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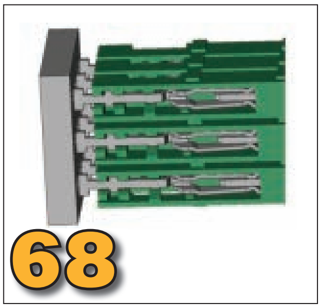

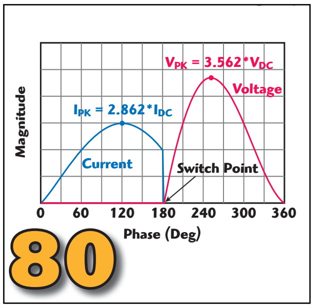

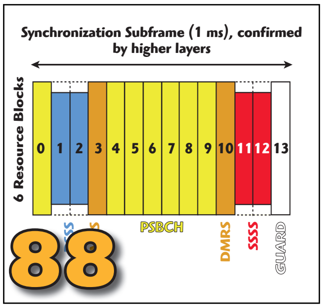

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Dr. Greg Henderson, vice president of Analog Devices' RF and microwave business unit, discusses how the company is now positioned to supply the entire radio signal chain as a partner to their customers after the acquisition of Hittite in both the commercial and defense sectors.

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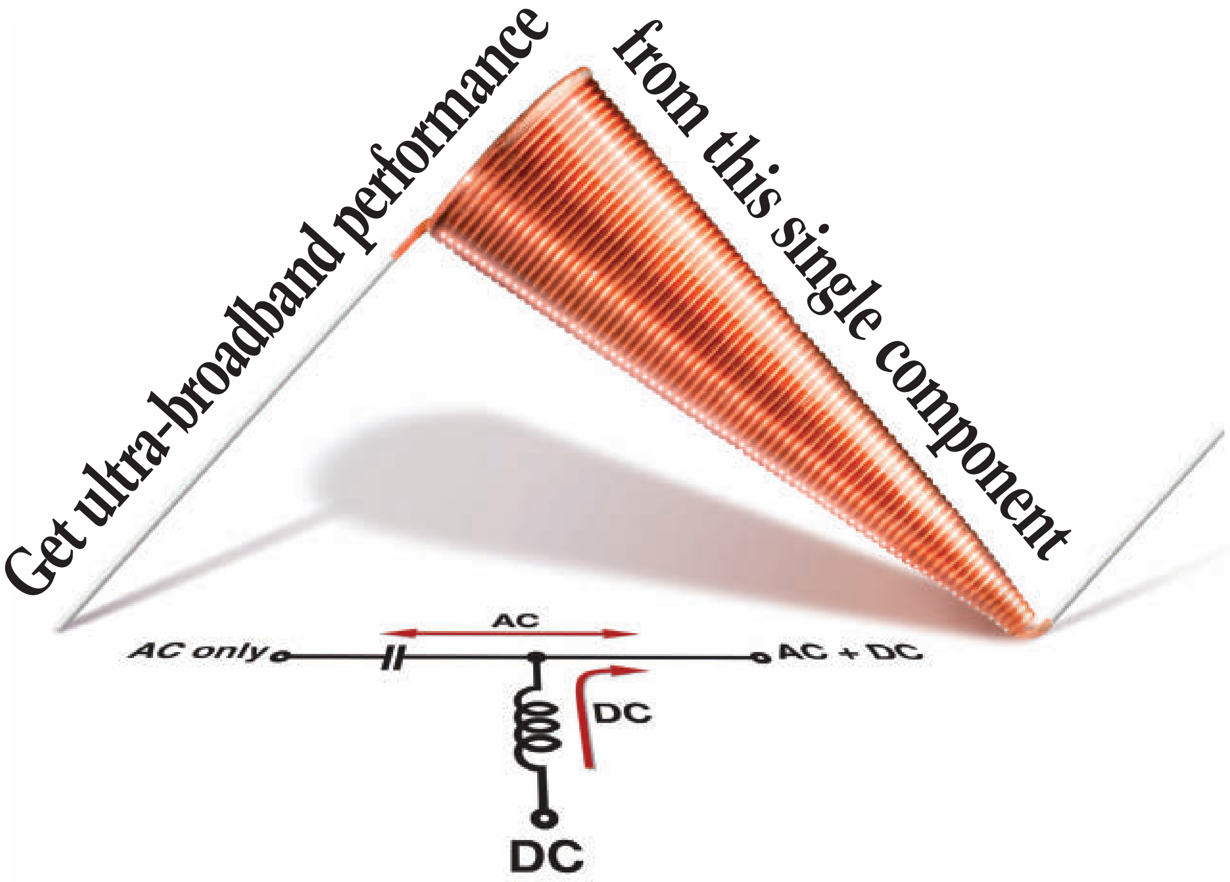

