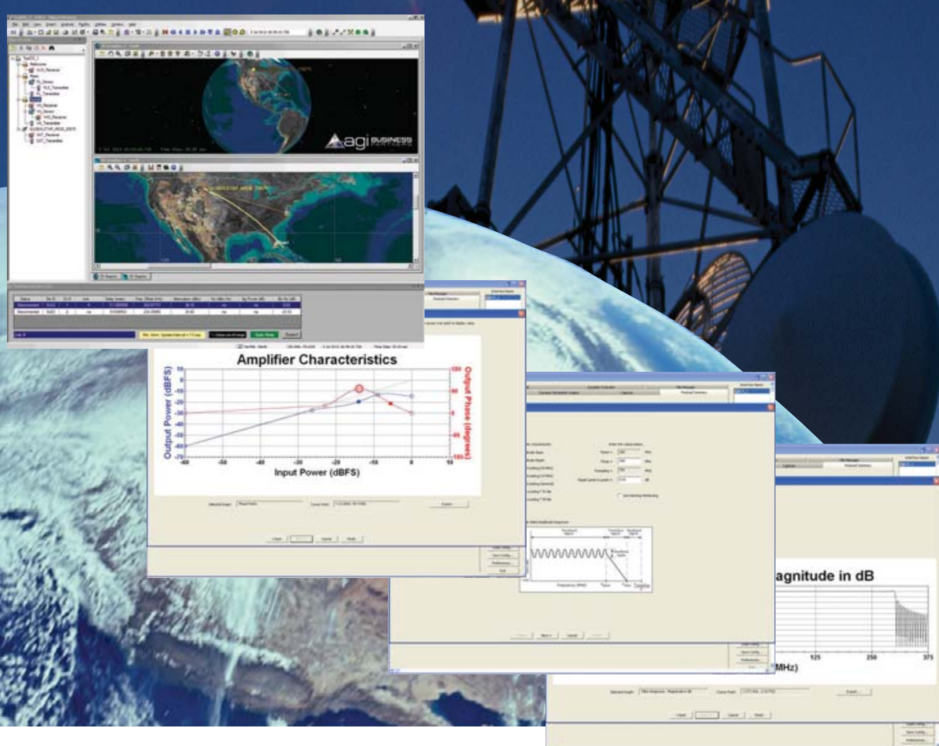

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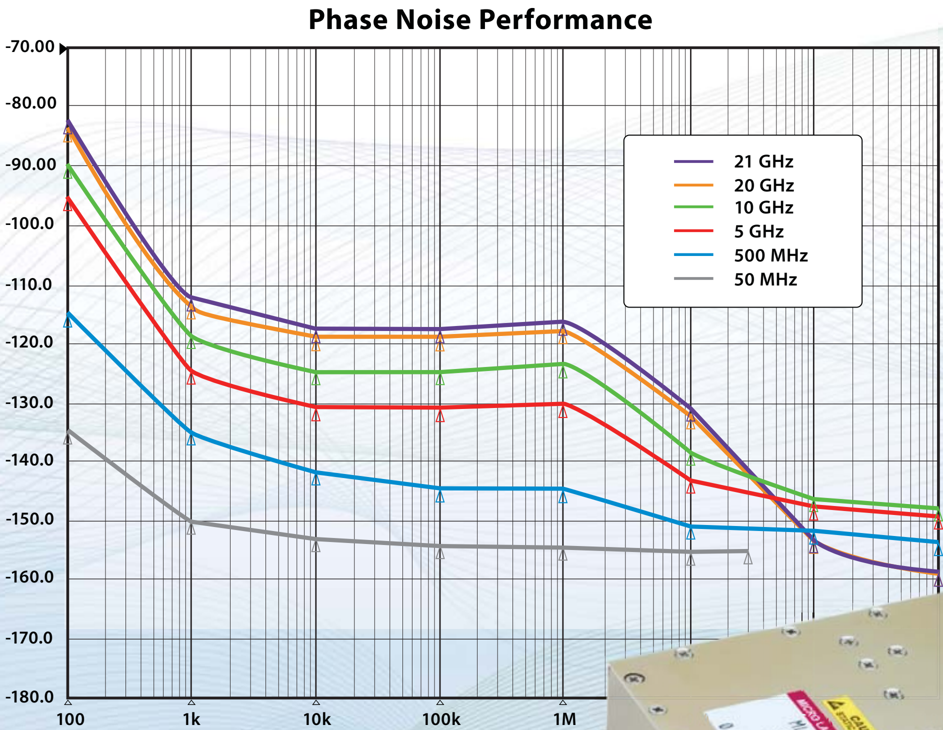

US patents: #9,793,904 B1, #9,734,099 B1, #10,218,365 B1

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