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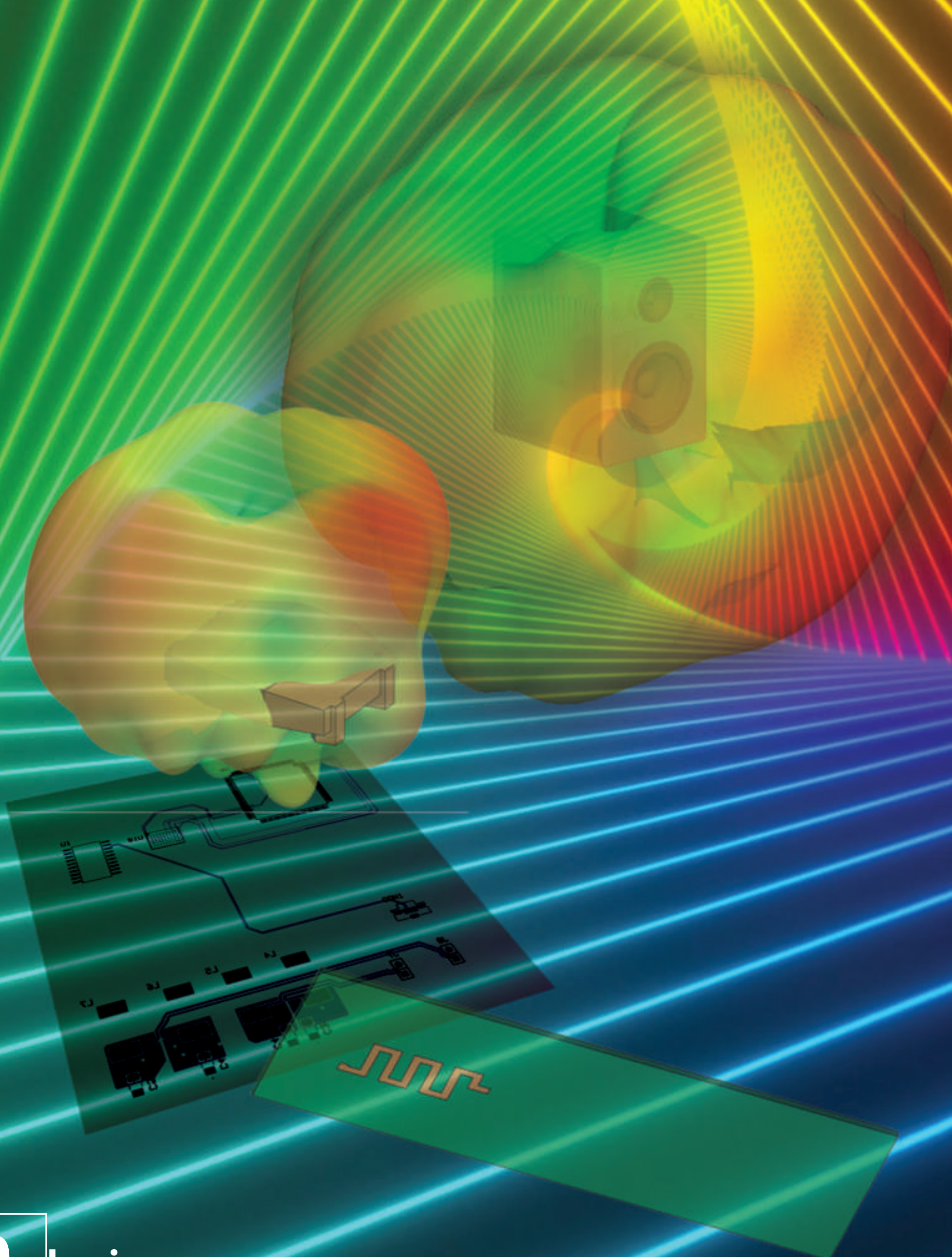

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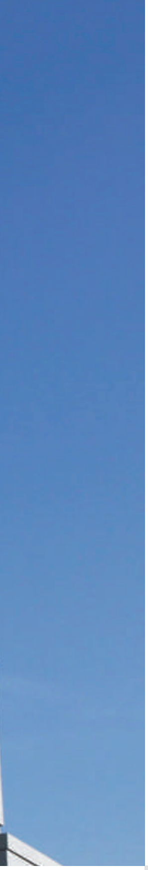

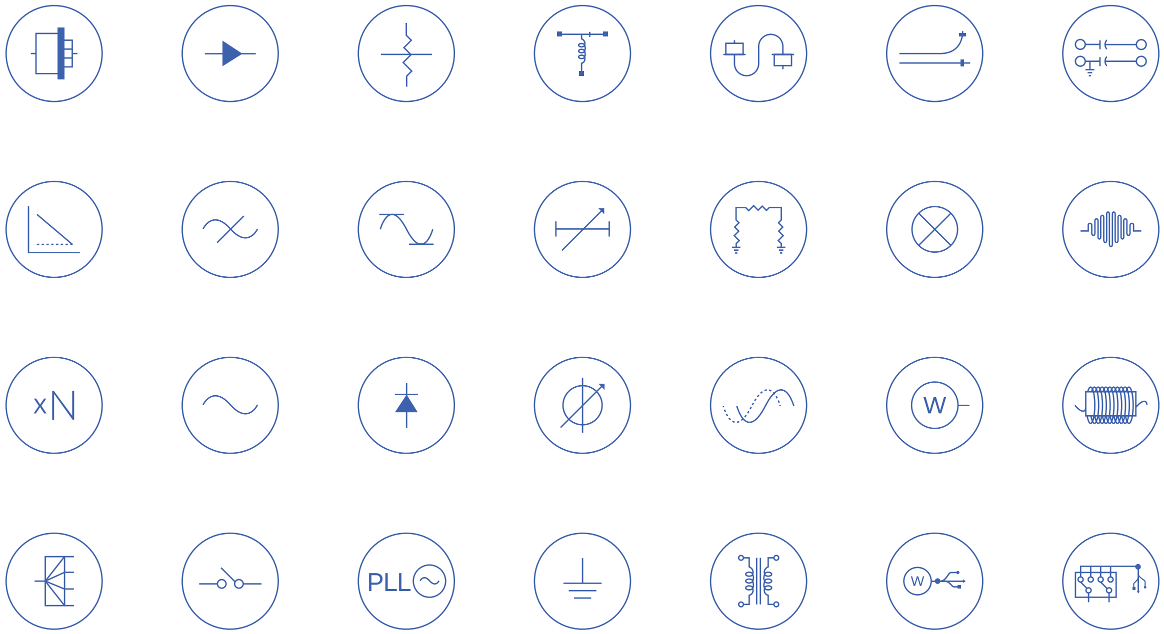

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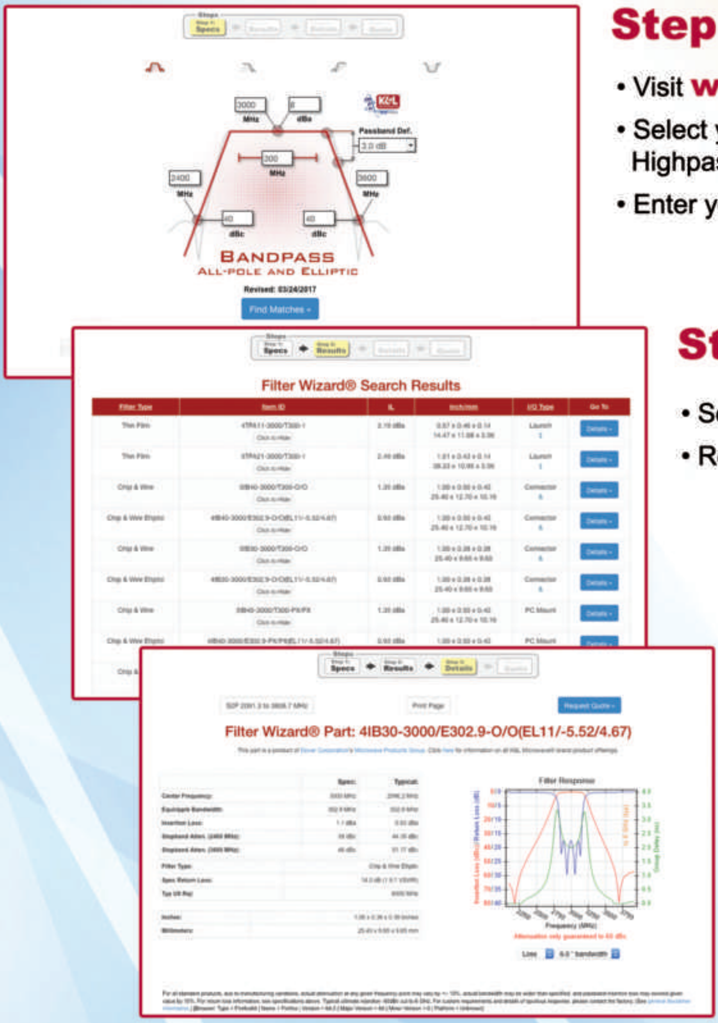

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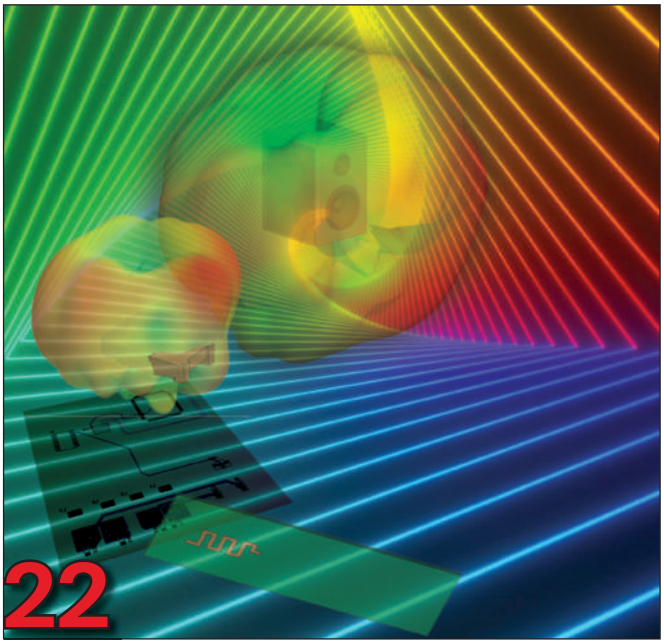

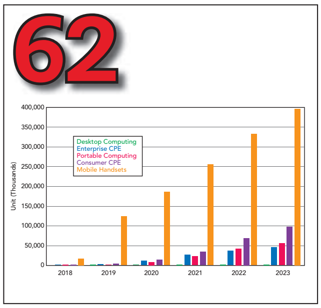

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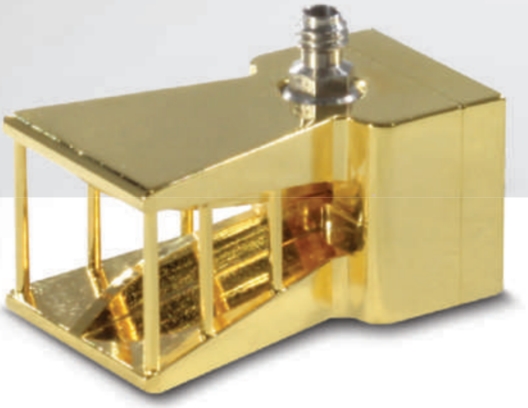

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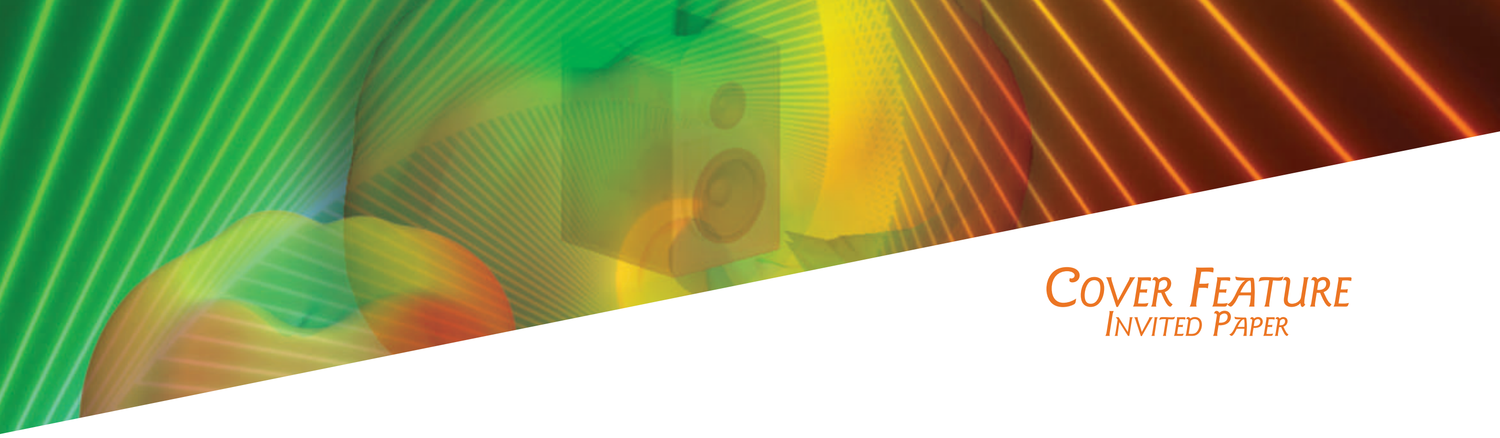

COVER FEATURE
INVITED PAPER

Simulation-Driven Virtual Prototyping of Smart Products

Jaehoon Kim, Smit Baua, Gopinath Gampala and Aniket Hegde
Altair Engineering, Troy, Mich.

Simulation-driven virtual prototyping is employed in the design of modern smart products to accelerate product development speed, ensure intrinsic product qualities and improve the decision-making process during development. It results in smart products that are more cost-effective with higher quality and reliability.

Over the past few decades, the wireless industry has experienced tremendous innovation and transformation, driven by the introduction of wireless communication standards such as 4G LTE, 5G, Bluetooth (BT) and Wi-Fi.[1] This, coupled with new rapid manufacturing techniques, requires advanced product design with complex multiphysics considerations. Competition in the consumer electronics market calls for designs that improve product performance while lowering development costs and reducing time to market. These challenges can be addressed by simulation-driven virtual prototyping to reduce physical testing.[2-4] Moreover, simulation-driven virtual prototyping can be employed in the design of modern smart products to accelerate product development speed, ensure intrinsic product qualities and improve the decision-making process during development. Simulation-driven design is important for ensuring the completeness and timely market launch of smart products.

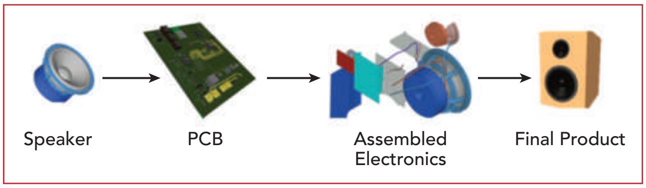

Fig. 1 **Smart speaker components.**

For example, ***Figure 1*** shows the product development process for a smart speaker assembly comprising a speaker component, printed circuit board (PCB), assembled electrical components and cabinet. A three-step simulation-driven virtual prototyping methodology was used in its development: 1) the design, verification and analysis of the PCB; 2) the design and integration of the BT antenna on the PCB inside the speaker cabinet; 3) a wireless communication performance evaluation of the smart speaker considering a neighboring wireless product.

PCB DESIGN

The current generation of smart speakers receives audio signals wirelessly. One of the most popular RF standards supporting audio transmission to speakers is BT. A smart speaker includes a mostly BT wireless section, charging circuitry, audio amplifier for quality audio output, user display and the main controller with mem-

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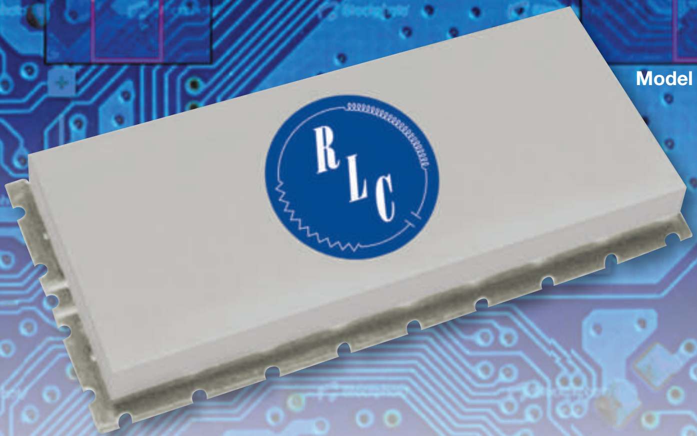
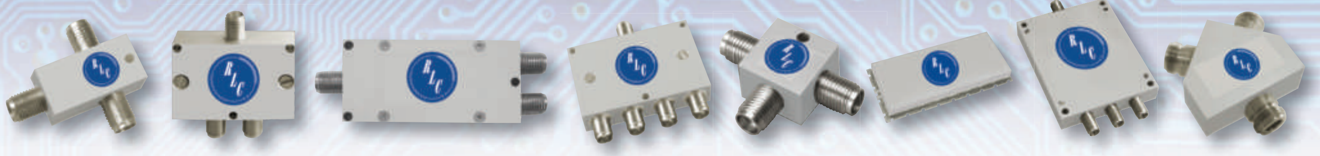


Model DSM-0520-2 shown here



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ory that provides a reliable connection with the functional blocks. For a high-quality smart speaker, aspects such as audio signal quality, BT antenna performance and interference with other wireless signals must be considered.

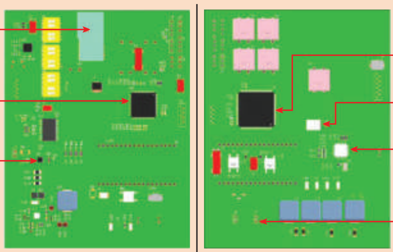

Fig. 2 Assembled PCB top (a) and bottom (b) views.

Figure 2 shows the six-layer PCB with its electronic circuitry, which measures 106 × 137 × 0.7 mm thick. The board contains the audio amplifier; memory for storing wireless information such as pairing details, battery status and smart applications; USB connectivity for charging or diagnosing; charging and power supply circuitry; BT IC and antenna for wireless connectivity; and an LCD driver and display module. A microcontroller synchronizes the functionality of all the parts.

Although the ICs that define operational functionality are important, equally important are the other parts ensuring system reliability. The differential nets in audio lines, connectivity between the controller and the memory IC (i.e., the clock, address, command and data lines), differential data lines from the USB to the controller and the antenna for the BT module are crucial for meeting the quality and efficiency requirements.

VERIFICATION AND ANALYSIS

Layout of the audio, USB and memory lines must be carefully designed for reliable operation, using verification and analysis methods to ensure design integrity. ***Figure 3*** shows the target layouts for verification and analysis of the differential audio and high speed lines (i.e., the USB interface and memory bus). To verify the differential audio line layout, a rule-based checker, Altair's PollEx PCB Verification for Design for Electrical Engineering, was used.[5] Signal integrity (SI) analysis was conducted to evaluate the layout of the high speed

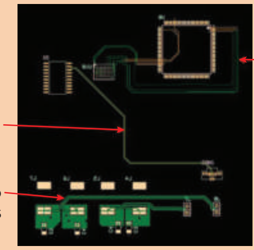

Fig. 3 PCB layout to be verified and analyzed.

lines and the effects on transmitting and receiving digital signal waveforms and voltage/time margins. In addition to SI analysis, the thermal characteristics of the PCB were analyzed. Thermal analysis early in the design stage can identify excessive component temperatures and uneven board temperature.