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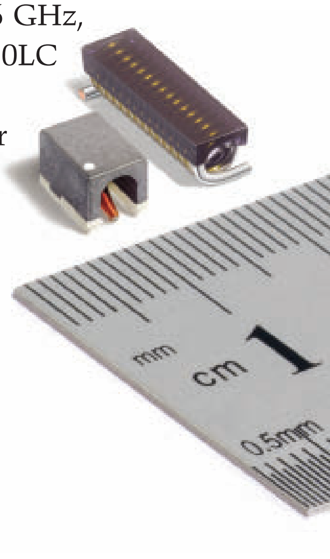

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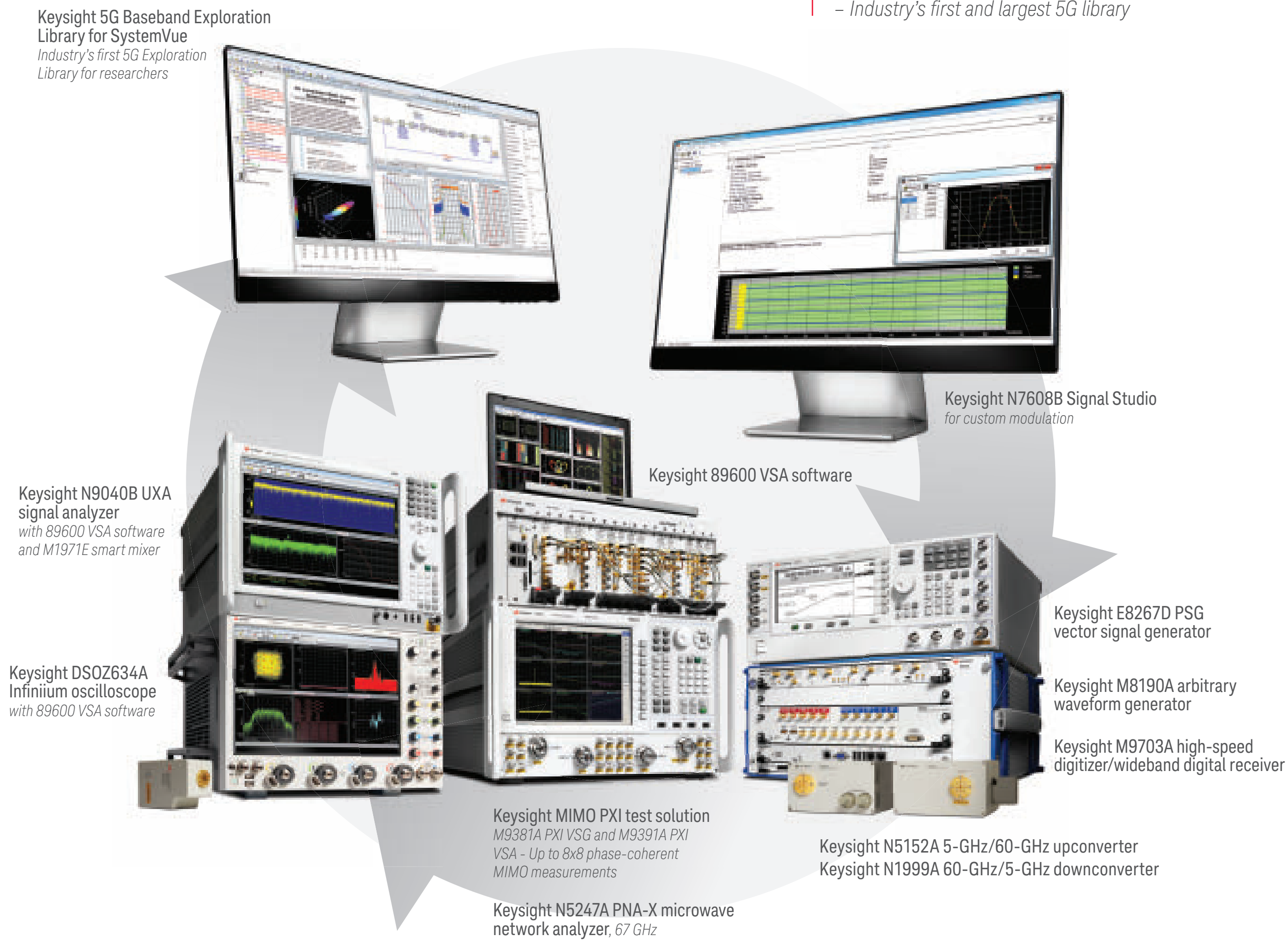