The 0.5 mm wide differential audio lines were evaluated to assess the paired lines separation and coupling rate, because positive and negative lines must be tightly coupled within a specific distance. In ***Table 1***, the separation criterion (center-to-center distance of 0.75 mm) was determined by adding the line width (0.5 mm) and the spacing between the lines (0.25 mm). The coupling rate criterion of better than 80 percent was determined by considering the structures of the USB IC and connector. From the verification solver, the maximum separation was 0.893 mm between the two lines, with a coupling rate of 76.6 percent. Referring to Table

TABLE 1

DIFFERENTIAL AUDIO LINE DFE RESULTS

	Separation (mm)	Coupling Rate (%)	Ground Shield Ratio (%)
Criterion	0.75	> 80	> 80
Verified	0.893	76.6	Pass

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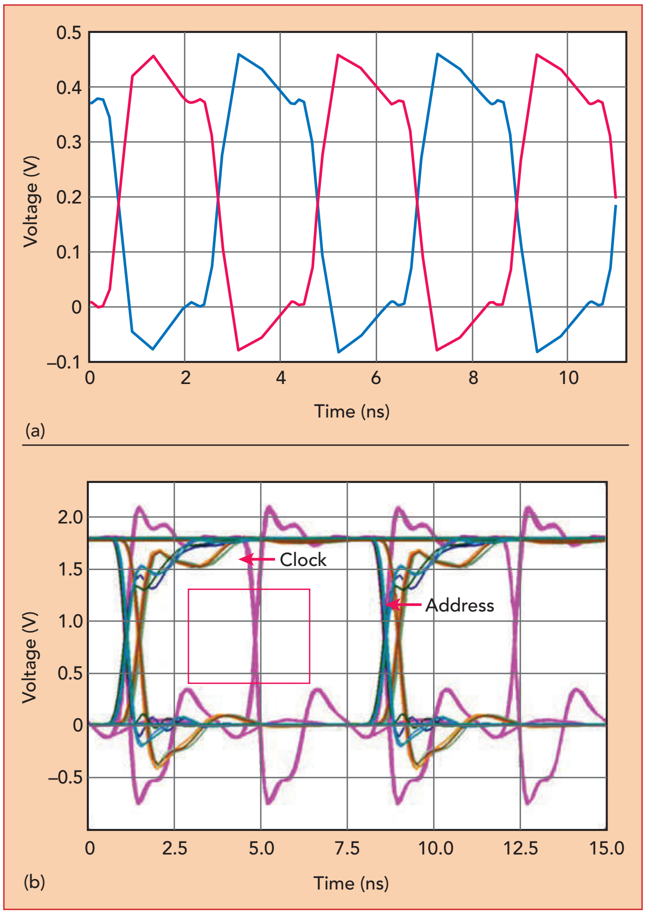
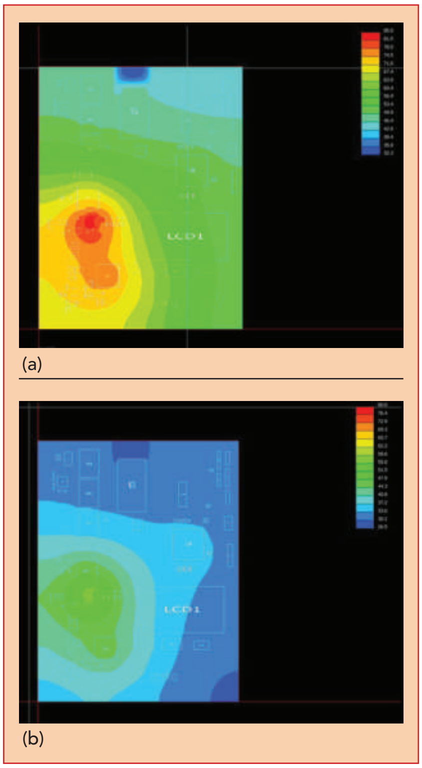
1, the criteria were not satisfied. However, the ground shield ratio, which shows the extent the audio lines are shielded by a ground plane, does meet the specification of greater than 80 percent. These results are useful for verifying the layout of the audio lines.

Figure 4 shows the characteristics of the USB data lines (D+/D-) and memory bus lines, studied using the SI solver in PollEx. For the USB study, the ideal digital signal transmitted from the USB IC and received at the USB connector has a pulse width of 2.08 nS, corresponding to a data rate of 480 Mbps, with a peak voltage of 0.4 V. In Figure 4a, the received signals show enough voltage margin for normal USB operation because both the high threshold (0.3 V) and low threshold (0.1 V) USB 2.0 specifications are satisfied.[6]

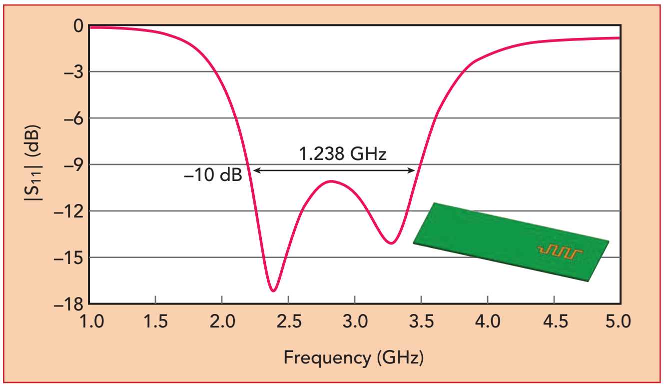


▲ **Fig. 4 SI results: received signals at USB lines (a) and eye diagram for the clock and address lines of the memory bus (b).**

Similarly, the memory interface lines between the controller and the pseudo-static random access memory were analyzed (see Figure 4b). For this analysis, one differential clock line and a group of address lines were selected from the PCB design. The controller was assumed to send the clock signal with a frequency of 133 MHz and the address signals at a data rate of 256 Mbps. The eye diagram was simulated at the memory ports. The clock signal is used as a criterion to estimate the interface with the eye mask, whose



▲ **Fig. 5 PCB surface thermal contours with natural convection (a) and forced air (b).**



▲ Fig. 6 |S_{11}| of the MLA designed for BT.

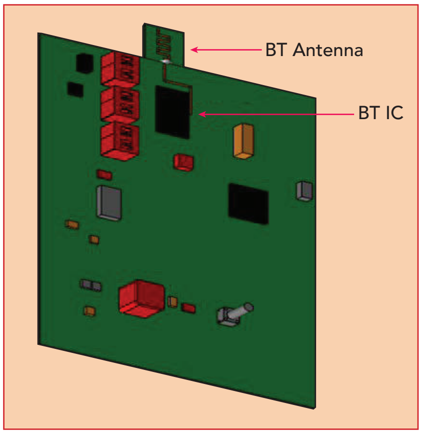
high and low thresholds are 1.3 and 0.4 V, respectively. Additionally, it is assumed that the required setup and hold times for the interface are 2 and 1.5 ns, respectively. As the eye diagram shows sufficient voltage margin, the interface lines are well routed for reliable 256 Mbps data exchange between the controller and memory.

A board thermal analysis was performed to check the main audio amplifier's operating temperature, using the amplifier's quad flat package and 5 W power rating at room temperature. ***Figure 5*** shows the temperature contours for two conditions: 1) natural convection (see Figure 5a) and 2) forced air convection with an air flow of 5 m/s (see Figure 5b). With natural convection, the highest temperature of 85°C is the maximum allowed for normal amplifier operation. Forced convection decreased the temperature from 85°C to 59°C, which improves reliability.

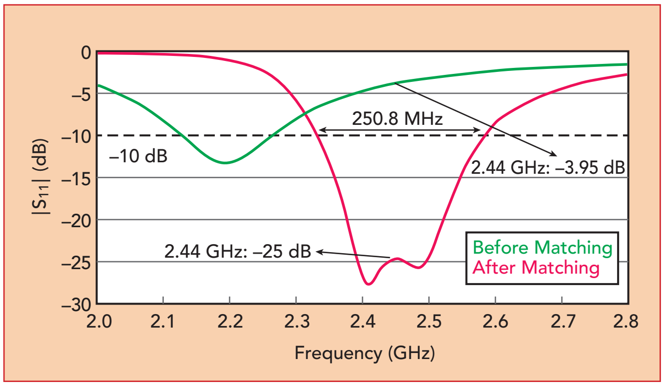
ANTENNA DESIGN AND INTEGRATION

The antenna design was inspired from the meander line antenna (MLA) concept proposed by Rashed and Tai.[7] The antenna was integrated on the PCB and placed in its working environment within the speaker assembly to identify the optimal location. Antenna electromagnetic (EM) characteristics in different configurations changing the location and orientation of the PCB inside the speaker cabinet were simulated using the 3D high frequency EM simulation tool, Altair Feko.[8]

Meandering the antenna increases the surface current path and enables reducing the antenna size. The resonant frequency of an MLA is a function of the meander separation and meander spacing; the resonant frequency can be reduced by increasing the meander separation, and vice versa.[9] As shown in ***Figure 6***, the simulation showed the magnitude of the reflection coefficient of the MLA design on an FR4 substrate was ap-



▲ Fig. 7 MLA integrated with the BT PCB.



▲ Fig. 8 |S_{11}| of the MLA integrated with the PCB.

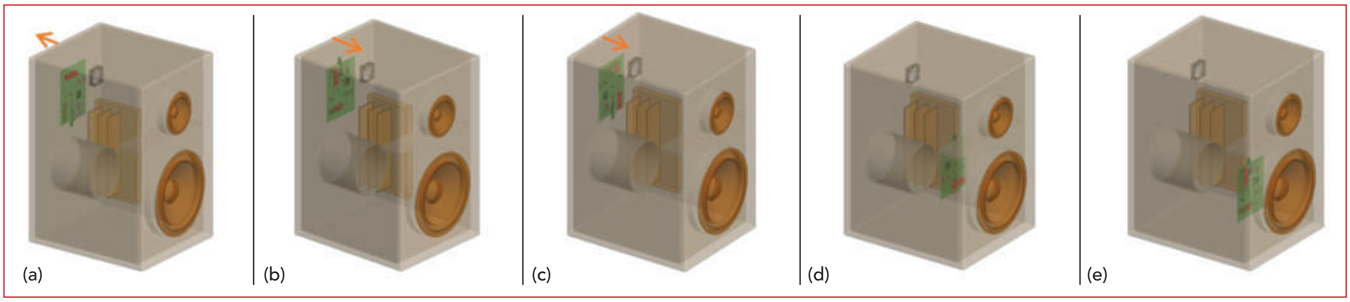


Fig. 9 Antenna locations within the speaker cabinet: 1 (a), 2 (b), 3 (c), 4 (d) and 5 (e).

proximately -17 dB at 2.4 GHz. The MLA integrated on the BT PCB is shown in ***Figure 7***. The components on the PCB surrounding the antenna alter its resonance characteristics significantly (see ***Figure 8***), requiring a matching circuit to restore the performance. The matching circuit comprises a simple LC network with a 0.778 pF series capacitor and a 53 nH shunt inductor, which shifts the resonance back into the BT frequency range.

The speaker cabinet is made of balsa wood with a dielectric constant of 1.3 and dimensions of 355 × 305 × 450 mm. In addition to the PCB, the components inside the speaker include a cooling fan, metallic heat exchanger, acoustic port and the speaker module. The location and orientation of the PCB

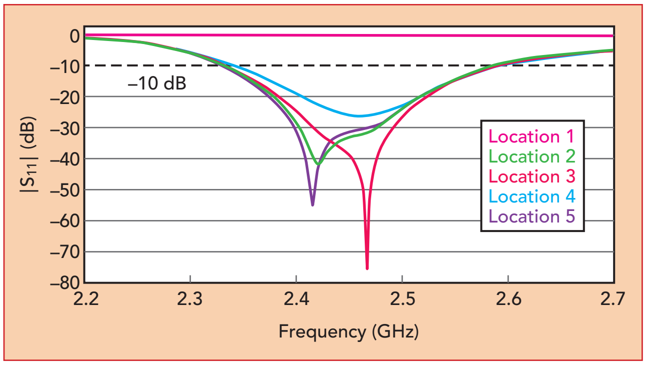


Fig. 10 MLA $|S_{11}|$ for locations 1 to 5.

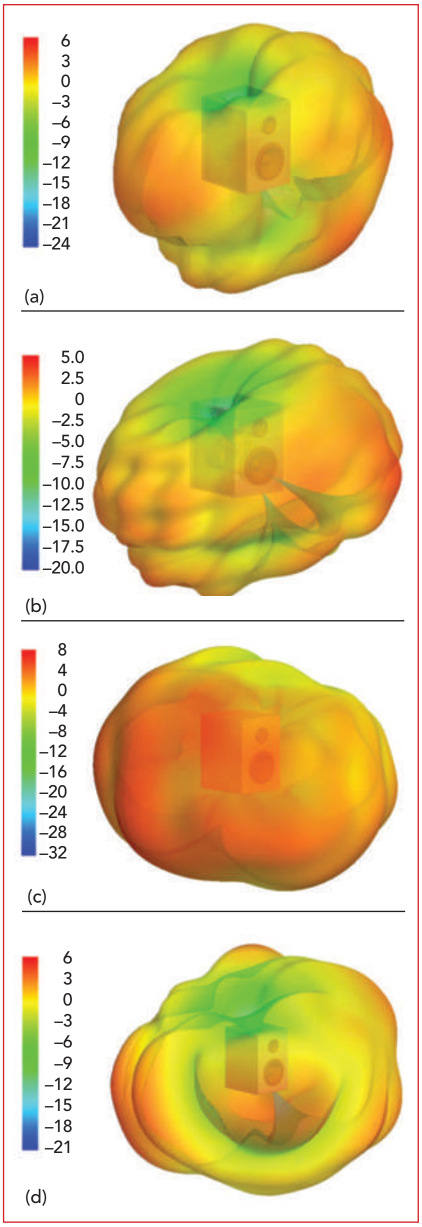


Fig. 11 3D radiation patterns showing the total realized gain (dBi) for locations 2 (a), 3 (b), 4 (c) and 5 (d).

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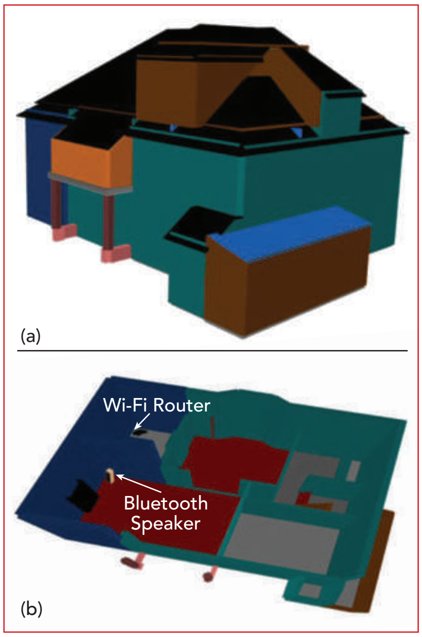

Fig. 12 Multi-story house (a) and cross-section (b) showing the locations of the router and BT speaker.

are influenced by the spacing inside the cabinet, mounting support options and thermal efficiency. Taking these into account with the physical constraints, a complete in-situ analysis of the speaker assembly was performed considering several locations and orientations (see *Figure 9*). Location 1 places the antenna near the back wall of the speaker facing outward, i.e., toward the back side. Locations 2 and 3 mount the PCB on the same back wall facing inward, with the antenna pointed up and down, respectively. Locations 4 and 5 mount the PCB in free space between the components, facing inward and close to the back and front walls, respectively. Comparing the five positions, the magnitude of the reflection coefficient is less than -10 dB for all the locations except 1 (see *Figure 10*). The 3D radiation patterns (see *Figure 11*) show that locations 2 and 3 have nearly omnidirectional coverage along the horizon, which is required for good BT performance.

Fig. 13 Maximum achievable DL throughput for the BT speaker.

Location 2 was chosen for the next step of the analysis, evaluating BT wireless coverage and the speaker's coexistence with Wi-Fi.

WIRELESS COVERAGE AND INTERFERENCE

With the advent of 5G and IoT, the trend is toward smart household electronics, including speakers. These smart devices use standards such as Wi-Fi, BT, LTE and ZigBee for connectivity, and some of these technologies operate in closely separated frequency bands, which can cause interference.[10] BT and Wi-Fi, for example, operate around 2.4 GHz and coexist, although interference from BT can reduce Wi-Fi throughput and vice versa. Analyzing interference through virtual prototyping early in the design stage can avoid costly rework later.

The effect of interference from Wi-Fi on the BT speaker was evaluated inside a multi-story residential building using Altair's wireless propagation and radio network planning software, WinProp.[8] For accurate analysis, the residential building model was detailed, comprising the multi-story design with thick walls, flooring, staircase, fireplace, cabinets, doors, windows and roof (see *Figure 12*). The BT speaker was placed in one corner of the living room and the Wi-Fi router in the corner of an adjacent room (see Figure 12b). The speaker was assumed to use the latest BT5 technology[11] and the Wi-Fi router the 802.11n standard.[12]

The BT speaker has near omnidirectional coverage along the horizon, as shown in Figure 11a. BT is a packet-based protocol with a master/

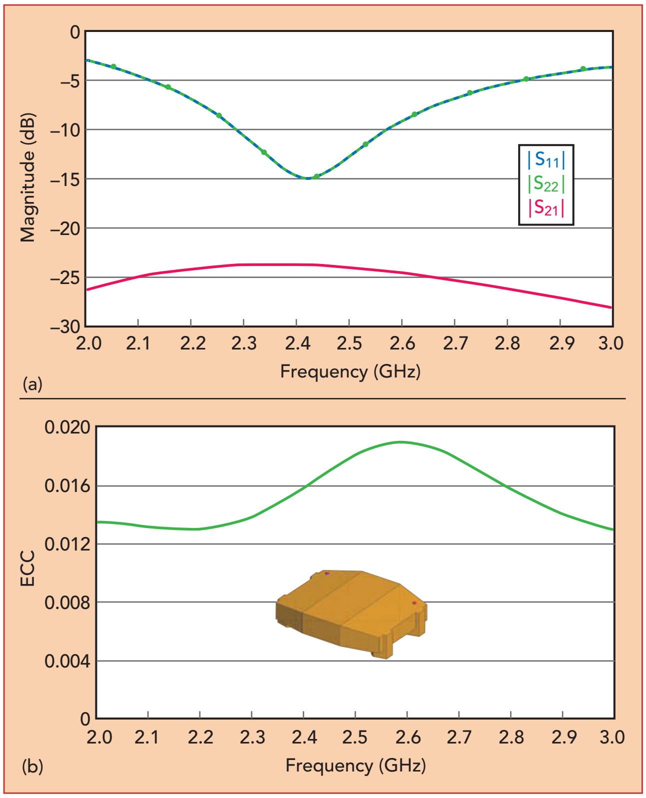

Fig. 14 Wi-Fi router antenna matching and isolation (a) and ECC (b).

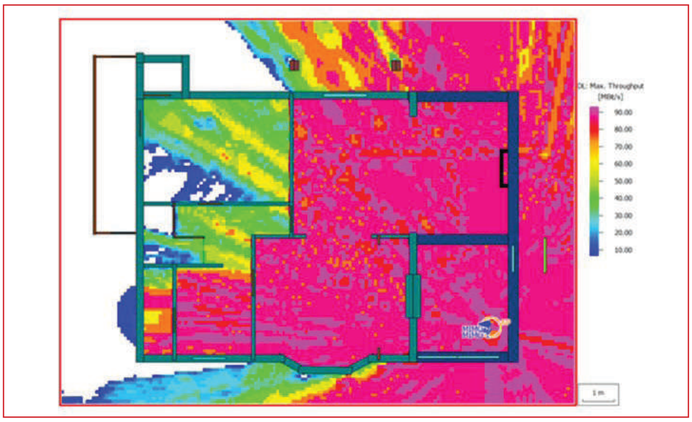

Fig. 15 Maximum achievable Wi-Fi throughput using 802.11n, showing good coverage throughout most of the house.

slave architecture, one master can communicate with up to seven slaves in a piconet. For this CDMA-based technology, the maximum number of codes available for a user on one carrier is seven. As BT supports a maximum data rate of 3 Mbps for the uplink (UL) and downlink (DL) through the enhanced data rate transmission mode, the maximum achievable throughput should be 21 Mbps. Due to non-ideal orthogonality among the codes, however, the maximum achievable DL throughput is 19 Mbps (see ***Figure 13***).

As 802.11n supports MIMO systems, a router with two antennas was used for the analysis, where each antenna carries one data stream in a 2 × 2 MIMO scenario. The router antennas are well matched for the 2.4 GHz Wi-Fi bands (see ***Figure 14a***). For MIMO, the antennas must be well matched at the carrier frequency and well isolated to avoid interstream interference. Figure 14a shows the two antennas have good isolation, approximately ~25 dB. A better indication of independent behavior is the envelope correlation coefficient (ECC), shown in ***Figure 14b***. For MIMO applications, an ECC value of 0.5 is considered okay, higher than 0.5 is considered bad and 0.3 or less is good. Being an orthogonal frequency-division multiplexing technology, 802.11n uses time-division duplex separation. The maximum achievable throughput is, therefore, the maximum achievable data rate. ***Figure 15*** shows the Wi-Fi access point in the modeled location provides good coverage for most of the house.