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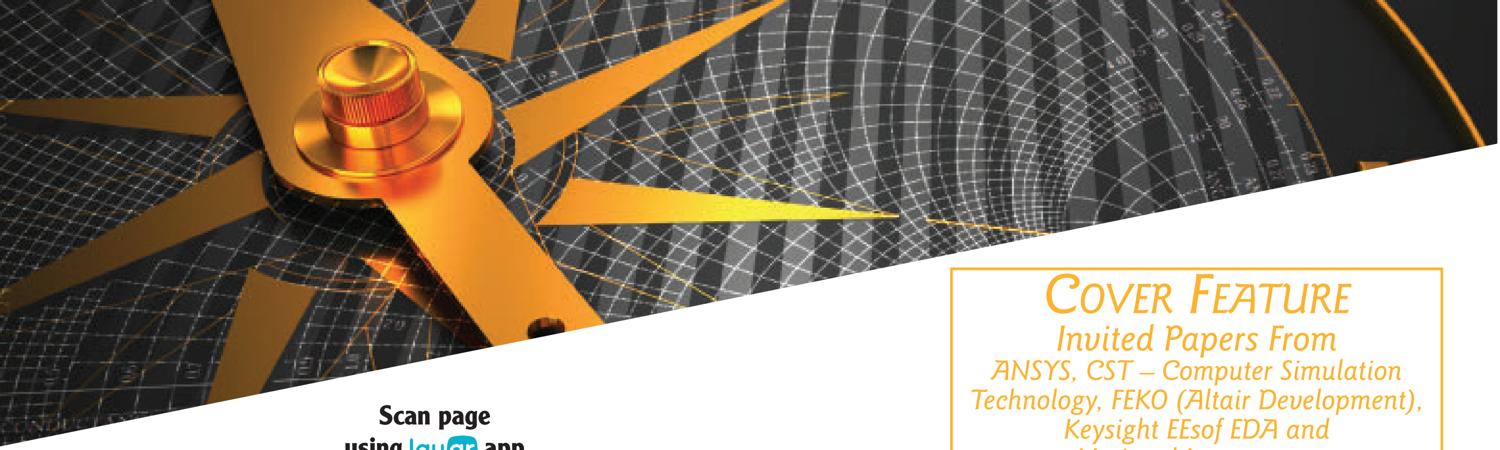

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COVER FEATURE
Invited Papers From
ANSYS, CST – Computer Simulation Technology, FEKO (Altair Development), Keysight EEsof EDA and National Instruments

RF/Microwave EDA Supporting IoT Design

Editor's Note: As the Internet of Things (IoT) becomes a growing trend of design and development, we asked some leading software EDA companies to provide practical examples of how their tools are enabling IoT design. These examples range from wearable devices to 5G, medical and industrial applications.

Supporting the IoT Design Chain

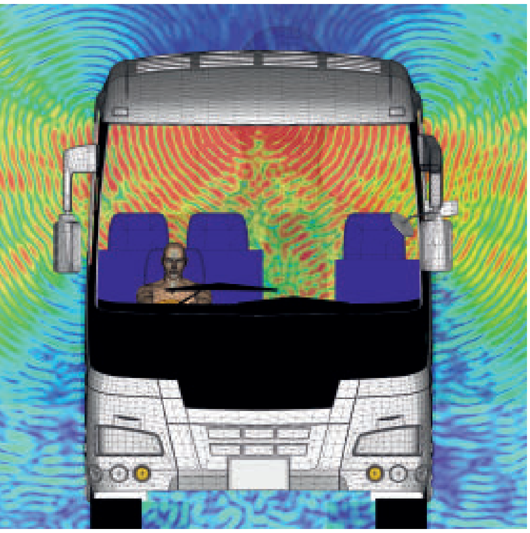
ANSYS
Canonsburg, Pa.

IoT will be developed on such a large engineering scale across so many industries (medical, transportation, industrial, etc.), that it will transform the electronics industry, revolutionize the RF/microwave component supply chain and place new demands on design tools, workflows and skill sets. Estimates call for 200 billion smart devices by 2020 with devices outnumbering people by a ratio of 26 to one. The IoT ecosystem will enable massive data collection (sensing), connectivity M2M (machine to machine) and H2M (human to machine) on a host of platforms (wearables, connected homes, cars, cities, medical, industry, etc.) supported by cloud infrastructure.

Furthermore, power consumption, data security and communication standards compliance will be critical design requirements for connected applications. Striking an optimal balance between power efficiency, antenna integration and performance, security and cost is a key design challenge faced by engineers developing IoT devices and infrastructure. Therefore, design tools must help engineers develop robust, high-fidelity communications, power conservative mixed signal-processing and cost optimized electronics. These capabilities have been the focus of ANSYS' software development and strategic acquisitions, leading to a product portfolio and roadmap that is uniquely aligned with a complex design chain developing the full range of integrated circuits (IC), sensors, antennas and embedded software that will define IoT.

Since the industry's inception, market leaders have relied on simulation-driven product development to launch their devices quickly, cost-effectively and with a high degree of confidence that they will perform as expected. Moving forward, engineering teams will need to adopt new technologies more rapidly than ever before. Technologies adopted for IoT will be developed and integrated with software tools that accurately address real-world physical design, offering solver technologies with the speed and capacity to simulate smart devices in their operating environment using a workflow that optimizes engineering productivity.

With smaller, portable devices operating at low power, designing components in isolation is no longer a valid approach. Engineers cannot work from the abstract of a schematic for individual components; they must consider the geometry of the actual device to include all of the physical effects. This means being able to visualize the entire physical design, insert appropriate components (such as surface-mount devices, connectors and ICs), and run both frequency and time domain simulations with all electromagnetic and thermal/mechanical effects included. ANSYS multiphysics products support virtual prototyping through simulation of the electrical, thermal (with ANSYS Icepak) and mechanical behavior of components based on geometries and materials defined by the



engineer. Structures can range from a miniaturized, embedded antenna array to stacked die in electronic package on a complex PCB.

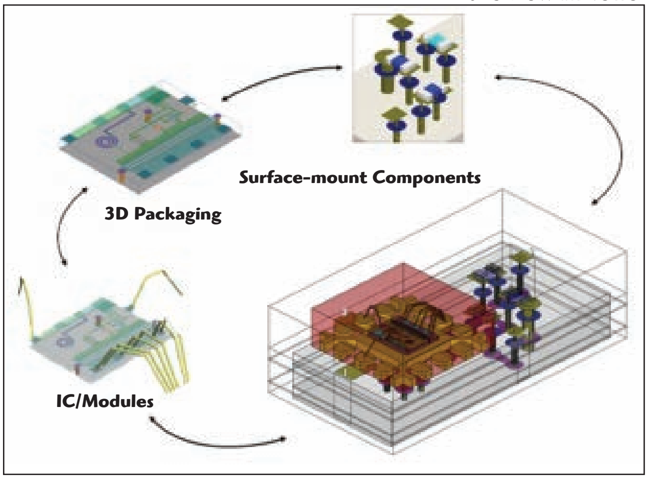
ANSYS addresses electronic design from the chip to the package and board, through the mobile/base station antennas and over-the-air – from baseband to RF. IoT electronics will require a chip–package–system workflow coupled to multi-physics for thermal and mechanical stress analyses (see ***Figure 1***). The ANSYS CPS workflow includes Chip Power Model (CPM), a compact SPICE-correlated model of the full-chip power delivery network. CPM comprises spatial and temporal switching current profile as well as nonlinear on-chip devices to accurately represent chip behavior for package and PCB simulation. The workflow employs advanced meshing and multi-CPU solver technologies to rigorously solve Maxwell's equations and generate accurate broadband models of the package and PCB. This approach enables engineers to identify and address root causes of signal integrity and power integrity issues, balancing the lower operating voltages needed to conserve power with the consistency and reliability required to eliminate device failures.

Design Examples

Using simulation to achieve extremely low power, compact size and comprehensive connectivity is exemplified in Atmel's IEEE 802.11 b/g/n IoT network controller SoC and family of ARM Cortex-M0+ MCUs. The design team leveraged ANSYS HFSS, ANSYS RedHawk and ANSYS Totem to design and validate these complex SoCs and platforms used across multiple IoT application segments. These simulation solutions enabled the company to meet stringent power/performance requirements, ensure reliable operations across a wide-range of frequencies and deliver products with tight time-to-market constraints.

ANSYS software development is focused on several notable innovations that allow engineers to leverage component level IP that can be incorporated into simulation models and combined hierarchically into complex systems with an accuracy previously reserved for design verification. Moving to this level of simulation fidelity earlier in the design process saves significant time and costs, but does require more computing power. High performance computing (HPC) delivers this computational power for HFSS simulations by leveraging more nodes of a compute cluster or cloud environment to accelerate design efforts through combined distribution of design parameters, frequencies and multi-core/multi-domain EM solvers. With several notable features, such as distributed direct matrix and domain solvers, HPC is becoming widely adopted among HFSS users.

The exchange of design information between engineering disciplines (i.e., electrical and mechanical) and across organizations (i.e., vendor and OEM) will be one of the major challenges for IoT. Along with simulation run times, design entry (model set-up) and workflows between tools play a major role in defining engineering productivity and limiting design exploration. In 2015, HFSS became fully integrated with the company's circuit and system simulation tools in the new ANSYS Electronics Desktop, a single-window, highly integrated interface that provides a seamless working environment to maximize productivity and to ensure users are following simulation best practices. In addition, the ANSYS Electronics Desktop features a 3D EM (electromagnetic) component library.



▲ *Fig. 1 System workflow to address complete design cycle.*

The 3D EM library, which both engineers and CAD support teams can use, can be coupled with IP (intellectual property) protecting encryption to share HFSS components between design teams and across high-frequency supply chains to expedite communication system integration, a critical factor in support of a broad IoT eco-system. Users can create 3D components and integrate them into larger electronic assemblies. Simulation-ready 3D components stored in library files can be added to larger system designs without requiring the user to apply excitations, boundary conditions and material properties.