The Wi-Fi router operates on a 2412 MHz carrier, with the BT at 2442 MHz. The two are close to each other both in frequency and physically in the house. This leads to a decrease in BT throughput due to leakage from Wi-Fi into the BT frequency band, especially in the areas close to the Wi-Fi router (see


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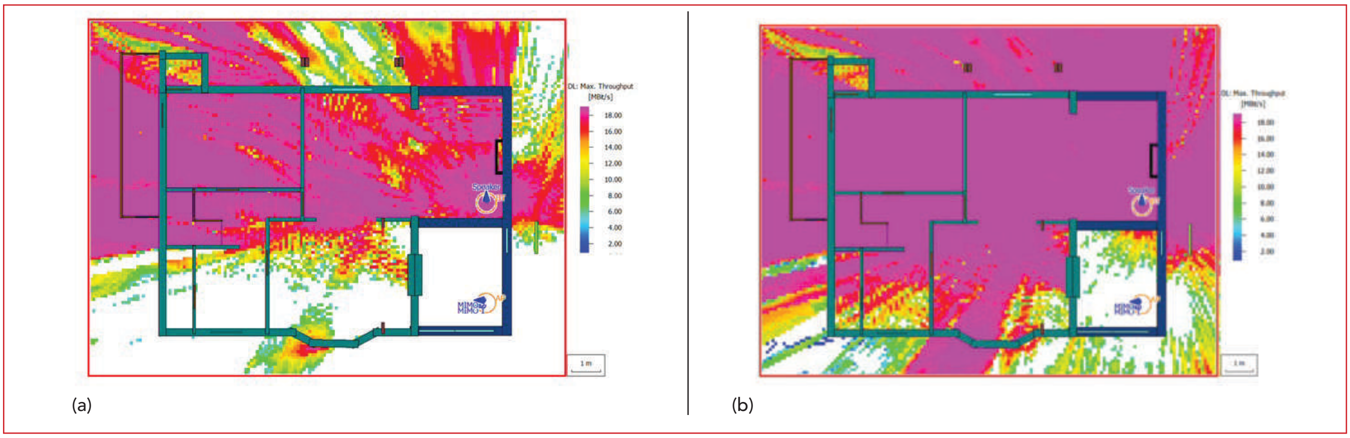

Fig. 16 Effect of Wi-Fi interference on BT throughput: The white area near the Wi-Fi router indicates little BT coverage (a). Coverage can be improved with filtering to attenuate Wi-Fi leakage (b).

Figure 16a). The interference from Wi-Fi to BT can be mitigated with additional filtering in the BT module. When the leakage from Wi-Fi causing the interference is attenuated by an additional 20 dB, the throughput is improved, as shown in ***Figure 16b***.

CONCLUSION

Simulation-driven virtual prototyping used during a smart product's development will reduce development time and ensure the design qualities of the product. These techniques were illustrated in three development stages of a wireless speaker: 1) PCB layout, 2) antenna design and integration and 3) wireless coverage and interference evaluation. Simulation-driven virtual prototyping results in smart products that are more cost-effective and provide higher quality and reliability.■

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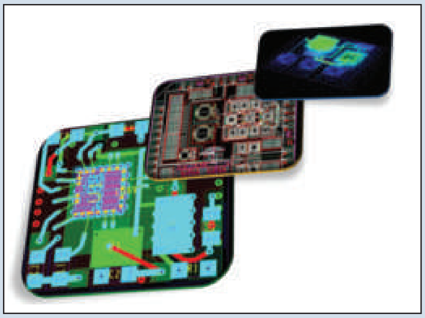

Cadence AWR Design Environment Version 16 Enables Integration of Heterogenous Technologies

Cadence Design Systems, Inc.
San Jose, Calif.

5G wireless systems and connected devices are proliferating across every imaginable industry, driving technology leaders to capitalize on market opportunities for RF-enabled products defined and differentiated by performance, size and cost. Traditionally, custom or proprietary integrated circuit (IC) designs leveraging the latest advanced technology node have been the path forward to realize differentiation, but today's complex designs are moving beyond the chip.

RF and mixed-signal engineering efforts have embraced not only diverse semiconductor processes but advanced cross-fabric packaging and system-in-package (SiP) and package-in-package (PiP) technologies, as well as 3D ICs implemented using advanced interconnect technologies. Successful products require every possible component interaction which might influence the overall performance of the final product be considered at the system level throughout the design, analysis and signoff phases of development. All electrical factors affecting the outcome—micro and macroscopic—must be considered.

To win in the highly competitive 5G wireless markets, companies require electronic design automation (EDA) solutions enabling complete and comprehensive RF workflows from the chip to the system. To this point, engineering teams and EDA platforms, as well as simulation and analysis technologies, have converged to ensure valuable engineering time is spent designing—not transferring and translating data from one tool to another. EDA software developers must provide an efficient front to back end interoperable workflow to maximize user productivity.

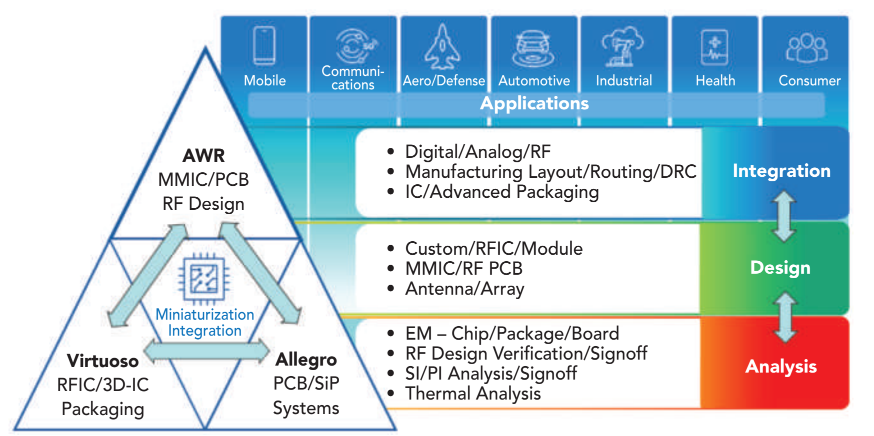

Fig. 1 **The Cadence RF EDA solution provides a comprehensive design workflow.**

With the Cadence acquisition of AWR® from National Instruments in 2020, the latest V16 release of the Cadence® AWR Design Environment® platform offers complete and comprehensive RF workflows (see ***Figure 1***).

HETEROGENEOUS TECHNOLOGIES

Heterogeneous integration mitigates the high cost of homogeneous system-on-chip (SoC) solutions by enabling designers to combine proven RFIC and MMIC designs on substrates using newer packaging technologies. Advanced integration methods such as fan-out wafer-level packaging can result in smaller and more efficient systems, yet these highly integrated systems are more complicated and prone to error from the interdependencies of the individual components, the complex network of cross-fabric interconnects and the challenges of assembling cross-platform design data from multiple sources. Platform interoperability is crucial for multi-technology integration across chip, package and board design (see ***Figure 2***).

The new V16 release of AWR Design Environment enables at least a 50 percent reduction in turnaround time through workflow automation. It achieves this by leveraging RF intellectual property (IP) creation and cross-platform simulation, including the IC and package (Virtuoso flow) and the board (Allegro flow). Additionally, integration and interoperability of the Clarity™ 3D Solver and Celsius® Thermal Solver provide electrothermal

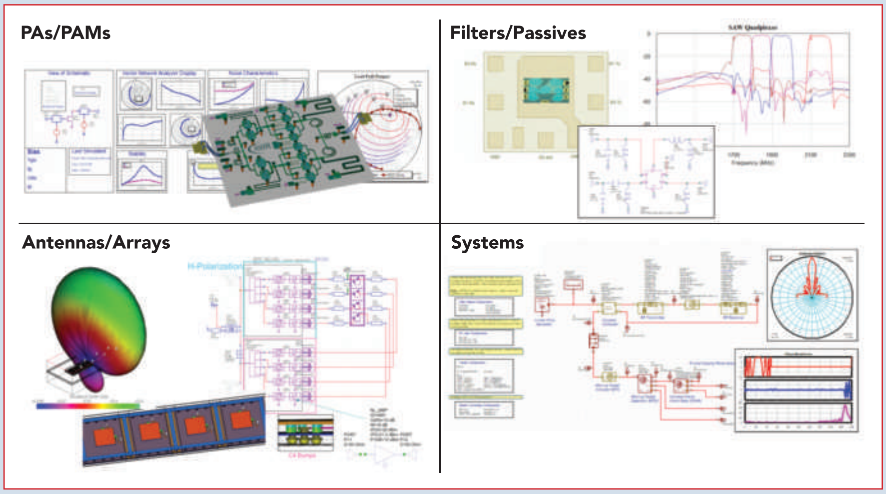

Fig. 2 The AWR software platform supports IC to system design.

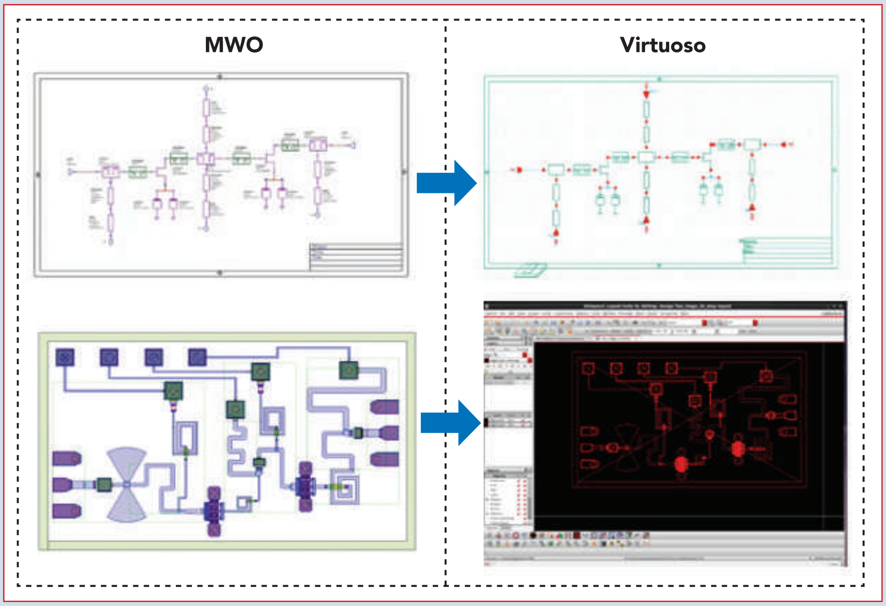

Fig. 3 A two-stage MMIC amplifier design imported from AWR into Virtuoso.

co-simulation and coupled analyses of large, densely populated designs such as RF front-ends. The RF workflow innovations enabled by the V16 release start with a foundational advance in the way design data and software IP are shared and transferred across manufacturing-specific design platforms. Under the Cadence umbrella, the level of RF integration being introduced with V16 software significantly improves engineering team productivity.

Cadence platforms have continually evolved to address the manufacturing, design and analysis requirements of the process technologies they support, with the design flow automation to manage the development of extremely complex chip, package and board systems. As system-level integration calls for RF design across these different technologies, prior to starting the design, engineers are pulling information from multiple sources: business requirements, reliability constraints, manufacturing processes and supply chain data. For enterprises and large design teams, the need to efficiently share libraries and work with company-authorized and pre-approved component parts and material stackups adds to the challenge of getting a product to market quickly. Interoperability between platforms is necessary to share design data and leverage the unique features of the different tools and reduce or eliminate system integration bottlenecks. Any disconnect between the RF design and manufacturing layout teams consumes engineering resources and directly impacts development schedules.

Imagine RF IP created within AWR software seamlessly integrated into systems designed with newer process technologies and integration methodologies. Development teams now have a highly efficient RF workflow enabling them to extract AWR RF IP/design data and reuse it in the appropriate RFIC, PCB or SiP platform. The V16 release introduces this support for Cadence unified libraries and technology files, establishing interoperability between the AWR, Virtuoso and Allegro platforms.

VIRTUOSO & AWR WORKFLOW

Leveraging a shared architecture and data across the Cadence EDA solutions, the V16 release provides for new RF workflows taking completed designs from Microwave Office software and passing both the schematic and layout to the Virtuoso and/or Allegro platforms. The data is in a unified library and contains all the building blocks of the circuit design. This enables design teams to operate the Allegro SiP or Virtuoso SiP bidirectional implementation flow and Virtuoso RF Solution physical implementation flow as the primary layout tool, with V16 software providing the RF IP schematic and layout design data. The Virtuoso RF Solution flow captures Microwave Office RF IP, enabling designers to represent, integrate and verify the MMIC and embedded RF package design within a single environment. The shared database enables more practical package and IC co-design by simplifying the design flow with easy and reliable access to RF IP developed within Microwave Office.

For example, Microwave Office users can design passive off-chip components through circuit design, optimization and EM verification and then decide the best implementation technology. In some cases, a network of passive components may best be implemented across the IC package boundary. This is often true for RF modules, where the ideal filter design, matching networks and power amplifier output stage load termination use components on both the die and the package substrate.

Within the Virtuoso RF Solution environment, the Spectre® Simulation Platform engine can simulate Microwave Office linear models to support IC and module co-design with embedded Microwave Office IP. The ability to import this IP into the Virtuoso flow extends to MMIC designs. Since most MMIC model and PCell libraries are defined and implemented by the III-V foundry as a process design kit (PDK), the Microwave Office MMIC design flow uses this PDK for the target semiconductor process in the design. The resulting MMIC schematic and layout can then be exported as a unified library design and imported into the Virtuoso environment (see ***Figure 3***).

ALLEGRO & AWR WORKFLOW

Moving from the IC to the board, an RF to PCB workflow starts with the creation

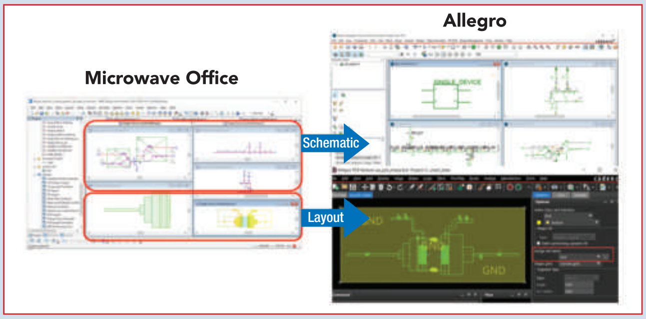

Fig. 4 Allegro RF to PCB workflow using the V16 import wizard.

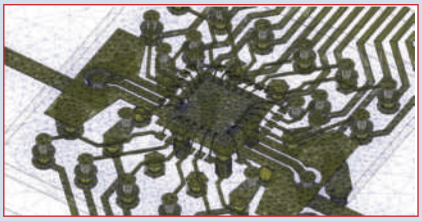

Fig. 5 Microwave Office V16 provides large scale EM analysis using Clarity.

of unified libraries and technical files from Allegro parts and board definitions. The new unified library import wizard in V16 software reads the Allegro symbols and footprints in the universal library and technology file and converts this data into an AWR PDK that can be used to create an RF design using standard design entry and simulation methods. After completing the design, the RF engineer exports the schematic and layout of the subcircuit with all the underlying hierarchy into a unified library design using a new utility in AWR V16 software (see ***Figure 4***).

On the back end, the layout engineer needs access to the uncompromised data designed to the company approved bill of materials (BOM) and target manufacturing process. Starting with Allegro-sourced component parts from an organization's approved BOM and process technologies, the RF engineering and layout teams can then improve design hand-off efficiency and reliability while reducing the back and forth to reconcile differences between RF design and manufacturing requirements.

MULTIPHYSICS

Historically, large RF structures, such as phased-array feed networks, have been manually sectioned into smaller structures for analysis using the largest and most powerful computing resources. The Clarity 3D Solver 3D EM simulator, used for designing critical interconnect, RFIC, MMIC, module, PCB and SoC designs, overcomes the limitations of legacy EM analysis software by leveraging Cadence's distributed multiprocessing technology, which delivers virtually unlimited capacity at 10x the speed. Now integrated within AWR software, the Clarity 3D Solver provides RF designers with ready access to high capacity EM analysis for design verification and signoff of large, complex RF/mixed-signal systems, with capabilities beyond those offered by the AWR AXIEM 3D planar and AWR Analyst 3D finite element method (FEM) solvers.

Clarity integration with the Microwave Office platform is an automated process where the entire analysis is fully within the AWR environment. Once simulation is complete, a dataset with input geometry, simulation setup and S-parameter results is automatically assembled and associated with the given EM document for plot, measurement and subsequent extraction, circuit simulation, tuning and optimization. The link supports mesh, current and field visualization data in addition to S-parameters, enabling designers to use the rich set of EM 3D annotations already in the AWR Design Environment platform (see ***Figure 5***).

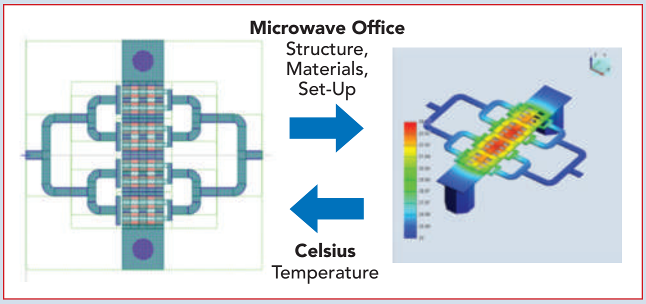

Fig. 6 **Coupled electrothermal analysis with Celsius Thermal Solver.**

THERMAL ANALYSIS

IC and electronic system companies, particularly those using IC packaging and/or multi-technology modules, face thermal challenges that can derail project schedules. The Cadence Celsius Thermal Solver within AWR software offers a solution for RF device, PCB and module designs supporting electrothermal analysis using model information sourced from AWR Microwave Office software, using existing MMIC design data and geometries such as layout, material properties and power source values from the RF simulation. The solver provides a full IC temperature profile at the relevant resolution of the IC layout, available as a graphically viewable 3D temperature overlay, as well as a temperature-annotated netlist for circuit simulation, as shown in ***Figure 6***.

Thermal analysis provides insight regarding the operating temperatures that can degrade RF performance and threaten device reliability. By using model and power dissipation information obtained from Microwave Office software directly in Celsius Thermal Solver, designers can achieve better accuracy. Additional objects such as a heat sink can be added to the die and exported as a new structure for thermal analysis, which enables designers to investigate heat sinking strategies to best manage heat.

SUMMARY

As RF-enabled systems proliferate and adopt heterogeneous technology integration for greater functionality in smaller footprints, design platforms and multi-technology workflows must be interoperable. The AWR Design Environment V16 platform encompasses innovative functionality increasing engineering productivity through seamless cross-platform and multiphysics integration of the AWR platform RF/microwave design IP within the Virtuoso and Allegro design platforms, as well as EM and thermal analysis of complete large-scale designs through Clarity and Celsius solvers.

Engineers working from the IC through the system can better address cross-fabric, multi-technology product development challenges within the comprehensive front-to-back RF workflows offered by Cadence. AWR V16 is further streamlining product development and user productivity, eliminating inefficiency and lost insight when designers spend unproductive time and cycles switching among siloed tools.

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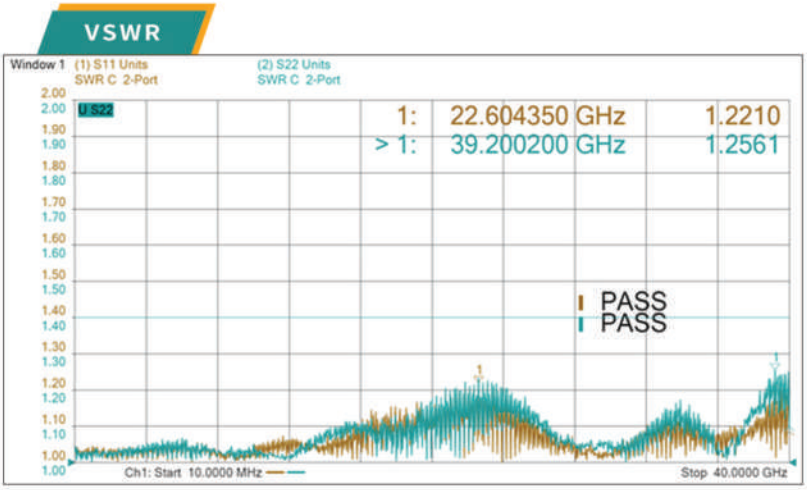

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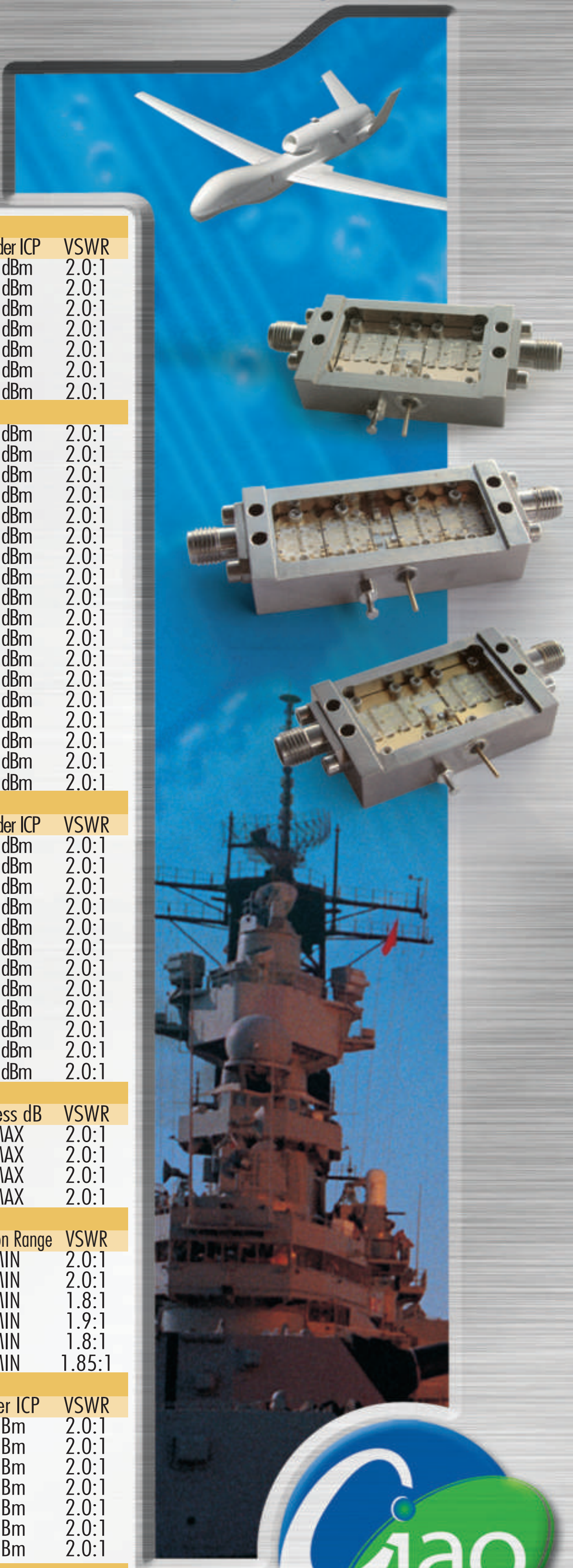

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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DefenseNews
Cliff Drubin, Associate Technical Editor

Quantum Communication in Space Moves Ahead

A new generation of supercomputing power delivered by quantum computers is currently being developed that will be almost unimaginably powerful at cracking the most complex problems upon which encryption it is based.