The potential impact 3D EM components will have on the IoT design chain is perhaps most evident in the case of antenna design and placement. Embedded antennas in wearable devices often radiate in all directions with considerable energy being absorbed by the body. Using HFSS and Optimetrics, engineers at Vortis Technology Inc. were able to explore more design scenarios in the development of their micro array antenna using interferometry to reshape the RF energy fields and reduce the unwanted RF signal strength toward the user while enhancing the emissions toward the receiving sites. Design exploration through parametric modeling and optimization automates the design process, while the analytic derivative can extract design sensitivity from a single simulation. Designers at Vortis were able to determine the optimum placement of the two antennas phased 180 degrees in order to create a null of energy against the body while the signals enhance each other in the desired direction. The result was a 10 fold drop in energy toward the body and an equal enhancement in the radiated far fields thereby improving efficiency and extending battery life. The encrypted antenna could then be distributed in a component library to IoT mobile device manufacturers for further design and integration into their platform.

IoT models (mechanical designs) will come from many sources. To accelerate model development, ANSYS simulation tools can import electronic CAD (ECAD) and mechanical CAD (MCAD) data from a variety of sources, streamlining the transfer of design databases from EDA layout tools offered by Altium, Cadence, Mentor Graphics and Zuken or 3-D geometries from mechanical CAD (MCAD) packages using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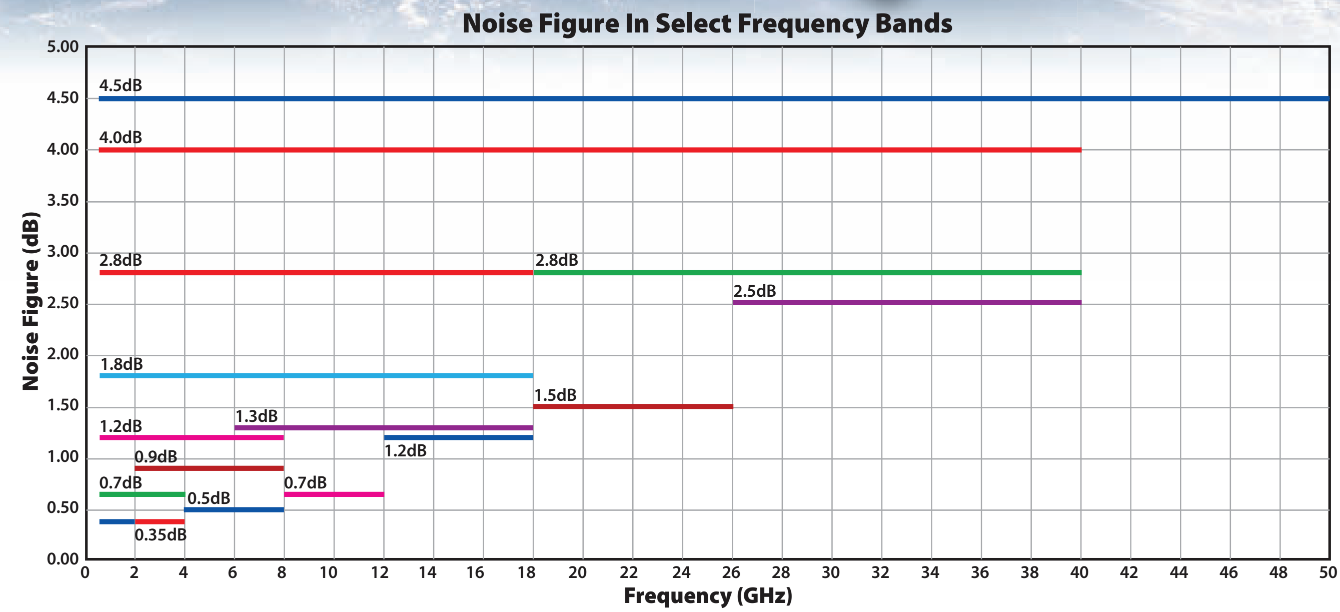
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Noise Figure (dB)
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0.00
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0.9dB
0.7dB
0.7dB
0.5dB
0.35dB

common file formats, such as IGES, STEP, ACIS and Parasolid. With ANSYS SpaceClaim Direct Modeler, designers can quickly prepare geometries from these CAD systems for simulation by cleaning up and simplifying geometries, adding parameters, and a host of pre-simulation model prepping operations. The imported CAD model becomes completely dynamic, allowing designers to move, stretch, add and remove with mouse movements. All changes to the CAD model occur in real-time on the screen for instant feedback, ready for export into HFSS and reducing labor-intensive model prep from weeks down to hours.

Simulation of Antennas for Wearable IoT Devices

CST – Computer Simulation Technology
Darmstadt, Germany

The whole idea of the Internet of Things is to network together physical objects so that they can exchange data with each other, with the operator and with the manufacturer. This improves the value of the devices and the quality of the service. In order to monitor and affect the surroundings, the "things" containing sensors, controllers and actuators need to be connected together.

The proliferation of smart devices and installation challenges of cables mean that the majority of IoT devices are designed to operate wirelessly. Electromagnetic simulation allows the antennas that connect these devices to be modeled in a realistic environment in order to analyze installed performance, with the aim of improving the reliability and efficiency of the IoT.