The European Space Agency (ESA) has formed a Partnership Project with Arqit, a leader in the quantum encryption field, based in the U.K., to keep information safe in a world where quantum computers are becoming commonplace.

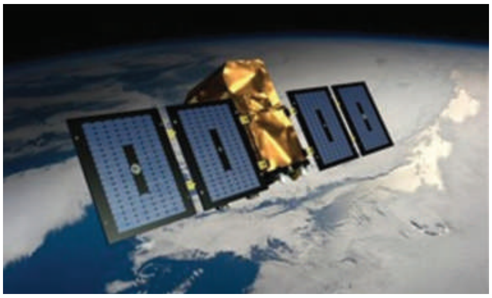
ArQit recently announced that it was merging with a subsidiary of Centricus, a global investment firm, in a transaction expected to provide Arqit with up to €330 million in gross proceeds.

The deal fully finances Arqit's endeavors to develop state-of-the-art satellites for quantum key distribution, dubbed QKDSat, through its key provision platform.

QKDSat distributes symmetric keys through a cloud-based system to end-use devices, with a tiny computational load of less than 200 lines of code, leveraging the laws of quantum physics to prevent any eavesdropper from gaining access to the encryption key.

A series of QKDSat satellites will enable the exchange and distribution of secure encryption keys to countless locations and billions of devices anywhere in the world, thanks to their optical quantum space-to-ground link. This improves resilience to future hacking threats because the quantum keys are generated from high-quality random sources and distributed across the cloud network.

QKDSat is being developed as an ESA Partnership Project, which brings together the skills, expertise and resources of the agency to support the development of commercial applications of space technology in a public-private partnership. In 2019 ESA placed a contract with Arqit co-funding the development of the first QKDSat satellite. The development is progressing and the satellite is due for launch in 2023. Under U.K.-based Arqit's leadership, QKDSat is being developed by a pan-European team from several other ESA member states including Austria, Belgium, Canada and the Czech Republic.



Comm Satellite (Source: ESA)

Artificial Intelligence Used at Sea for the First Time

This operational experiment on the Type 45 Destroyer (HMS Dragon) and Type 23 Frigate (HMS Lancaster) used artificial intelligence (AI) applications, Startle and Sycoiea, which were tested against a supersonic missile threat as part of Europe's recent Formidable Shield air and missile exercise.

As part of the Above Water Systems programme, led by Defence Science and Technology Laboratory (Dstl) scientists, AI improves the early detection of lethal threats, accelerates engagement timelines and provides Royal Navy Commanders with rapid hazard assessments to select optimum weapons or measures to counter and destroy targets.

Dstl has worked closely with industry partners Roke (Startle App), CGI (Sycoiea App) and BAE Systems to ensure the new AI-based applications work alongside existing radar and combat management systems.

The Startle AI system is designed to help ease the load on sailors monitoring the 'Air Picture' in the Operations Room, providing live recommendations and alerts. The Sycoiea system builds upon this with threat evaluation and weapons assignments identifying the nearest threat and how best to deal with it.

Exercise Formidable Shield is Europe's biggest and most complex air and missile exercise. Designed to improve allied interoperability and capabilities, it is a three-week exercise that carries out live-fire integrated air and missile defense activity with more than 15 ships, 10 aircraft and around 3,300 military personnel from around the world taking part.

Held every two years, Formidable Shield is led by NATO Naval Striking and Support Forces on behalf of the U.S. Sixth Fleet. Using NATO command and control reporting structures, 10 nations participated this year, including Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, the U.K. and the U.S.

Enabling Human Control of Autonomous Partners

A major benefit of increasingly advanced automation and AI technology is decreased workload and greater safety for human—whether it is driving a vehicle, piloting an airplane or patrolling a dangerous street in a deployed location with the aid of autonomous ground and airborne squad mates. But when there is a technology glitch and machines do not function as designed, human partners in human-machine teams may quickly become overwhelmed trying to understand their environment at a critical moment—

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especially when they have become accustomed to and reliant on the machine's capabilities.

This reality played out in crashes of modern jetliners in recent years killing hundreds, because advanced automated systems failed in flight and pilots were not able to assess the situation and respond appropriately in time. Such examples underscore the need to design human-machine interfaces (HMIs) that allow humans to maintain situational awareness of highly automated and autonomous systems so that they can adapt in the face of unforeseen circumstances.

DARPA recently announced its Enhancing Design for Graceful Extensibility (EDGE) program, which aims to create a suite of HMI design tools to be integrated into systems design processes. By prioritizing and orienting these tools toward quantifying, supporting and testing situational awareness—rather than on cognitive load at the expense of situational awareness—EDGE will help create HMI systems that allow operators to not just monitor autonomous systems but also adapt their use to meet the needs of unanticipated situations.

"As highly automated machines and AI-enabled systems have become more and more complicated, the trend in HMI development has been to reduce cognitive workload on humans as much as possible. Unfortunately, the easiest way to do this is by limiting information transfer," said Bart Russell, EDGE program manager in DARPA's Defense Sciences Office. "Reducing workload is important because an overloaded person cannot make good decisions. But limiting information erodes situational awareness, making it difficult for human operators to know how to adapt when the AI does not function as designed. Current AI systems tend to be brittle—they don't handle unexpected situations well—and warfare is defined by the unexpected."

The EDGE design tools will focus on supporting the ability of operators of autonomous systems, who are not necessarily data scientists or AI experts, to understand enough about the abstract functioning of a system that they can adapt with it when they encounter off-nominal situations. Designers will be able to leverage EDGE design tools to create HMIs that help operators understand an AI system's processes, or how it works; the system's status against its performance envelope (i.e., if it is in its "comfort zone," or near the edges of its speed, range, etc.); and the environmental context, which is often where the most unanticipated elements come in.

The suite of EDGE HMI design tools will include models that quantify situational awareness demands to enable detailed co-design between software engineers and HMI designers, composable design methods to speed and mature design implementation and an HMI breadboard for realistic test and verification early in the design process.

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RIC to Become the Operating System for Future 5G RAN

In collaboration with global Tier-1 operators and vendor partners, the O-RAN ALLIANCE aims to reshape radio access network (RAN) deployment toward more intelligent, virtualized and multi-vendor interposable strategies. By disaggregating software from hardware and developing standardized interfaces and open reference designs, a flexible and agile network architecture is expected to help operators reduce the total cost of ownership and offer end-users an optimized quality of experience. Among many research activities, the RAN Intelligent Controller (RIC) platform and corresponding xAPPs/rAPPs development are mainstream focuses and have attracted much attention from the telco community. Open RAN RIC will disrupt the status quo and create new opportunities for a wider ecosystem in this market segment. ABI Research expects the trend of standard RIC deployment to dominate the market around 2024 and 2025.

"The O-RAN ALLIANCE specified the RIC framework and corresponding interfaces for both non-real-time (RT) RIC and near-RT RIC addresses increased network service requirements from different verticals and complex RAN operation with automation," explained Jiancao Hou, 5G & Mobile Network Infrastructure senior analyst at ABI Research. "The separation of RIC functionality according to different time scales (i.e., non-RT and near-RT) aims to facilitate a vast reduction in development and deployment costs, while helping to drive standardization and expand the ecosystem in a timely manner." Moreover, "Designing non-RT RIC functionality in a service management and orchestration platform, but not the RAN itself, secures access to contextual information and coordinated optimization of radio resources and network policies."

Promising application use cases for RIC can be divided into three main categories, including proactive radio resource management, massive MIMO optimization and interference mitigation, with other system applications such as end-to-end network slicing, key performance indicator monitoring and anomaly detection. The list does not limit actual RIC application use cases. Depending on the specific implementation environment in either the consumer market or enterprise market, more use cases, such as precise positioning, highly accurate channel estimation and power saving, can be introduced for different service-level assurance.

The development of RIC solutions is expanding rapidly, but the new approach may not dominate mainstream global deployment within the next two to three years due to ongoing standardization and the lack of a mature application ecosystem.

Over 500 Operators in More Than 170 Countries Now Hold Spectrum Licenses for Low-Band LTE or 5G

The Global mobile Suppliers Association (GSA) recently announced that 515 operators in 173 countries now hold licenses enabling the launch of LTE or 5G using the low-band spectrum and that nearly 400 operators are known to have launched LTE or 5G networks using this spectrum.

In its new "Low-Band Spectrum for LTE and 5G Report," GSA reported that not only are there now over 15,000 LTE devices that can support the low bands according to its GAMBoD database, but that out of 316 announced 5G devices supporting the low-band spectrum for new radio (NR), 219 are already commercially available.

This latest report also discloses that 37 countries/territories have announced formal (date-specified) plans for allocating 5G-suitable low-band frequencies between now and 2022 (including technology-neutral licenses or licenses for mobile broadband services). As a result, GSA foresees an increase in the number of auctions of low-band spectrum in the coming years, as well as 5G NR deployments using already assigned spectrum licenses.

"Low-band spectrum is very important for expanding network coverage especially in suburban/rural deployment scenarios, ensuring service continuity across different geographies, enhancing service quality in indoor environments and helping to close the digital divide," commented Joe Barrett, president of the GSA. "Mobile operators are demanding low-band spectrum, and some specific bands like 410 to 430 MHz, 450 MHz or 900 MHz also play important roles in specific industries for the creation of private networks. For these reasons, GSA foresees an increase in the number of auctions of low-band spectrum in the coming years, as well as 5G NR deployments using already assigned spectrum licenses."

With 681 Million 5G Handsets Set to Ship in 2022, Mobile Device Vendors Scramble for Differentiation

Despite a backdrop of the ongoing effects of the pandemic and the geopolitical landscape, the impact on 5G supply chains throughout the past year has been minimal when compared to the wider smartphone market. This has led to 5G mobile device models becoming more diverse, brought to market quickly at a wide variety of price points, accelerating affordability and adoption. The mobile market is

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quickly transitioning to 5G and many leading OEMs are pushing deeper into the lower-priced 5G smartphone segment. According to a new report from ABI Research, 681 million 5G handsets will be shipped in 2022. The race is on for OEMs to find that all-important level of differentiation in their flagship portfolios to help boost margins and improve market share.

While there is a continuing need for vendors to drive adoption of cutting-edge trends in industrial designs, screen technology, chipsets and camera setups, notably in flagship smartphones, they are also looking to alternative points of differentiation to keep pushing the envelope on innovation and an enhanced user experience. "As the market will bear witness over the next 12 to 18 months, and with the quickening ubiquity of 5G, upcoming flagship smartphones from key vendors will need to embrace a host of additional features and functionalities to continue to provide industry-leading high-end products," commented David McQueen, research director at ABI Research. "Upcoming 5G flagships from leading vendors, such as Apple, Samsung, Xiaomi and OPPO, are expected to incorporate new features and form factor innovations such as ultra-wideband (UWB) and Wi-Fi 6 connectivity, super-fast charging technologies, foldable and rollable displays and improved camera setups. These are all designed to help spark further evolution in device user interfaces, the growth in technology ecosystems and enhanced experiences."

> **Upcoming flagship smartphones must embrace a host of additional features and functionalities to continue to provide industry-leading high-end products.**

While 5G is quickly penetrating smartphones, there is anticipation that 5G integration and "always-on" connectivity will appear more readily on tablets, Chromebooks and notebooks as the portable computing and mobile value chains converge more than ever. With a slew of new models due out in the next year, 5G is set to become a more prominent feature of these device types, with Samsung, Apple and Huawei all lined up to create more 5G connected compute devices, benefiting from their vertical integration approach.

Cellular connected compute devices have only accounted for a small proportion of sales due to their mostly nomadic use case and high price differential, but it is expected that dozens of always-on 5G portable device models, tablets, notebooks and ultrabooks will hit the market in 2021; and, according to ABI Research, sales of these 5G devices will exceed 10 million by 2022.

Remembering Howard Ellowitz

By Harlan Howe Jr.

Howard Ellowitz, who passed away on May 23, 2021 at age 95, had a long and prestigious career with significant impact on the microwave community. He married his childhood sweetheart, Charlotte Brandwene, and they enjoyed over 72 years of marriage. He started as an engineer in the semiconductor group at Microwave Associates and continued at Alpha Industries until he joined Horizon House in 1973 as Publisher and Editor of *Microwave Journal*. He also served briefly as the first Publisher and Editor of the *Journal of Electronic Defense*.

When the IEEE MTT-S decided to add a professional exhibition to the annual International Microwave Symposium in 1976, Horizon House won the contract and Howard became the Exhibition Manager. He continued to serve in that capacity for 32 years. During that period he interacted with many of the pioneers and presidents of the microwave industry, made many personal friends, a few golfing buddies and advised, when requested, on marketing aspects of the industry's growth. He also maintained the integrity of the IEEE MTT-S contract by treating all exhibitors equally.

In 1989 Howard announced his intention to retire. During the previous five years, I had served as a guest editor a few times. Howard called me and asked if I was interested in taking his job. After clearing up some personal obligations, I joined Horizon House in 1990 as the new Publisher/Editor of MWJ. While Howard no longer had the day-to-day responsibilities of the magazine, he was far from retired. He continued to manage the IEEE MTT-S exhibition for another 18 years until he really retired in 2008.

On a personal note, Howard was a good friend, colleague and mentor. We worked hard together, met some wonderful people and above all, we had a lot of fun and good times. The good times are the most important memory.

Howard hired me in 1988 as the Northeast Regional Sales Manager for *Microwave Journal*. He took a chance on a young but enthusiastic guy with no experience in B2B media. I like to think that his decision was a good one, as I eventually became Publisher upon Harlan's retirement from the role. I further followed in Howard's footsteps by transitioning to Exhibition Director for the IEEE MTT-S IMS event.

Howard navigated *Microwave Journal* and IMS through many years and many challenges, always in a stern but fair manner. For IMS, his goal was to apply the rules set out by IEEE evenly and without bias. It could be trying for a salesperson like myself dealing with clients, but it kept everyone on an even playing field. And *Microwave Journal* and IMS both thrived under his long tenure.

Howard was both a mentor and a friend. He taught me a lot about the microwave industry and the media and event business. I found him to be a straightforward, honest and kind person. He will be missed.

Carl Sheffres

COLLABORATIONS

ERZIA Technologies announced a successful ELINT system collaboration with **Raytheon Deutschland GmbH**. Electronic Intelligence (ELINT) systems are dedicated to obtaining as much information as possible from radar and electromagnetic (EM) sources present in a determined area. These systems are widely used in modern armies to detect, identify and classify EM signals from RADARs, communication emitters and hostile jammers for threat intelligence characterization and analysis. These ELINT detection systems are continually evolving as the RF sources are constantly introducing sophisticated techniques that make adversary radar signals more difficult to detect.

Kyocera Corp. and **AVX Corp.** announced that the companies have established a new integrated brand, "KYOCERA AVX," to be used for the Kyocera group's electronic components business starting in October 2021 (or later) following the integration of Kyocera's "Corporate Electronic Components Group" and "AVX" into a new segment, "Electronic Components Business" as of April 1, 2021. The new brand structure will accelerate and strengthen the growth of Kyocera's electronic components business worldwide. In addition, sales organizations in the U.S. and Europe will unify starting in October 2021 (or later), and sales in Japan, China and other Asian nations will follow beginning in April 2022 (or later).

The European Space Agency has formed a Partnership Project with **Arqit**—a leader in the quantum encryption field, based in the U.K.—to keep information safe in a world where quantum computers are becoming commonplace. This new generation of supercomputing power, delivered by quantum computers, is currently being developed to be powerful at cracking the most complex prob-

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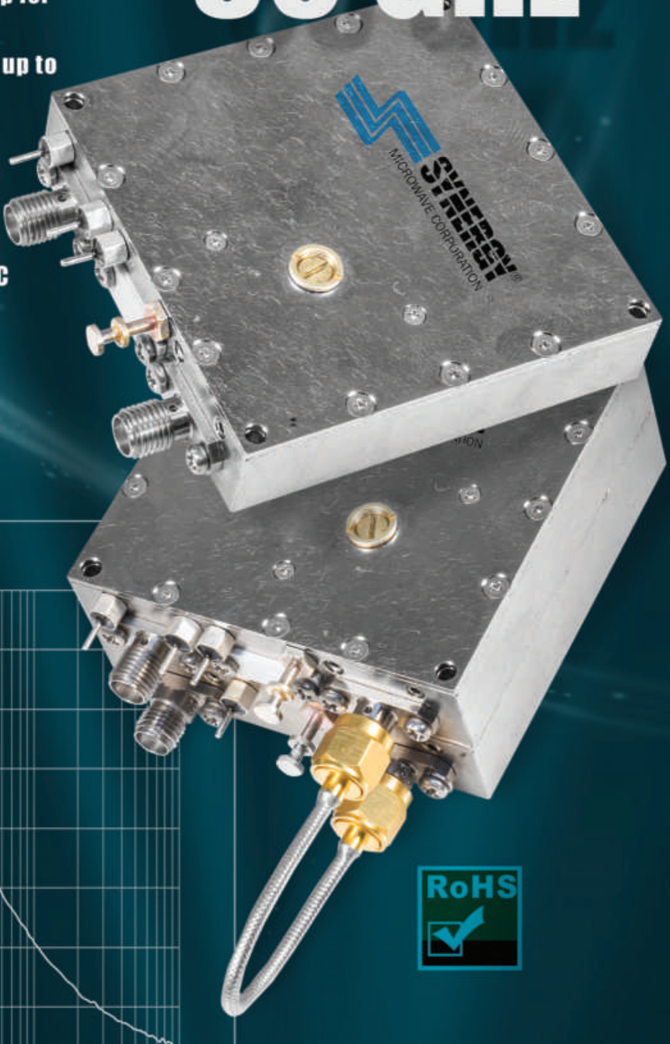

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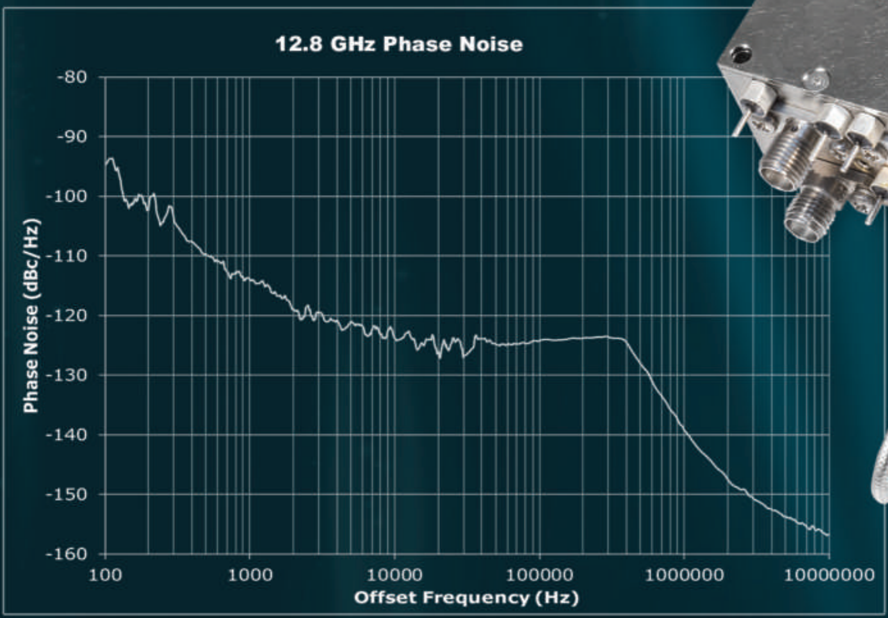

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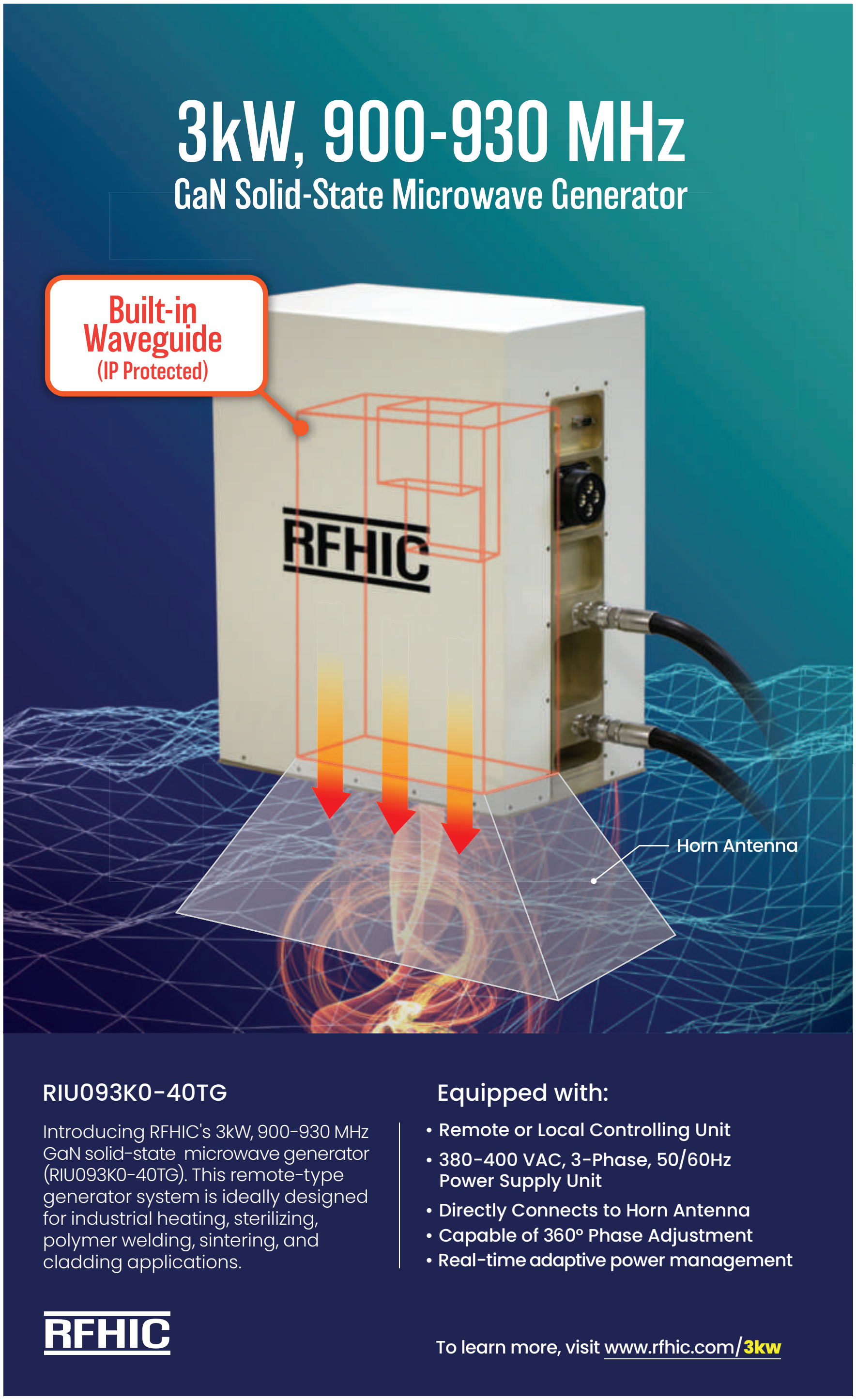
lems upon which encryption is based. Arqit recently announced that it was merging with a subsidiary of Centricus, a global investment firm, in a transaction expected to provide Arqit with up to €330 million in gross proceeds. The deal fully finances Arqit's endeavors to develop state-of-the-art satellites for quantum key distribution—dubbed QKDSat—through its key provision platform.

Wilson Electronics, an industry leader in cellular signal amplifier technology, announced a collaboration with 5G mmWave technology leader **ED2 Corp**. ED2's expertise will round out Wilson Electronics' 5G technology offerings, supporting the addition of a 5G highband and future midband solution for both indoor and outdoor coverage. Based in Tucson, Ariz., ED2 is an emerging technology company with a strong technical team building 5G mmWave products and solving engineering challenges. As the commercial cellular industry moves to higher frequencies in search of more spectrum and higher performance, the team's capabilities are a perfect match for the industry's needs.



Sivers Semiconductors announced that its subsidiary **Sivers Photonics** has reached a significant milestone, together with its partners **imec** and **ASM AMICRA**. In their joint silicon photonics project, they have successfully managed a wafer-scale integration of indium phosphide distributed feedback laser from Sivers' InP100 platform onto imec's silicon photonics platform (iSiPP). This is a significant achievement since it will boost the adoption of silicon photonics in a wide range of applications from optical interconnects, over LiDAR, to biomedical sensing.

Spirent Communications has collaborated with **Amazon Web Services (AWS)** to bring automated 5G testing capabilities to communications service providers (CSPs) building 5G networks on AWS. Spirent's Landslide 5GC Automation Package is designed to help carriers to rapidly deploy 5G networks on AWS, significantly reducing operational costs, time and resources compared to manual testing.

ACHIEVEMENTS

Rohde & Schwarz announced that it has been chosen to supply the R&S QPS201 quick personnel security (QPS) scanners to **Heathrow Airport**, reducing wait times for passengers and enhancing security checkpoints. R&SQPS201 scanners will be rolled out across the airport, ensuring that all passengers, staff and contractors accessing airside locations are scanned on entry. The installation enables the airport to achieve its vision of a secure and safe environment while at the same time providing a positive passenger experience by making their journey through the airport as fast and efficient as possible.

Keysight Technologies announced that the company's 5G Device Test Platform was used to achieve the first validation of 5G new radio (NR) radio resource management (RRM) test cases in frequency range 2 (FR2) by the **Global Certification Forum (GCF)**. The validation took

place at the GCF conformance agreement group meeting. Mobile operators use RRM to achieve performance gains in energy usage, higher throughput, lower delays and decreased packet loss. It was also confirmed that Keysight continues to support a leading number of GCF mandated 5G NR RF, protocol and RRM conformance test cases.

Gowanda Electronics was awarded "Supplier of the Year for Electronic Components and Distribution" at the **Collins Aerospace 2021 Avionics Supply Chain Recognition Event**. Collins Aerospace recognized Gowanda Electronics for its broadened capabilities, strong engineering support and account management accommodations, when selecting the company for this prestigious award. Gowanda was one of only eight companies selected by Collins Aerospace for supply chain recognition this year.

Richardson Electronics Ltd. announced it was recognized as a Gold Tier Supplier for exceptional performance and contributions to supply chain success in 2020 for **BAE Systems' Electronic Systems** sector. BAE Systems honored Richardson Electronics at a virtual ceremony and selected the company from the pool of suppliers that worked with BAE Systems in 2020.

Filtronic plc announced that it has been honored with a Queen's Award for Enterprise for International Trade. Filtronic is one of 205 organizations nationally to be recognized this year with a prestigious Queen's Award for Enterprise, of which 122 are for International Trade. Filtronic's successful award entry focused on the outstanding short-term growth in export sales of its microwave and mmWave solutions over a three-year period.

CONTRACTS

Janus Global Operations, a Caliburn International company, has been awarded one of nine contracts under the Multiple Award Military Munitions Services (MAMMS III) contract through the **U.S. Army Corps of Engineers (USACE) Baltimore District**. The multiple award task order will have a shared capacity of $240 million.

Palantir Technologies announced it had been selected by the **United States Special Operations Command (USSOCOM)** to continue its work as their enterprise data management and AI-enabled mission command platform as part of the Mission Command System/Common Operational Picture program. The contract is valued at a total of $111 million, inclusive of options, with $52.5 million executed upon award.

Curtiss-Wright Corp. announced that it was awarded a contract by **Lockheed Martin** to provide its modular open system approach computers and video processing modules to upgrade the mission computer and flight management computer (MC/FMC) on the U.S. Navy's fleet of Sikorsky MH-60R/S Seahawk helicopters. The initial contract is valued at $24 million, with an estimated lifetime value of

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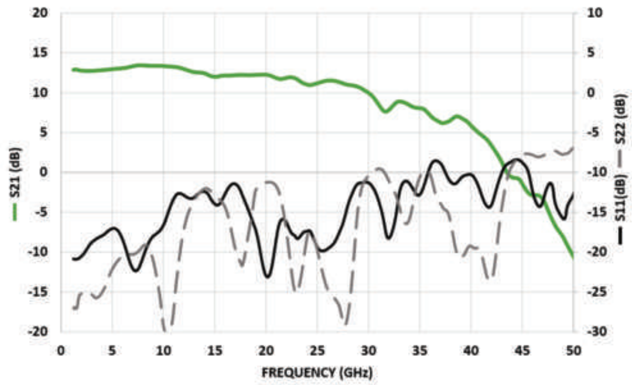
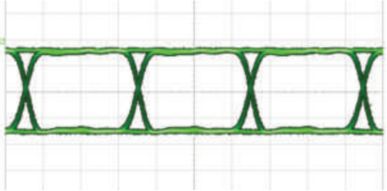
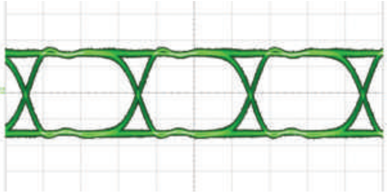




INPUT: 12.5 GBPS PRBS31 250 mV



OUTPUT: 12.5 GBPS PRBS31 1100 mV

- Optimized step response with exceptional topline flatness
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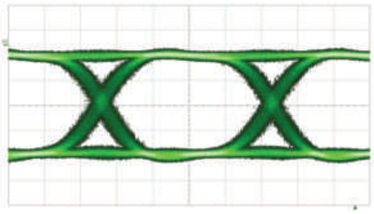
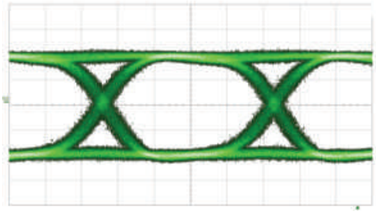


INPUT: 32 GBPS PRBS31



OUTPUT: 32 GBPS PRBS31

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$70 million. Under the contract, Curtiss-Wright is providing Lockheed Martin with rugged single board computers and video processing modules.

Comtech Telecommunications Corp. announced that during its third quarter of fiscal 2021, its Santa Clara, Calif.-based subsidiary, **Comtech Xicom Technology Inc.** was awarded a $2 million order for rugged Ka-Band high-power traveling wave tube amplifiers for a U.S. military communications system that provides a secure internet connection to U.S. soldiers without the need for fixed infrastructure.

Advent Technologies Holdings Inc. announced that its subsidiary, **UltraCell LLC**, has received a contract from the **U.S. Department of Defense (DoD)** to focus on completing the MIL-STD certification of UltraCell's 50 W Reformed Methanol Wearable Fuel Cell Power System "Honey Badger." The contract was signed with the U.S. Army DEVCOM Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center with funding through the Project Manager Integrated Visual Augmentation System (PM IVAS).

Sensor systems supplier **HENSOLDT** was awarded a contract worth approximately 200 million euros under the 'Quadriga' procurement program of 38 Eurofighter/Typhoon combat aircrafts by the **German Air Force**. The contract placed by Airbus Defence and Space comprises production and delivery of radar systems and core electronics components which will be produced at HENSOLDT's site in Ulm, Germany, and at consortium partner Indra's site in Spain. The new radar is based on state-of-the-art active electronically scanned array technology. In contrast to conventional systems with a purely mechanically rotating antenna, the radar beam is electronically controlled by a multitude of individual transmit/receive modules.

PEOPLE

▲ *Emily Campbell*

Infinite Electronics Inc. has appointed **Emily Campbell** to the position of chief marketing officer. In this role, Campbell will lead Infinite's global marketing strategy and execution, including brand strategy, direct and digital marketing, eCommerce, customer experience, acquisition and retention, internal and external communications, PR, analytics and marketing operations. Campbell joins Infinite Electronics with more than 20 years of extensive B2B and B2C marketing leadership experience. Prior to Infinite Electronics, she was CMO with Berlin Packaging, head of global marketing and digital innovation for Arrow Electronics Enterprise Computing Division and led Arrow's eCommerce business as the GM of Global eCommerce. Campbell also held eCommerce and marketing leadership roles at National Instruments, Dell and Compaq.


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Refined Test Approaches for Verifying Wi-Fi 6 Designs

Craig Hendricks
Anritsu Company, Morgan Hill, Calif.

The IEEE 802.11ax standard, commonly referred to as Wi-Fi 6, was developed to support the ever-changing Wi-Fi traffic. For better communication efficiency with limited frequency resources, it is designed to handle multiple simultaneous connections to one access point (AP), as well as opening bandwidth to address increased video use—with special attention to 4K video streaming—and substantially more voice traffic due to carrier offload. Implementation of Wi-Fi 6 will yield better spectral efficiency and use of the new 6 GHz band, known as Wi-Fi 6E, as 802.11ax enables far better coexistence schemes, traffic scheduling and higher performance in dense scenarios. It does pose design challenges for engineers, however, and affects the test environments used to verify performance.

The impact of Wi-Fi 6 is expected to be profound. ***Figure 1*** shows the projected growth of the technology in mobile handsets, consumer products and other network elements. Most premium phone models, particularly 5G enabled, already have Wi-Fi 6 embedded. Its cooperative solution with 5G is one reason for the expected fast rise of Wi-Fi 6. Practically speaking, Wi-Fi 6 is a local area context, and 5G is wide area. Wi-Fi 6 frees spectrum, as 5G use cases can be offloaded to use it.

WI-FI 6 ENHANCEMENTS

To understand the increased testing requirements for Wi-Fi 6, we will first describe the changes in the 802.11ax standard that are providing these improvements.

SCHEDULING

Wi-Fi 6 is optimized to increase the average throughput by 4x for users in dense and congested environments. To achieve this enhanced throughput, Wi-Fi 6 can schedule down to 2 MHz bandwidth slices, a 10x improvement over the previous contention-based generations with 20 MHz bandwidth slices. The narrower slices create a dramatic drop in the noise floor by 8 dB, resulting in greater signal range or 8 dB more tolerance to noise and interference. This also increases efficiency by narrowing the subcarrier frequency spacing from 312.5 to 78.125 kHz.

Scheduling the 2 MHz slices extends battery life, as does the Wi-Fi 6 feature of target wake time (TWT). TWT enables a Wi-Fi 6 AP to trigger a client device to wake up and use battery power only when it's needed. Wi-Fi 6 also makes better use of time and frequency resources, modulation, coding and spatial streams to minimize contention and improve capacity.

OFDMA/QAM INTEGRATION

Wi-Fi 6 uses orthogonal frequency-division multiple access (OFDMA), similar to the modulation used in 5G and LTE. OFDMA enables multiple stations to be served simultaneously, which improves capacity, latency and efficiency in dense signal environments. Wi-Fi 6 uses up to 1024 QAM modulation compared to 256 QAM in previous generations, increasing the peak data rate for a single user by 25 percent. This creates device design challenges, however; better modulation accuracy and more dynamic range for over-the-air (OTA) testing.


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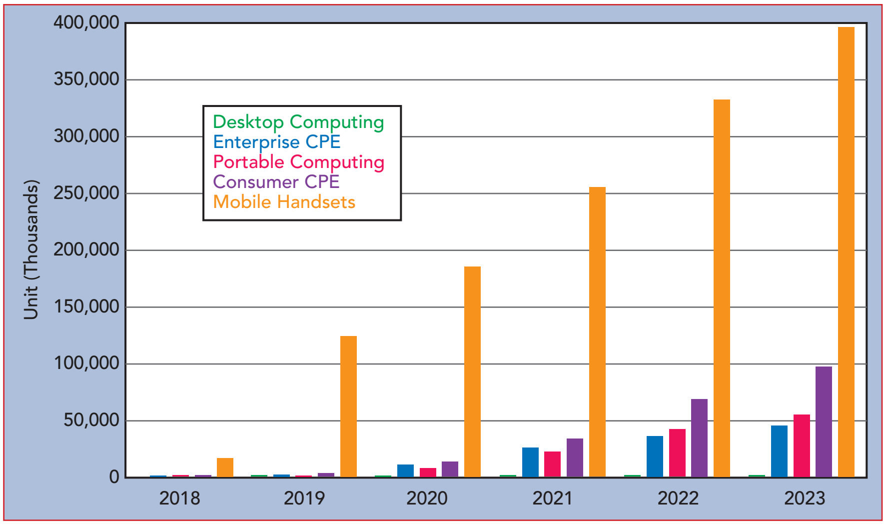

Fig. 1 Forecast Wi-Fi 6 IC shipments. *Source:* Omdia.

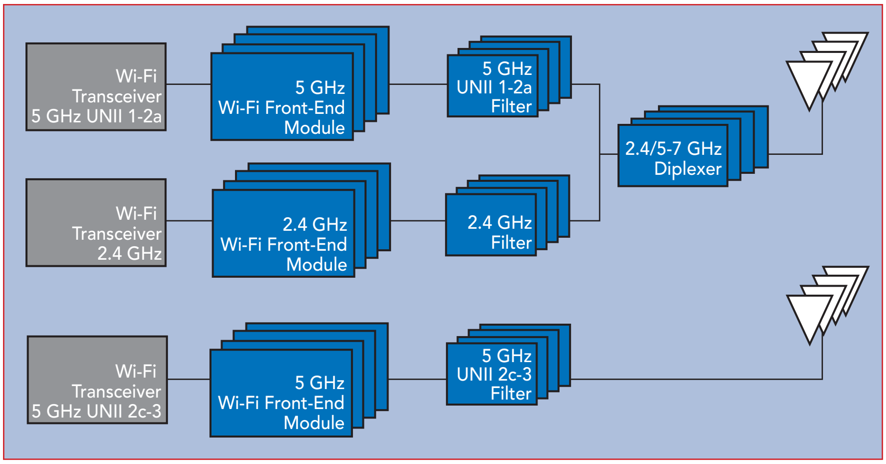

Fig. 2 Wi-Fi 6 tri-band architecture.

OFDMA is a new extension to multi-user MIMO (MU-MIMO) to increase the speed of Wi-Fi 6. MU-MIMO combines signals from separate antennas and spatial path differences to provide up to 12 spatial streams (eight in the 5 or 6 GHz bands and four in the 2.4 GHz bands), a considerable upgrade from the four provided by Wi-Fi 5. In beamforming mode, an AP can direct signals to desired clients and aim the effective receive (Rx) signal power away from other devices.

NEW PDDU FORMATS

At the PHY layer, 802.11ax distinguishes itself from legacy frames with four new packet protocol data unit (PPDU) formats: high efficiency, single user (HE SU), HE extended range (HE_EXT_SU), multi-user (HE MU) and HE trigger-based (HE_Trig).

Multi-user uplink (UL) transmissions typically require devices to be carefully calibrated to meet stringent power and measurement accuracy requirements. The 802.11 specification, however, allows device implementations with a wide range of capabilities. While the requirement for every device to support all PPDU formats has not been determined, every device must process the preamble for all transmission modes.

TRI-BAND ARCHITECTURE

A new tri-band architecture is used in Wi-Fi 6 designs (see ***Figure 2***). The design requires advanced filtering to split the 5 and 2.4 GHz streams, which are divided into sets of three. Duplexing is necessary to reuse the advanced capabilities of the antennas to support the transmission of 2.4 and 5 GHz. The new architecture uses thermal efficiency isolation to compensate for the close spacing of active and passive components on the PCB, with advanced packaging required to maximize the thermal conductivity and minimize size.

Wi-Fi 6E EXTENSION

With the adoption of the Wi-Fi 6E (Extended) standard, the Wi-Fi Alliance expanded the spectrum to 7.125 GHz, enabling the 6 GHz band to also be used for unlicensed Wi-Fi operation. In conjunction with the tri-band architecture, Wi-Fi 6E establishes dedicated client communications and backhaul spectrum. Because of this, there is no longer a need to split the 5 GHz spectrum. The 6 GHz band can be dedicated to backhaul, creating an almost greenfield environment; i.e., it does not have to be compatible with legacy standards.