New antenna technologies require multiple antennas (sometimes with MIMO antenna diversity) operating in multiple frequency bands within a small physical profile. Antenna placement plays a significant role in determining the performance of an antenna, and can also lead to potential co-site interference effects between systems.

Wearable antennas, as used in body-area networks, pose a special challenge in this regard. Currently, the most familiar commercial application for wearable technology is the rapidly-growing market for smart watches and fitness trackers. However, the antennas also have considerable potential to allow better diagnostic technology for medical patients, and to allow rescue personnel and other workers in dangerous environments to be monitored in real-time.

These antenna requirements are stringent: they have to achieve a given performance with severe restrictions on form factor (low profile, lightweight, integrated into clothing or worn devices) and are installed in a challenging environment next to a large volume of high permittivity lossy material – the human body. In addition, there are legal constraints regarding human exposure to EM fields that need to be considered.

Because IoT devices often need to be small and low cost, integrated printed antennas offer a considerable advantage over off-the-shelf designs. Antenna Magus and CST STUDIO SUITE make it possible to quickly synthesize and optimize printed antennas on a densely populated PCB.

Design Example

Simulating the device on a human body model offers a far more accurate picture of real-world than simply considering the antenna's performance in isolation. Other components within the device as well as the body itself will absorb or reflect power (shown in ***Figure 2***), and changes to the antenna itself will also affect its efficiency and directivity. This is especially important

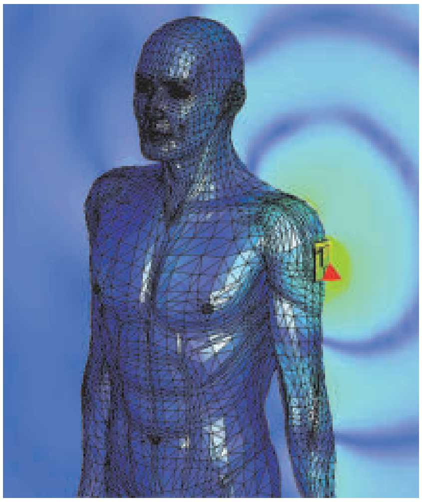
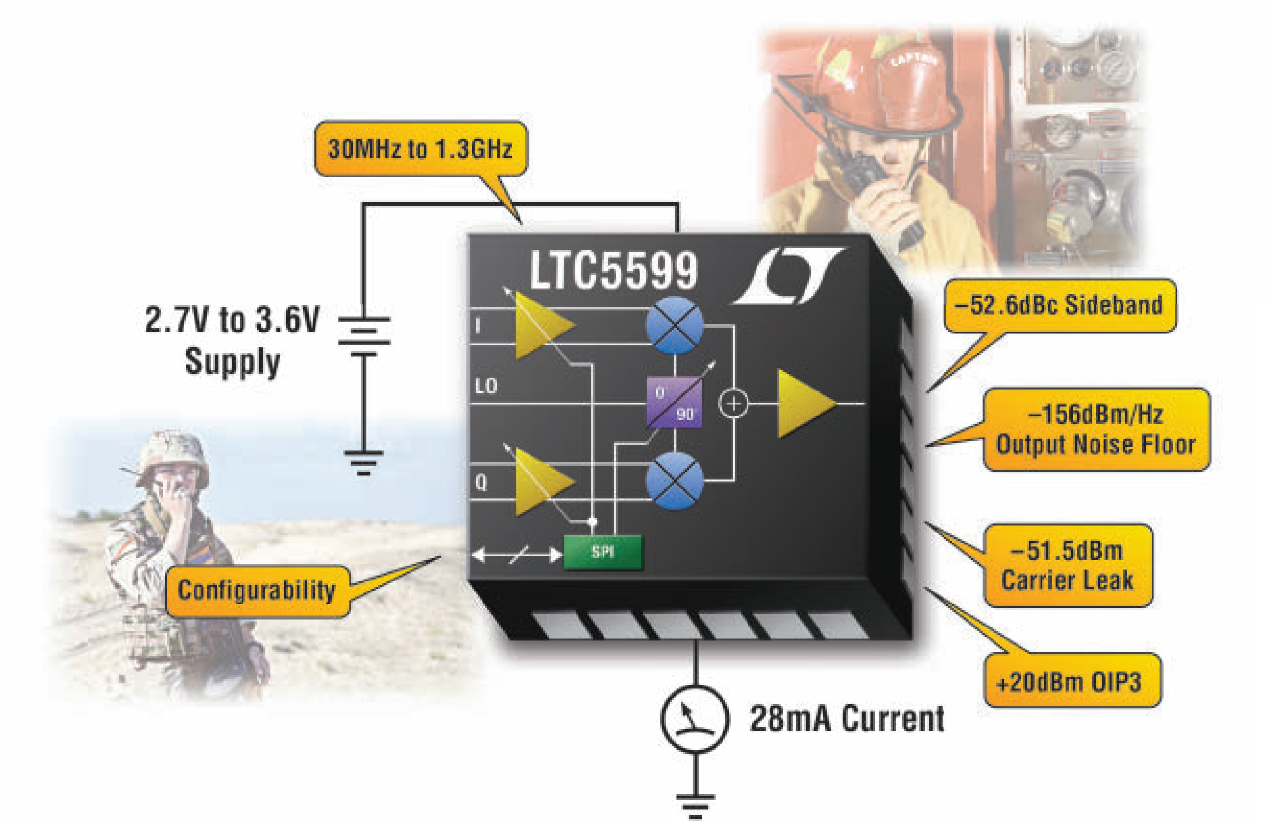