TEST REQUIREMENTS

The technology improvements of Wi-Fi 6 do more than enhance performance; they change the way products must be verified and the configuration of test systems. Instruments must measure to tighter parameters with tests performed OTA. New test items and complex measurement methods are being added to the IEEE 802.11ax standard, with the antenna as a key evaluation element for the 6 GHz band, because the antenna performance requirements change with frequency.

The European Telecommunications Standards Institute (ETSI) originally specified using a spectrum analyzer to conduct key performance measurements such as output power, spurious and occupied bandwidth. New specifications (ETSI EN 300.238 for 2.4 GHz and ETSI EN 301.893 for 5 GHz) require a Wi-Fi call box in the test system for regulatory testing to support the receiver blocking test. This test configuration is superior to using a non-signaling tester or AP to control the minimum data rate. The earlier approaches make it more complicated to control devices designed with several chipsets to the minimum data rate, because proprietary software is required for each chipset.

In addition to regulatory testing, mobile operators require power level tests during call connection to ensure there is no excessive output power that can lead to a disconnect.

As this can occur in some cases, a useful capability is to measure transmit (Tx) power before call connection to find devices with excessive output power not caught by the IEEE procedure (see ***Figure 3***).

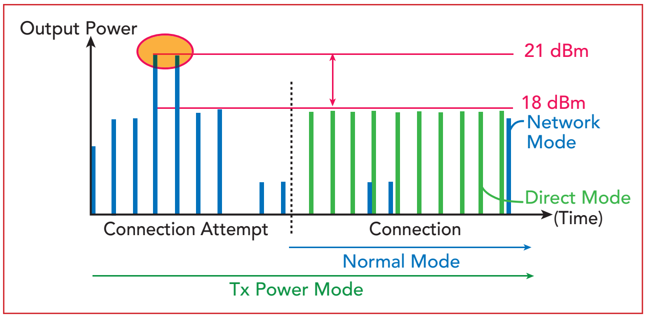

Fig. 3 Call disconnect caused by excessive Tx power.

The 802.11ax standard specifies Tx and Rx tests. Among them are the HE TB PPDU format Tx test using the OFDMA method and evaluation of 1024 QAM modulation. Tx power, received signal strength indicator (RSSI) measurement accuracy and carrier frequency offset error tests are also important. Rx tests are also required because performance varies with conditions such as frequency and modulation method. These include:

Modulation Accuracy — User equipment performance is affected as the modulation method changes at each data rate. Two measurements are used to characterize modulation accuracy: Tx local oscillator (LO) leakage and error vector magnitude (EVM). Tx LO leakage measures the amount of energy leaking and appearing at the RF LO frequency. Too much power leakage may lead to poor demodulator performance. Further, if the power level is too high, a receiver may falsely trigger on the signal. For 802.11ax, the specification requires the power to be measured at the location of the RF LO using a resolution bandwidth of 78.125 kHz. The measured power should not exceed the greater of -20 dBm or the Tx power per antenna, in dBm, minus 32 dB.

Because Wi-Fi 6 uses 1024 QAM, EVM requirements are tighter. The requirements for HE SU, HE_EXT_SU and HE MU PPDUs for modulation and coding schemes (MCS) 0 to 9 are the same as in 802.11ac. For the new MCS 10 and 11, the EVM requirement is -35 dB if amplitude drift compensation is enabled in the test equipment and -32 dB if amplitude drift compensation is disabled. The 802.11ax EVM calculation uses compensation of estimated frequency offset and sampling offset drift; this differs from 802.11ac, which only compensates for frequency offset. The different requirement is due to the much longer symbol times in 802.11ax, which can lead to a larger timing drift and intercarrier interference (ICI). For HE TB PPDU, the EVM requirements must account for multiple stations (STA) transmitting simultaneously. The AP will integrate noise from multiple sources as total cumulative noise, and network performance will degrade if the noise is too large. In addition, a STA unintentionally transmitting power outside of its allocated resource unit (RU) will degrade the EVM of other STAs.

Fig. 4 Measured Tx power, EVM, signal constellation, spectral mask and power profile.

Power Adjustment — Referred to as pre-correction, this measurement tests the respective total values of the RSSI and absolute Tx power measurement accuracies, performed by displaying the difference between the TargetRSSI set by the user and the actual device under test (DUT) signal received by the test set.

Figure 4 shows measurements of

Tx power, EVM, constellation, spectral mask and the power profile.

OTA TESTING

Support for the 6 GHz band in the 802.11ax standard requires antenna performance evaluation using OTA tests. Test systems must have wide dynamic range when conducting Wi-Fi 6 OTA measurements to maintain connectivity over a radiated connection, i.e., sufficient to overcome the large path losses—which can easily reach 50 dB—from the Wi-Fi device through the anechoic chamber, antenna and cables, back to the test system. With a null in the antenna pattern being measured OTA, the connection can drop, with nulls unable to be measured without sufficient dynamic range.

The dynamic range of Wi-Fi test systems has grown over time. With 802.11a/b/g, the maximum channel bandwidth was 20 MHz. For 802.11n, the bandwidth doubled to 40 MHz, raising the receiver noise floor and reducing the dynamic range by 3 dB. With 802.11ac and 802.11ax, the maximum channel bandwidth increased to 160 MHz, increasing the noise floor by 9 dB compared to a 20 MHz channel.

With the newer Wi-Fi standards, maximum data rates are achieved with a more complex modulation. Lower data rates and coding schemes such as MCS0 BPSK only required 4 dB signal-to-noise ratio (SNR) to demodulate the signal. With Wi-Fi 6, however, the MCS9 256 QAM modulation requires 29 dB SNR to demodulate the signal, adding to the dynamic range of the test system.

Cellular/Wi-Fi equipment suppliers require OTA tests in an anechoic chamber, in accordance with CTIA/WFA Converged Wireless Group. Version 2.1 specifies OTA environment test items such as Wi-Fi total radiated measurements including total radiated power and total isotropic sensitivity, which require setting multiple data rates for each frequency band to analyze the power of the radio waves received by the DUT in all directions (see ***Figure 5***). Cellular and Wi-Fi desense measurements must also be conducted OTA. Wi-Fi desense measurements assess any deterioration in Wi-Fi reception while the DUT performs cellular communications. Correspondingly, cellular desense measurements are conducted with the Wi-Fi transmitter on to determine any degradation in cellular reception.

OTA tests are also conducted to verify use case performance. These tests simulate the behavior in the field and are performed with a reverberation chamber to consider the influence of a real environment containing fading and multipath. Simulating the effect of a human hand, head or body shielding the antenna of a smartphone is one example. Another is testing the connection of an AP antenna despite an interfering signal or when the data rate changes during a connection.

EMC TESTS

Wi-Fi 6 designs need to meet

the EMC parameters established by 802.11ax. This is a challenge because it is difficult to control the data rate of an AP. More efficient, accurate and repeatable testing can be achieved using a test solution with a data rate control capable of connection preservation. Connection preservation enables the data rate to be changed by the test set without dropping the connection.

FRAME CAPTURE

Preferably, the test set will capture the packets communicating with a DUT, which provides more confident results than the alternative method of integrating a sniffer tool into the measurement environment. Packets are often missed by a sniffer, resulting in improper analysis and adding time to the test. Capturing the packets enables easier debugging of connection issues.

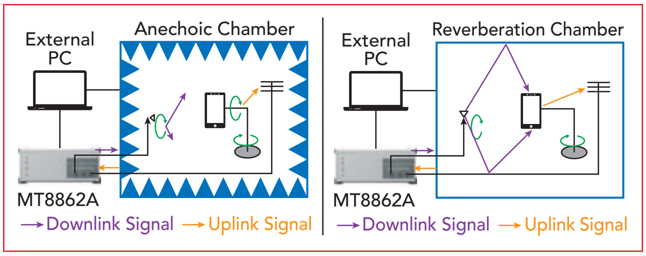

Fig. 5 TRP/TIS measurement configuration.

SPECTRAL FLATNESS

Spectral flatness measures whether the subcarriers have similar power by determining the average energy of a subcarrier range and verifying that no individual subcarrier's energy exceeds a specified value. The 802.11ax spectral flatness measurement is made using BPSK modulated OFDM subcarriers, with the test signal containing at least 20 PPDUs, each with at least 16 data symbols. Unoccupied subcarriers are ignored during testing and averaging. In addition, RU power boosting and beamforming is not used during the test.

Rx INPUT SENSITIVITY

The minimum input sensitivity test verifies the receiver successfully demodulates a signal at a minimum input level with a packet error rate less than 10 percent. For 802.11ax, the minimum input sensitivity depends on the modulation, coding rate and bandwidth. For this test, the 802.11ax packets should be HE SU PPDUs that are 4096 bytes long with an 800 ns guard interval. Binary convolutional coding is used if the PPDU bandwidth is 20 MHz, and low-density parity-check is used when the bandwidth is greater than 20 MHz.

SUMMARY

IEEE 802.11ax was designed to support the overall increase in Wi-Fi traffic, particularly streaming video, and is a strong complement to 5G. Testing of Wi-Fi 6/6E devices requires test solutions able to conduct measurements with tighter parameters and capable of OTA testing.■


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INVITED PAPER

For Robust mmWave Performance: Capture Thermo-Structural Effects with Multiphysics Simulation

Jiyoun Munn
COMSOL, Inc., Burlington, Mass.

Multiphysics simulations capture mmWave circuit performance under realistic operating conditions without performing costly and time-consuming environmental testing. Simulation reduces the number of iterations in the development cycle and expedites design, fabrication and testing.

High speed, high data rate communication is essential for 5G terrestrial and satellite communications, such as broadband via low earth orbit satellites. While massive data transfer via multiple devices is already part of daily life, even greater bandwidth is needed to provide more information through communication channels. This is being accomplished through increased system bus speeds and carrier frequencies; to support this, the operating frequencies of communication systems and components has been migrating from legacy microwave to mmWave.

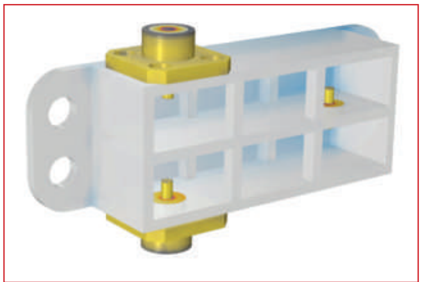

Fig. 1 Cascaded cavity filter with 2.92 mm (K) connectors. The front panel is removed to show the interior.

Higher frequency devices have smaller wavelengths, resulting in reduced device size. Any physical perturbation of such small devices, especially those in resonant circuits, may impact performance through changes in impedance matching, insertion loss and frequency tuning. When a device is designed assuming ideal laboratory conditions is deployed in an operating environment, temperature variation will induce structural deformation. The effects of such environmental conditions, combined with fabrication tolerances, can shift performance outside the design specifications. If these physical effects are included with traditional electromagnetic (EM) component simulations during design, using multiphysics simulation, unexpected results can be identified without performing costly and time-consuming temperature chamber experiments and outdoor field tests. Multiphysics simulations reduce the number of iterations in the development cycle and expedite design, fabrication and testing.

MULTIPHYSICS DESIGN EXAMPLE

In the following example, the design of a cascaded cavity bandpass filter (see ***Figure 1***) using a traditional EM model adds multiphysics phenomena such as thermo-structural effects using COMSOL Multiphysics® software.[1] The filter operates over two mmWave 5G bands: 26.5 to 29.5 GHz for Japan, Korea and the U.S. and 24.25 to

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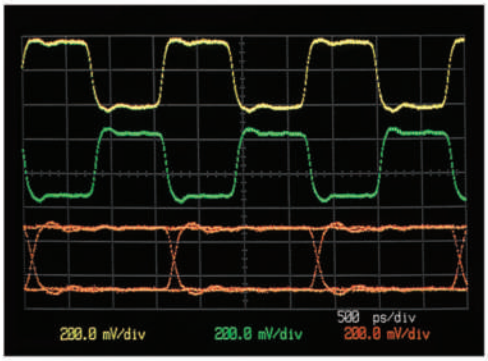

Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS evels. Traces have transition times of 80 ps and jitter less than 1 ps rms.

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27.5 GHz for the European Union and China. First, a conventional EM model of the cascaded cavity bandpass filter is constructed. This is followed by a structural mechanics simulation including the thermal deformation assuming a uniform temperature distribution, to assess its impact on the frequency response. Finally, a heat transfer simulation analyzes how thermal deformation from a nonuniform temperature distribution affects filter performance.

Cavity Filter EM Model

By solving the vector Helmholtz wave equation derived from Maxwell's equations (see equation 1), the wave propagation and resonant behavior of the device can be analyzed.

$$\nabla \times \mu_r^{-1}(\nabla \times \mathbf{E}) - k_0^2\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)\mathbf{E} = \mathbf{0} \tag{1}$$

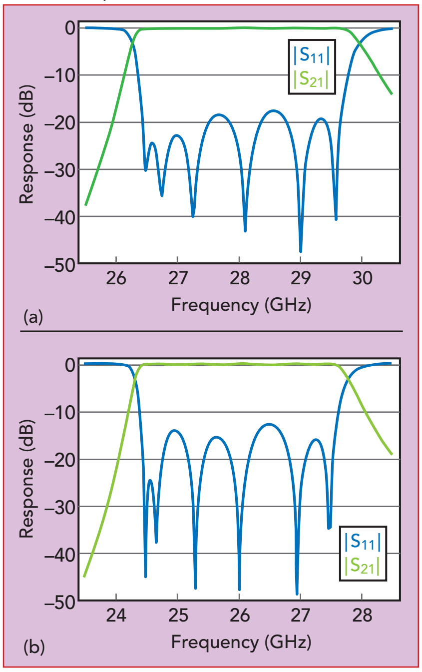
The cavity filter shown in Figure 1 comprises six rectangular cavities in two subsets, loaded by two 2.92 mm K connectors. The two subsets are each connected by inductive irises excited by the K connector coaxial pins and coupled to each other through a coaxial-type structure.

When designing such cavity filters, the initial size of each cavity can be estimated quickly from the resonant frequency of a rectangular cavity structure:

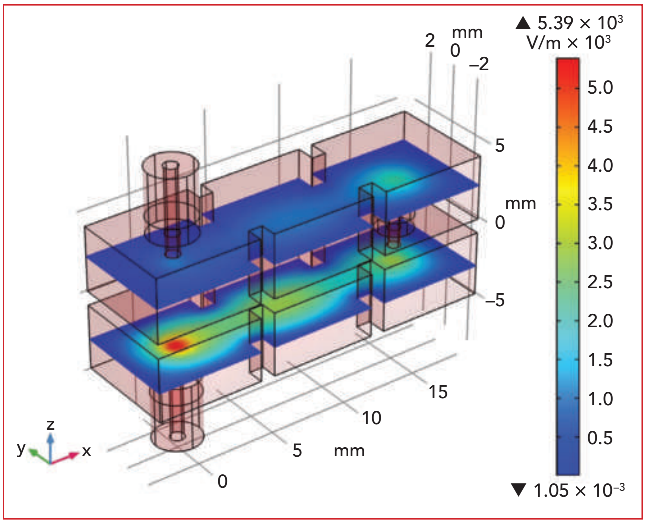
$$f_{nml} = \frac{c}{2\pi\sqrt{\varepsilon_r \mu_r}} \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{l\pi}{d}\right)^2} \tag{2}$$

where a and b are the dimension of the waveguide aperture, and d is the length of the rectangular cavity. The frequency for the TE101 mode is chosen. The volume of the metallic domain of the filter and connectors is thick compared to the resonant wavelength, so penetration is not expected. Hence, only the wall surfaces are included in the computation. When metallic surfaces are lossy with finite conductivity and the loss is not negligible, the surfaces can be modeled using an impedance boundary condition. Further simplifying, a certain part of the model can be assumed to be lossless and represented by a perfect electrical conductor. The dielectric part of the coaxial connectors is also assumed to be lossless.

The two coaxial connectors are excited and terminated using coaxial lumped ports, where the reference impedance is 50 Ω. A couple



▲ Fig. 2 Simulated filter responses for the mmWave 5G bands: Japan, Korea and the U.S. (a) and the E.U. and China (b).



▲ Fig. 3 Simulated internal TE_{101} E-field at 26.15 GHz.

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SAGE Millimeter is now Eravant, a change that renews our commitment to the millimeterwave industry. Since 2011, we have been delivering quality products and energizing the customer experience to meet the needs of RF engineers working on the technology of the future.

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The electric field inside the cavities is visualized in ***Figure 3***. The dominant TE resonance for each cavity is when the frequency is close to the center of the mmWave 5G band for Japan, Korea and the U.S.

Adding Thermal Deformation to the EM Model

The thermal deformation analysis includes the entire aluminum body of the filter and brass connectors, which were not part of the EM-only analysis. To account for simple thermal deformation, the material properties must be updated for other physics phenomena. The dielectric material model in the coaxial connectors includes the coefficient of thermal expansion, Young's modulus, Poisson's ratio, density, thermal conductivity and specific heat. For fast prototyping, values are chosen similar to those of FR4. An adhesive layer on one side of the connector body was added to the model. Using the thermal expansion of the linear elastic material addresses the effect of temperature variation on device performance. This includes uniformly different ambient temperatures and their impact when an adjacent component has overheated thermal drift.

As the solid housing body structure shrinks and expands due to temperature change, deformation of the solid part and the cavity air domains must be studied. The electric conductivity of the coating on the cavity walls may also change with temperature. Since structural deformation is involved, a few assumptions are made about the filter attachment to its surroundings. The structure may be firmly connected to a perfectly rigid area, the baseplate, where a small layer of adhesive attaches the filter to the rigid substrate structure. For modeling the connection between the deformed filter and rigid substrate, the COMSOL Multiphysics software Spring Foundation feature gradually transforms the connected part to the deformed state (see ***Figure 4***). The port boundaries sustain the geometry configuration regardless of thermal variations, such as planar and annulus cross sections. These faces are addressed by the two Rigid Connector features in the model, which constrain the boundaries to maintain their shapes and sizes while able to move or rotate due to the deformation.

Three isothermal conditions were simulated: -40°C, 20°C and 120°C. A Moving Mesh defines the

deformation of the air domain and a parametric sweep updates the temperature. For each temperature, an EU 5G band frequency sweep was performed. When the temperature decreases, the thermo-structural deformation makes the smaller cavity smaller, shifting the pattern of S-parameters to higher frequencies. With increased temperature, the frequency response shifts down. Overall, the filter bandpass is not severely affected by the changes in geometry due to the thermal change (see ***Figure 5***). ***Figure 6*** shows the structural mechanics analysis at the elevated 120°C temperature.

Advanced Thermo-Structural Model

With an unexpected heat source in the real world, the temperature distribution of the filter could be nonuniform. This can be computed by solv-

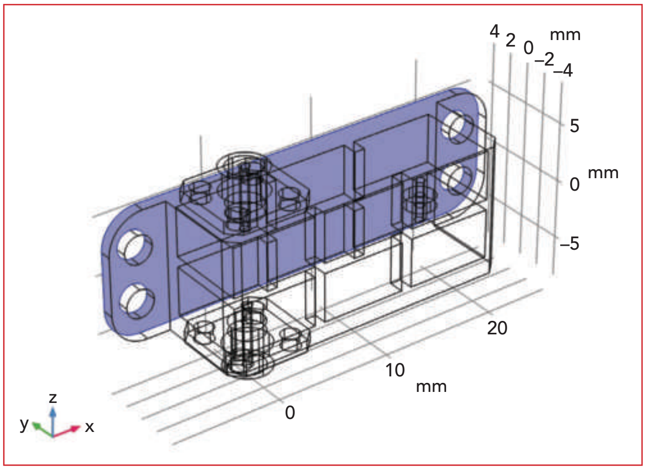

Fig. 4 **The boundary where the Spring Foundation feature is applied.**

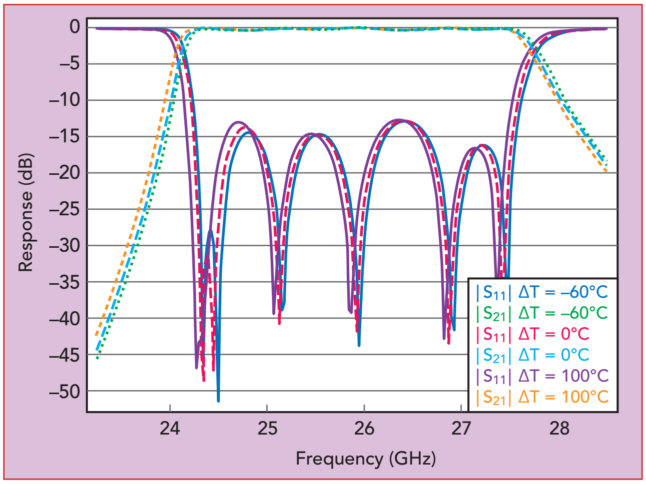

Fig. 5 **Simulated filter responses with ambient temperature shifts.**

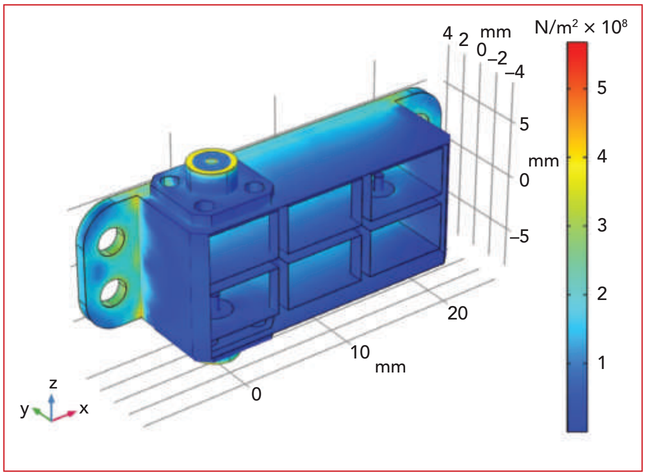

Fig. 6 **Simulated thermal expansion and von Mises stress with ΔT = 100°C.**

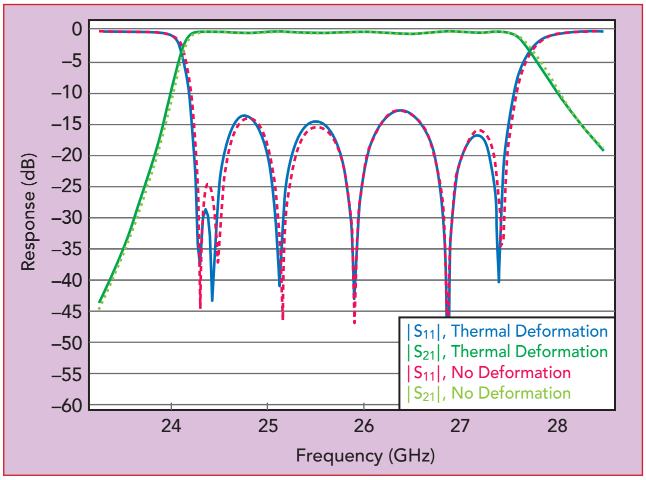

Fig. 7 **Shift in filter performance showing the simulation of an uneven heat source on the baseplate.**

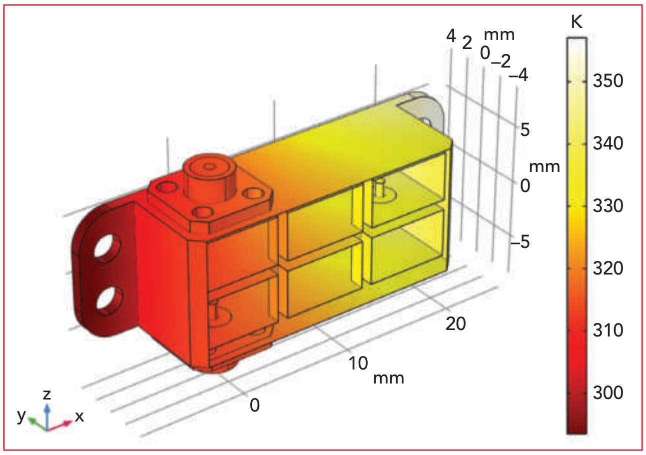

Fig. 8 **Simulated surface temperature.**

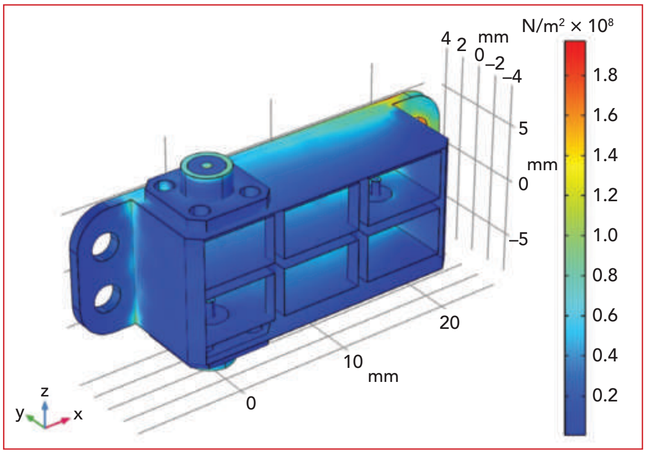

Fig. 9 **Deformed aluminum housing from heat expansion.**

ing the heat transfer equation (see equation 3), rather than imposing a fixed uniform temperature deviation.

$$\rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = Q + Q_{ted}, \quad \mathbf{q} = -k\nabla T \tag{3}$$

For the filter design example, assume the plate where the device sits experiences nonuniform heating from some external source. The nonuniform heating is defined as spatially increasing in one direction, distorting the filter and affecting its frequency response. The Heat Transfer in Solids physics interface in COMSOL Multiphysics is applied to all solid domains. The conductive and convective heat flux through the air inside the cavities is not considered, assuming the air is a good insulator. Because the conductive heat path to the baseplate is the most significant, radiation inside the cavities and toward the surroundings is neglected. The thin, high conductivity coatings are not thermally essential, so thermal effects here are also neglected.

The heat flux boundary condition addresses the temperature variation of the baseplate, which is a relatively large plate of metal with an external temperature distribution. The Solid Mechanics interface is identical to the previous model configuration. The impedance boundary condition for the EM analysis must read the computed temperature from the heat transfer multiphysics coupling. The Multiphysics Node in the Model Builder has a thermal expansion feature, which applies the calculated temperature distribution as a thermal expansion into the Solid Mechanics interface. Two physics interfaces are combined bidirectionally to couple multiple physical phenomena. First, the thermo-structural problem is solved, then the EM problem is solved for the deformed state.

Although the filter is deformed by the uneven heat source on the baseplate, the filter responses are not significantly affected (see ***Figure 7***). The deformation is less when compared to the ambient temperature change with the uniform temperature distribution, previously simulated. The temperature distribution plots show which areas of the aluminum housing are hotter (see ***Figure 8***) and affected by thermo-structural effects (see ***Figure 9***).

CONCLUSION

In this article, a conventional EM simulation was extended to include thermo-structural effects on a mmWave filter's performance. Through multiphysics analyses, the performance of a high speed communication system component, a cascaded mmWave cavity bandpass filter, was shown to be robust under harsh environmental conditions. This modeling methodology can be used to simulate the performance and reliability of many different types of sensitive components and subsystems in extreme operating environments, identifying potential problems early in the development process and saving costly redesigns.■

Reference

1. "Understand, Predict and Optimize Physics-Based Designs and Processes with COMSOL Multiphysics®," *COMSOL*, Web, www.comsol.com/comsol-multiphysics.

Waveguide Cal Kits Ensure VNA Measurement Accuracy and Precision

A network analyzer and a skilled operator are essential for accurately measuring the S-parameters of microwave devices and components. But measurement performance also depends on the calibration tools. The STQ series of waveguide calibration kits from Eravant help ensure accurate measurements, providing metrology-grade standards with the necessary tools for the waveguide bands from 18 to 220 GHz: 11 waveguide sizes from WR-05 to WR-42. Typical lead times range from stock to 6 weeks ARO.

Each calibration kit comprises one fixed short, one fixed load and three waveguide shims for offsets of λ/8, λ/4 and 3λ/8, which support multiline TRL calibration algorithms. Two waveguide Quick Connects; 10, 3/32 hex head waveguide screws; six 3/32 hex head extended waveguide screws; four alignment dowel pins; a 3/32 hex waveguide screwdriver; and a USB thumb drive with calibration data are included. The waveguide elements are constructed from durable beryllium copper alloy and are gold plated. All items are matched with precision and deliver exceptional electrical performance, such as 40 dB nominal return loss on the matching load.

The waveguide Quick Connects improve the longevity of the precision waveguide flanges. They uniformly distribute the contact pressure to create a solid connection, minimizing signal leakage from waveguide misalignment and improving repeatability. The Quick Connects work well in tight locations and eliminate the tedium of incrementally turning traditional waveguide screws.

Designed to work with standard network analyzers, each calibration kit is packaged in a rugged carrying case with foam liners to protect the components from dirt and moisture, as well as securely holding and protecting the elements in one place.

Eravant
Torrance, Calif.
www.eravant.com

Base Station Emulator Tests Parallel DUTs, Supports 2G to 5G

Making cellular device testing easier—from legacy GSM to the latest 5G standards—was the vision NOFFZ Technologies had when developing the Base Station Emulator (BSE) sUTP 5018. Validating cellular devices, like automotive telematic control units, new generation vehicle-to-vehicle communication modules, smartphones and IoT cellular interfaces, requires emulating complex RF testing scenarios in the lab. The NOFFZ BSE makes this possible by creating a custom cellular network in a compact (7U size) and cost-effective unit, combining high-power, real-time computing and a software-defined radio platform.

The BSE can configure up to four cells and attach up to 32 phone modules in parallel. The device under test (DUT) can initiate voice calls, send and receive text messages, exercise handovers or call emergency numbers like a "real" network. The BSE manager software enables monitoring the connections and high-level parameters of DUT calls: signal-to-noise ratio, bit error rate, transmit power, RSSI and the presence of the proper logical channels. Accessing data services exercises the download and upload test to verify the data throughput capabilities of the DUT with different modulations and MIMO modes.

For 5G testing, the BSE is compliant with NR release 15 and supports both non-standalone (NSA) and standalone (SA) network configurations with 256-QAM modulation. It emulates SISO, 2 x 2 MIMO for NSA and SA, 4 x 4 MIMO in SA mode and 3 x CC carrier aggregation.

The NOFFZ application focuses on verifying phone modules over long periods, where the test time is not minutes but days. The BSE enables testing and monitoring the performance of several devices in parallel under extreme conditions and extensive usage.

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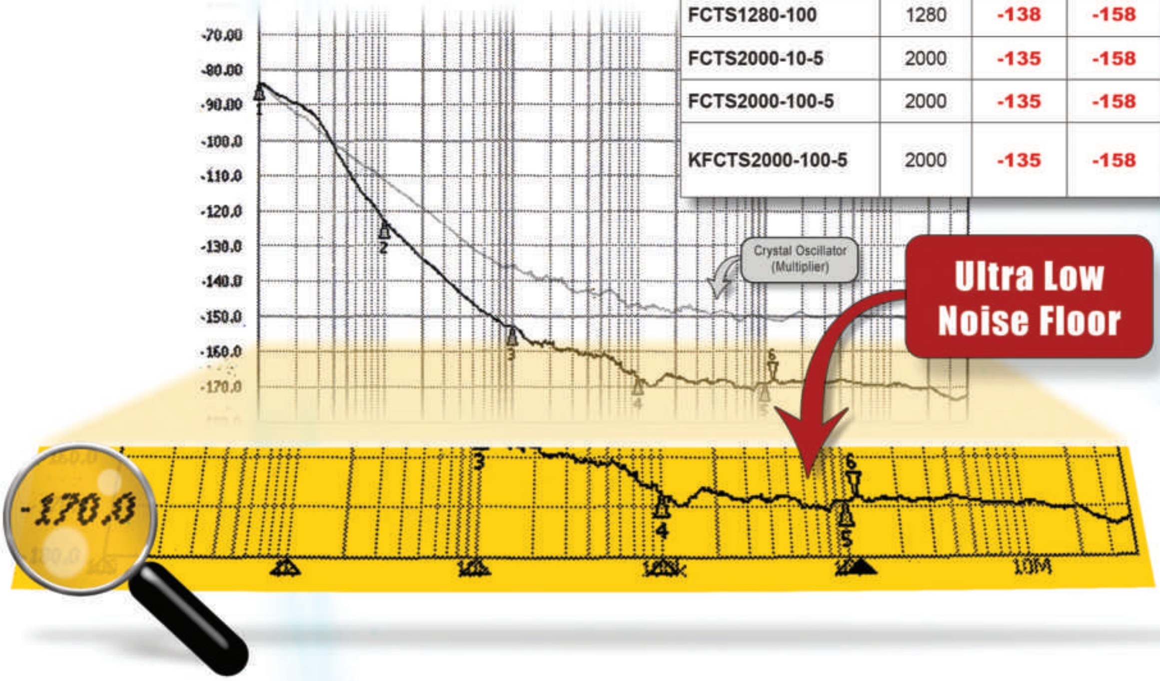
High Performance Frequency Converters
Base Station Applications
Agile LO Frequency Synthesis

Model	Frequency (MHz)	Phase Noise (dBc/Hz) [Typ.]		Package
		@10 kHz	@100 kHz	
VFCTS128-10	128	-155	-160	
FCTS800-10-5	800	-144	-158	
KFCTS800-10-5	800	-144	-158	
FSA1000-100	1000	-145	-160	
KFSA1000-100	1000	-145	-160	
FXLNS-1000	1000	-149	-154	
KFXLNS-1000	1000	-149	-154	
FCTS1000-10-5	1000	-141	-158	
KFCTS1000-10-5	1000	-141	-158	
FCTS1000-100-5	1000	-141	-158	
FCTS1000-100-5H	1000	-144	-160	
FCTS1040-10-5	1040	-140	-158	
FCTS1280-100	1280	-138	-158	
FCTS2000-10-5	2000	-135	-158	
FCTS2000-100-5	2000	-135	-158	
KFCTS2000-100-5	2000	-135	-158	



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AnaPico Product Catalog 2021

AnaPico is a technology leader developing, manufacturing and supplying RF and microwave test and measurement instruments. Their updated product catalog includes a selection of their signal sources and phase noise analyzers.

AnaPico

www.anapico.com/downloads/brochures-and-data-sheets/

Meet EXFO's 5GPro Spectrum Analyzer

The only modular, portable 5G RF spectrum analyzer that lets you analyze FR1, including CBRS/C-Bands, and FR2 with a single, field-upgradeable solution.

EXFO

www.youtube.com/watch?v=7OP2YmuhyDo

New Integrated Filter Assembly Division

MCV Microwave has announced the forming of their Integrated Filter Assembly Division to provide switched filter bank to the high-reliablity military customers.

MCV Microwave

www.mcv-microwave.com

New Butler Matrices Product Catalog Release

With the launch of their new butler matrices series, MIcable's new butler matrices catalog will release at the same time. The products are special for Wi-Fi/mobile phone/base station/IoT test. Check the details at the MIcable website.

MIcable

www.micable.cn

Pixus SOSA OpenVPX & RF Products

With a wealth of new specialty enclosures and SOSA OpenVPX chassis platforms with an RF focus, Pixus has updated its website to emphasize these product lines.

Pixus Technologies

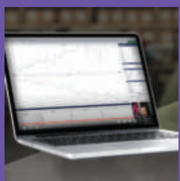
https://pixustechnologies.com/products/category/openvpx

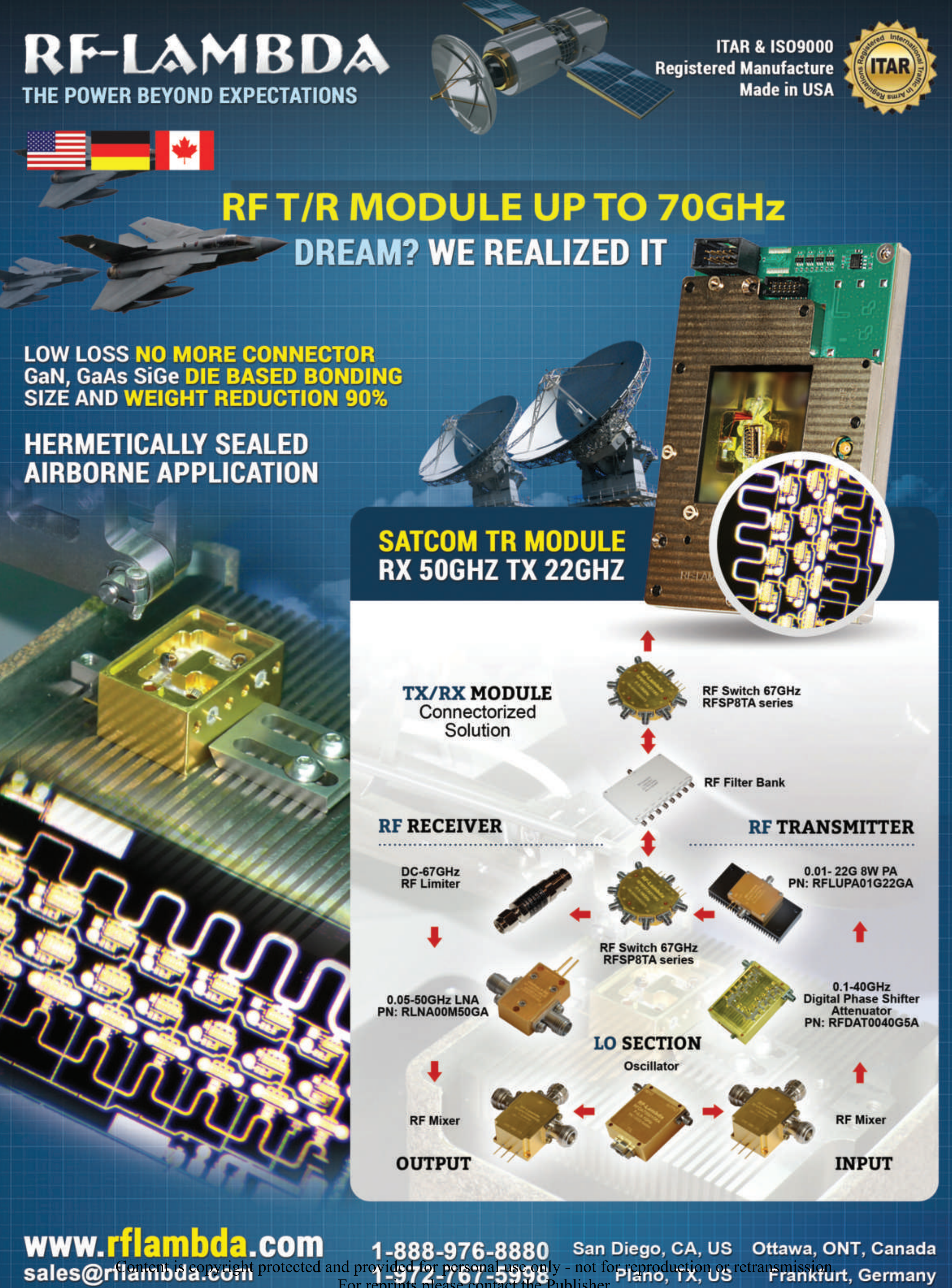
Noise Figure Measurement Video and Feature Overview

Signal Hound programmer Roger Rush walks through the process of making a basic noise figure measurement and explains why noise figure measurements are important.

Signal Hound

https://bit.ly/3vL1NfF

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COMPONENTS

High-Power Microwave Components

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CPI is one of the largest manufacturers of receiver protectors. CPI designs and manufactures a broad range of RF and microwave products for radar, communications, electronic warfare, medical and scientific applications. They also manufacture a broad range of pressure windows and pressure bypass windows. Their products are found in numerous radar systems operated by the U.S. military and militaries around the world.

CPI Beverly **www.cpii.com**

Mixer Runs

VENDORVIEW

Mini-Circuits' model MDB-54H+ is a surface-mount MMIC mixer with RF/LO range of 20 to 50 GHz and intermediate-frequency (IF) range of DC to 20 GHz. A good fit for mmWave communications and test, the InGaP HBT mixer works with +15 dBm (Level 15) LO power for frequency up-conversion/down-conversion and typical conversion loss of 11 dB. LO-to-RF isolation is typically 45 dB while LO-to-IF and RF-to-IF isolation is at least 20 dB. The MMIC mixer is supplied in a 12-lead MCLP package measuring 3 × 3 mm.

Mini-Circuits **www.minicircuits.com**

CABLES & CONNECTORS

SUCOFLEX® 550 Cables

VENDORVIEW

The new SUCOFLEX 550 cable from HUBER+SUHNER raises test and measurement applications to the next level of precision and reliability. This customisable solution boasts excellent reliability over an extended service life, providing industry professionals with an assembly that minimizes testing downtime and delivers excellent price-performance ratio. The HUBER+SUHNER high performance cable assembly SUCOFLEX 550 is suitable for up to 50 GHz, provides excellent return loss, phase and amplitude stability compared to bending as well as low loss.