Fig. 2 Electric field around a flexible worn slot antenna.

90mW I/Q Modulator



Powered from a single supply from 2.7V to 3.6V, the LTC®5599's 28mA supply current extends battery run time. The modulator offers superb –52.6dBc sideband and –51.5dBm carrier suppression—without the need of calibration. Its low noise floor of –156dBm/Hz and 20dBm OIP3 capability ensure outstanding transmitter performance. The LTC5599's built-in configurability allows users to optimize performance from 30MHz to 1.3GHz, minimizing external components and saving costs.

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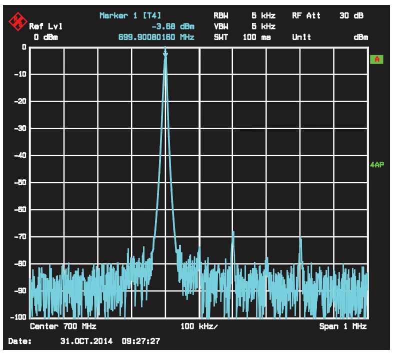

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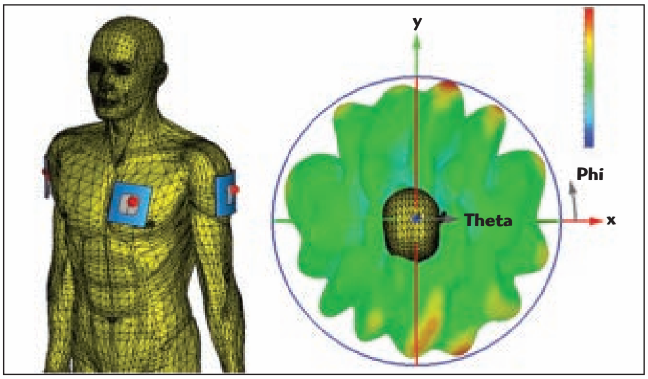

▲ *Fig. 3 Four flexible antennas combined into a MIMO body-worn system (a) and realized gain at 2.4 GHz with all antennas excited simultaneously (b).*

for flexible antennas which can be integrated into clothing, including state-of-the-art woven antennas. Bending, twisting or stretching the antenna changes its properties, and for applications where reliability is crucial, it is vital to ensure that the antenna performs within specifications for all plausible configurations. With virtual prototypes, antenna performance can be calculated and the design optimized to counteract detuning effects.

Another consideration – one that is vital for regulatory approval – is specific absorption rate (SAR). This is a measure of how much energy tissues within the body absorb, which is very difficult to measure in vivo. The human body is not homogeneous, and the different tissues that comprise it often have very different properties – muscle for example has rather different electrical and thermal properties to bone. Simulating the SAR – and finding the worst-case scenario – allows engineers to calculate how much power can be safely input to the antenna and can reduce the risk of failing to meet regulatory limits at the expensive physical prototyping stage.

A realistic SAR calculation requires a detailed heterogeneous body model – for example, a voxel model or a specially constructed CAD model – that includes all the relevant structures inside the body. CST STUDIO SUITE includes a toolbox of SAR calculation techniques that can calculate the power absorbed both at individual points within the body and averaged over volumes of tissue. Both the current standard, IEEE C95.3, and the upcoming standard IEEE/IEC 62704-1, are supported, and CST is involved in the ongoing development of SAR standards.

In order to improve connectivity in complex environments, MIMO systems and beam-steering are increasingly used in portable devices. A benefit of MIMO is that it can offer improved performance in complex multi-path environments – for example, built-up areas. Multi-path signal transmission may lead to destructive signal overlay, resulting in local deep dips in an effect called Rayleigh fading. Using multiple antennas (antenna diversity) allows this fading to be reduced.

CST STUDIO SUITE has several built in post-processing options to evaluate the potential MIMO performance which can calculate the envelope correlation (including spatial power weighting functions), diversity gain and multiplexing efficiency. ***Figure 3*** shows the antennas for a wearable device with MIMO – there are four antennas to cover the shadowed areas of the body, and each one is locally conformal. Because each flexible antenna is warped differently, and because the body beneath is lossy, the antennas individually have variable performance (the most distorted antennas on the arms have a frequency shift of about 50 MHz relative to the least distorted). Nevertheless, good performance is achieved using MIMO, with a good pattern and spatial diversity, a low correlation coefficient and a good multiplexing efficiency.