HUBER+SUHNER AG **www.hubersuhner.com**

HyperFlex™ Cables

MegaPhase introduced a new, innovative cable series providing a new level of flexibility for inside-the-box and small form factor applications. HyperFlex™ cables use a solderless connector design which enables bending directly behind the connector without affecting performance or function. Ideal for military applications, including airframes and airframe components, HyperFlex™ solderless cables are available in three sizes, 0.090, 0.120 and 0.141 in., with a frequency range through 67 GHz.

MegaPhase **www.megaphase.com**

RF mmWave Cable Assemblies

Samtec now offers Precision RF mmWave cable assemblies on 0.085" and 0.086" low loss flexible cable (RF085, RF086 Series). The RF085 Series includes 2.92 mm connector options, with operating frequency up to 40 GHz and maximum VSWR of 1.40. The RF086 Series includes 2.40 mm connector options, with operating frequency up to 50 GHz, and maximum VSWR of 1.40. Connectors, on both RF085 and RF086 assemblies, are solder clamped to the cable.

Samtec **www.samtec.com**

AMPLIFIERS

High-Power Amplifier

Model MPA-017060S51 is a 1.7 to 6 GHz 120 W solid-state power amplifier. Over 1.7 to 6 GHz, power output is typically 120 W, minimum 100 W, ±1.6 dB maximum gain flatness, -15/-25 dBc second and third harmonics, -70 dBc spurious, -10 dB maximum input/output return loss, 53 dBm OIP3 and 25 to 35 percent efficiency. The size is 240 × 240 × 25 mm, it has built-in control, monitoring and protection circuits, can work over -45°C to +65°C. For 1-9 pcs the price is $14,399 each, delivery is stock to four weeks. Rack mount amplifier is available.

Fujian MIcable Electronic Technology Group Co. Ltd. **www.micable.cn**

New**Products**

SDLVA

PMI Model No. SDLVA-0120-70-0225 is a SDLVA that operates over the 0.2 to 2.5 GHz frequency range. Dynamic range: > 65 dB; log linearity: ±1.2 dB typical, ±1.5 dB maximum at -60 to 0 dBm and ±1.5 dB typical, ±2.0 dB maximum at -65 to +5 dBm; minimum logging range: -60 dBm (-65 dBm typical); maximum logging range: 0 dBm (+5 dBm typical); VSWR input: 2.0:1 maximum (1.5:1 typical) tangential sensitivity: -60 dBm minimum (-65 dBm typical); limited IF output: -16 dBm typical; maximum RF input power: +10 dBm, +15 dBm typical; and log video output: output coupling: DC, maximum output voltage: 2.7 V, rise time: 25 ns maximum, fall time: 30 ns maximum, DC offset: 0.1 V nominal (adjustable), slope: 20 mV/dB nominal, propagation delay: 10 ns maximum, 7 ns typical and video load: 100 Ohms ± 10 percent. This model has SMA female connectors in a housing measuring 3.75" × 1.50" × 0.50".

Planar Monolithics Industries
www.pmi-rf.com

SOURCES

SMT Noise Sources

Fairview Microwave Inc. has debuted a new series of miniature SMT packaged noise sources that are ideal for built-in test equipment, dithering for increased dynamic range of A/D converters and as a source for bit error rate testing. Applications include microwave radio, communication systems, military and commercial radar, base station infrastructure, test and measurement and telecom data links. Fairview Microwave's new line of noise sources includes nine models with dual in-line pin and industry standard SMT gullwing pin surface-mount packaging options.

Fairview Microwave Inc.
www.fairviewmicrowave.com

RF Arbitrary Waveform Generator/Transceiver

Tabor Electronics' new addition to the Proteus series, RF Arbitrary Waveform Generator/Transceiver. The series offers the highest performance direct digital RF generation and acquisition with up to 12 channels 9 GS/s 16 bit, AWG and AWT configurations and 16 GS waveform memory. The RF AWT configuration has a complete control system with digitizer and feedback loop with the lowest latency available in the industry. Perfect for applications in telecom and aerospace and defense.

Tabor Electronics **www.taborelec.com**

ANTENNAS

LTE Antennas

Novocomms announced the global launch of the FPCB LTE 4G antenna. The FPCB LTE 4G is the latest addition to the British technology company's family of patented multi-channel antenna for use within the IoT sector. Novocomms has invested heavily to provide customized engineering support to their customers—unique within the industry. The company's highly qualified team of engineers have many years of industry experience in providing solutions within the IoT supply chain.

Novocomms **www.novocomms.com**

TEST & MEASUREMENT

RF Agile Transceiver

ADI's AD9351 RF agile transceiver has high performance and is highly integrated. Its programmability and wideband capability make it ideal for a broad range of transceiver applications such as vehicle tracking, telemetry, command and control.

The device combines an RF front-end with a flexible mixed-signal baseband section and integrated frequency synthesizers, simplifying design-in by providing a configurable digital interface to a processor and supports channel bandwidths from less than 200 kHz to 56 MHz. Features include wafer diffusion lot traceability and radiation testing.

Analog Devices **www.analog.com**

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The AnaPico External Battery adapter with an integrated voltage converter for 12 to 25 V supply is designed to operate our modules in a portable/bench-top and flange-mount enclosures. It can be connected between the signal source and an external battery. Ideally suited for outdoor field applications.

AnaPico AG **www.anapico.com**

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The only modular, portable 5G RF spectrum analyzer that lets you analyze FR1, including CBRS/C-Bands, and FR2 with a single, field-upgradable solution. The 5GPro Spectrum Analyzer with over-the-air measurements delivers an easy-to-perform and easy-to-interpret experience. Ready to adapt as your network transforms, the flexible, modular platform lets field techs and RF engineers analyze FR1 (sub-6 GHz) including CBRS/C-Bands, and FR2 (mmWave) bands with a single solution for extreme flexibility and upgradability.

EXFO **www.exfo.com**

SignalShark

When connected to Narda's powerful real-time receiver SignalShark, the ADFA 2 can precisely and reliably localize signals between 10 MHz and 8 GHz. This newly developed automatic DF antenna delivers extraordinarily stable measurement results in milliseconds. Additionally it is insensitive to reflections. Its wide frequency range means that direction finding at low and high frequencies is covered equally. This makes the ADFA 2 particularly interesting for use by mobile network providers and regulatory authorities, as well as for military applications.

Narda Safety Test Solutions
www.narda-sts.com

IMS

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Consider submitting a proposal for workshops, technical lectures, focus and special sessions, and panel and rump sessions.
Note: Preliminary workshop and technical lecture proposals due 16 July 2021.

IMS2022 is the centerpiece of Microwave Week 2022, which includes the RFIC Symposium (www.rfic-ieee.org) and the ARFTG Microwave Measurement Conference (www.arftg.org).

The Peaks of Microwaves

Join us as we explore the new Peaks of Microwaves including:

- Radar, Phased Arrays, OTA test: the triumvirate of modern microwave systems
- Microwaves for Tiny AI and IoT
- Hardware for Intelligent Mobility, Automotive, and IIoT applications
- Microwaves and satellites for Space 2.0
- 5G/6G Hardware: from components to system-on-chip and RF to THz
- Quantum RF Engineering
- Evolving RF/EM design strategies

Microwave Week provides a wide variety of technical and social activities for attendees and exhibitors.

New This Year: IMS2022 Systems Forum

- “The Connected Systems Summit,” presenting current thinking on next generation wireless technologies at mmWave and THz frequencies, will include presentations, panels and a pavilion on the exhibition floor
- Focused sessions investigating the synergy between radar, phased arrays, and OTA test and applications
- Space 2.0 event highlighting advances in aerospace, the Internet-of-Space and the MTT CubeSat competition

Something for Everyone

- Competitions for best Advanced Practices Paper and Student Paper
- RF Bootcamp intended for students, engineers, and managers new to microwave engineering disciplines
- Workshops and application seminars from our exhibitors, explaining the technology behind their products
- Networking events for Amateur Radio (HAM) enthusiasts, Women in Microwaves (WiM), and Young Professionals
- Guest hospitality suite

Important Dates

17 September 2021 (Friday)
PROPOSAL SUBMISSION DEADLINE For workshops, technical lectures, focus and special sessions, panel and rump sessions. **Preliminary workshop and technical lecture proposals due 16 July.**

7 December 2021 (Tuesday)
PAPER SUBMISSION DEADLINE All submissions must be made electronically.

2 February 2022 (Wednesday)
PAPER DISPOSITION Authors will be notified by email.

9 March 2022 (Wednesday)
FINAL MANUSCRIPT SUBMISSION DEADLINE
Manuscript and copyright of accepted papers.

6 April 2022 (Wednesday)
SLIDE PRESENTATIONS DEADLINE FOR ALL AUTHORS AND PRESENTERS

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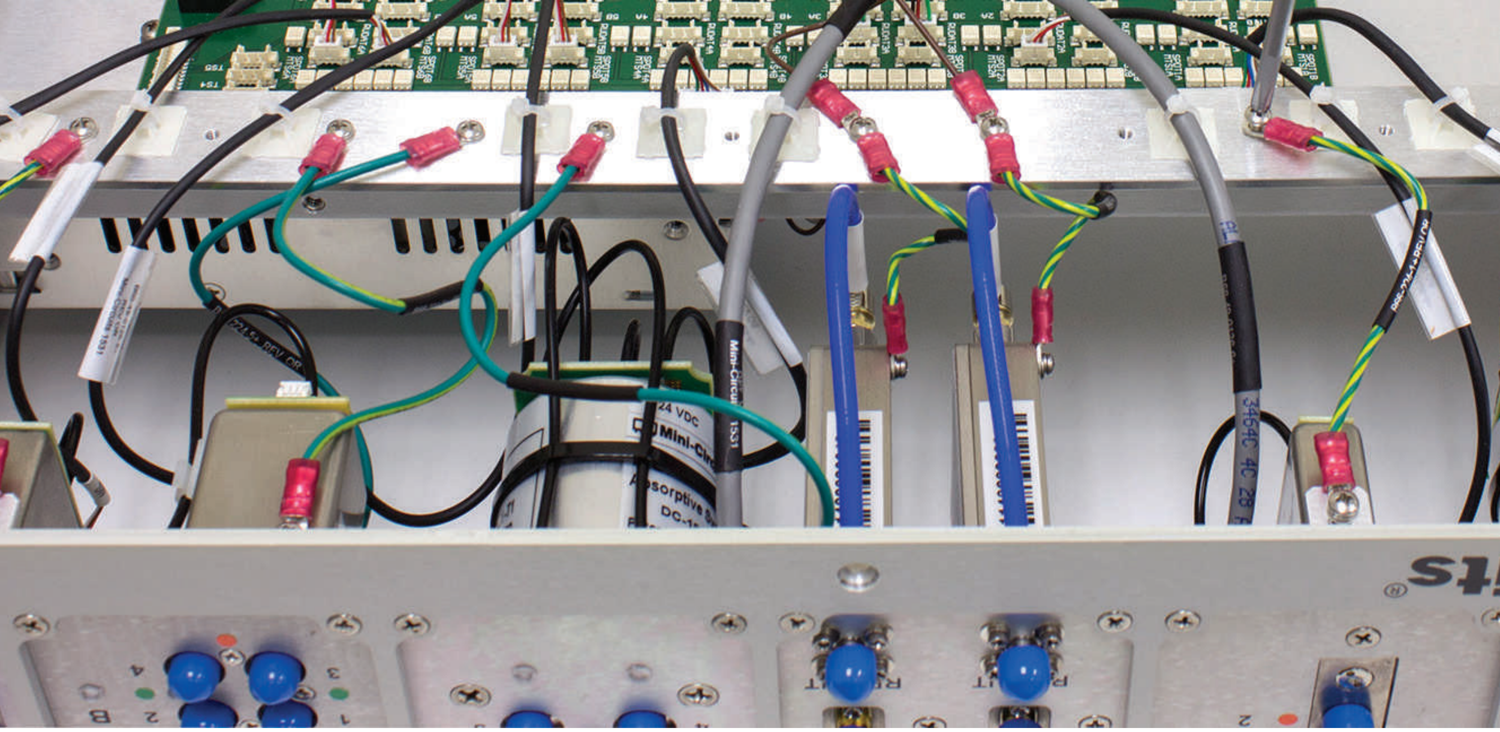

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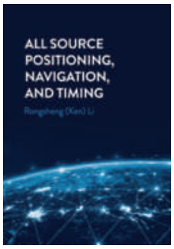

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On behalf of the **IEEE COMCAS 2021** Steering Committee, it is our pleasure to launch the 8th International IEEE Conference on Microwaves, Communications, Antennas, Biomedical Engineering and Electronic Systems (IEEE COMCAS 2021).

In 2021 the International IEEE COMCAS will go beyond the industry standard and provide a multidisciplinary forum for the exchange of ideas, research results, and industry experience in a range of key areas i.e., microwaves, communications and sensors, antennas, biomedical engineering, RF and Microwave devices and circuits, thermal management and electronic packaging, signal processing and imaging, as well as radar, acoustics and Microwave system engineering. In its entirety the event includes a technical program, industry exhibits, and guest presentations from global experts on recent industry advancements.

Israel is among the first countries to begin recovery from COVID-19. Thanks to our mass vaccination drive, face 2 face conferences and events are happening again, and we are pleased to have the opportunity to hold IEEE COMCAS before the end of 2021!

In launching the 2021 event, we would also like to welcome you to the sunshine of the eastern Mediterranean, in Tel Aviv.
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KEYNOTE SPEAKERS

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Thales Alenia Space, Italy

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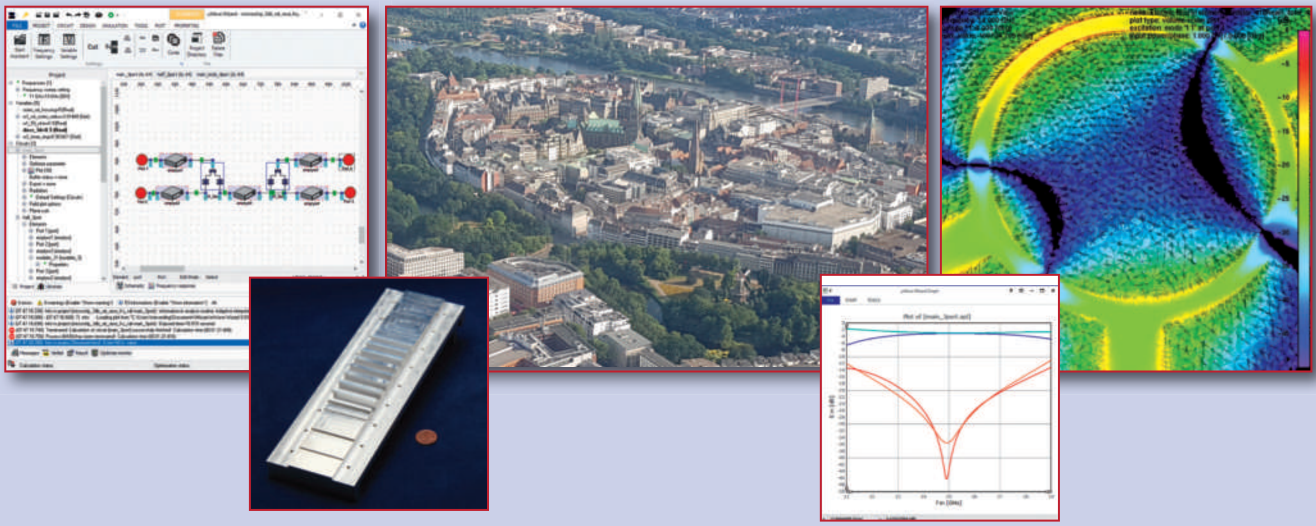
FABS and LABS

Mician: Fast, Accurate Simulation Wizard Speeds Microwave Design



In the beginning, RF design was a long, slow iterative process, with designers crafting their skills through trial and error, gradually developing an intuition of what works by accumulating many failures from what did not work. Successful designers who honed their capabilities were considered gurus, practitioners of both science and magic. Computer-aided design has since transformed RF design, beginning with linear circuit simulation, then evolving to nonlinear simulation and electromagnetic (EM) analysis. Software powered by ever-improving computational hardware has drastically reduced design risk and development time, making the holy grail of first-pass success achievable for many RF, microwave and mmWave designs.

Reflecting the desire to make accurate, fast EM simulation accessible to all, Mician was formed in 1998 by two friends who were PhD candidates at the University of Bremen. While 3D solvers provide the most comprehensive circuit analysis, the calculations consume time. Mician's founders thought they could streamline 3D analysis by applying mode-matching (MM) techniques and derivatives, even for structures which seemingly required 3D analysis. The gestation of their goal rolled out in 2001 and was subsequently named µWave Wizard™. The µWave Wizard platform combines MM with 3D finite element modeling (FEM) and other techniques in a hybrid solver with an easy-to-use graphical interface. The hybrid solver taps the flexibility of FEM and the speed and accuracy of MM, yielding a cost-effective simulation tool for passive microwave circuits, including antennas.

Mician's hybrid solver cascades predefined circuit elements from µWave Wizard's libraries with user-generated elements created by the conventional approach: drawing the structure in 3D. Each circuit element is simulated using the fastest, most accurate solver for its geometry, and the S-parameters of the complete structure are simply the cascaded responses of all the individual components. µWave Wizard's libraries contain irises, cavities, junctions, orthomode transducers, polarizers and horns, each described by a modal scattering matrix. The designer determines the accuracy and speed of the simulation by choosing the number of modes for each, which are defined by the cutoff frequency of the highest considered mode. This hybrid approach—combining predefined elements with user-generated geometries, rather than developing a 3D model of the entire structure—significantly improves the computational efficiency.

Several versions of µWave Wizard are available: the standard µWave Wizard, a rental version with more capabilities and customized versions tailored to contain only the features needed by the customer. Mician continues to improve µWave Wizard's capabilities by improving the speed and accuracy of simulation, adding library elements and interfacing with third-party applications.

More than 20 years after its founding, Mician retains its roots in Bremen from an office near the Weser River, with one in Redondo Beach, California, to better support its North American customers. The longstanding team remains committed to the founders' vision of accuracy, speed and user friendliness, which has made µWave Wizard the preferred simulation tool for many microwave designers around the world. They rely on Mician's responsive support and its stream of software updates, which continually improve the platform and their designs.

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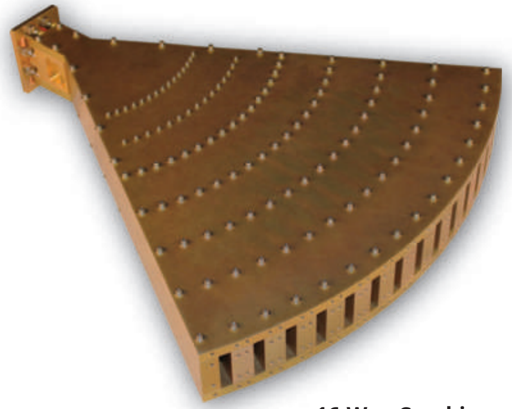

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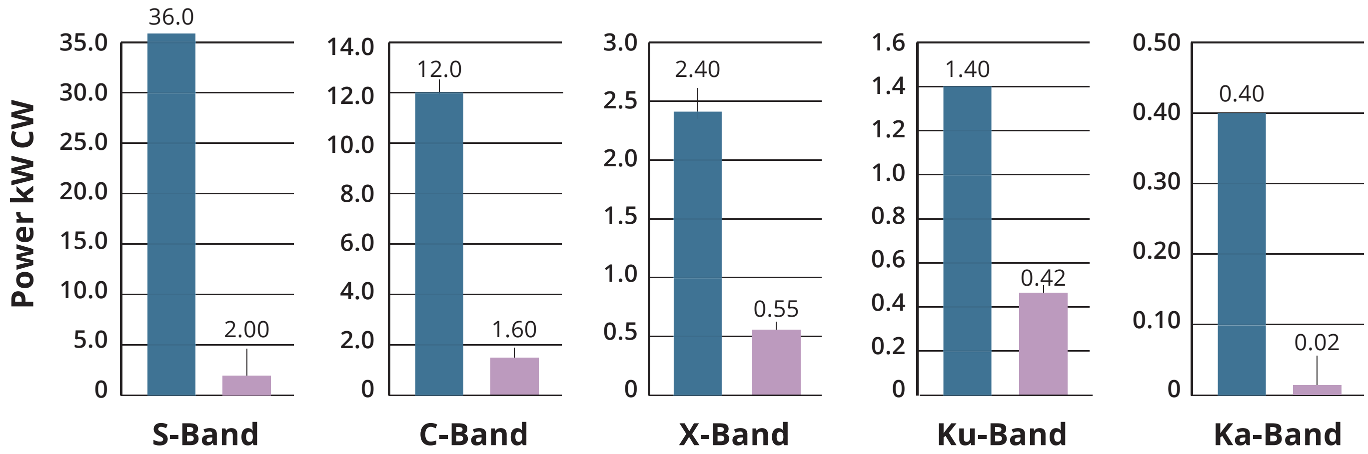

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