Simulation is an essential tool in the design flow for the realization of IoT devices. Different antennas at different frequencies can be integrated into a single compact device, and their performance analyzed in a realistic environment. Human body models can be integrated into the simulation model, and important biological results such the SAR can be calculated. The performance of the antennas integrated into a larger system can also be calculated, taking into account the MIMO principles of modern communications. Together, all of these features allow simulation to be used at any stage of the design process from a single integrated environment.

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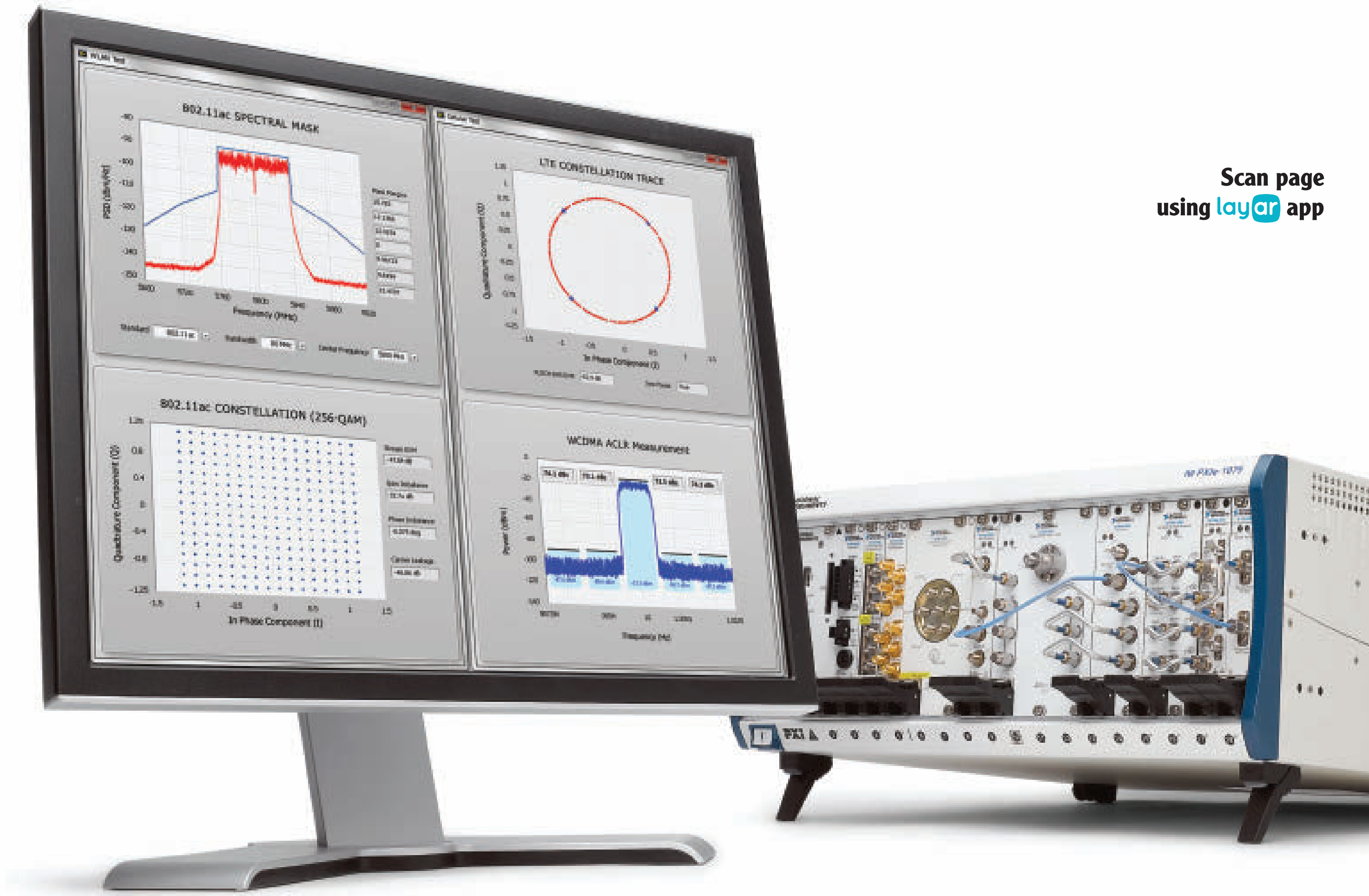

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5G and IoT Development Flexibility
FEKO (Altair Development)
South Africa

Along with the advancements in mobile communications technologies, there is a tremendous development in the mobile handset hardware over the years, and mobile phones have evolved from the "brick" model to the present-day "slick" models. This evolutionary process has also brought significant changes to the antennas that go into these mobile handsets. As a result, antenna designers have moved from the simple monopole and printed inverted-F antennas to complex electrically small antennas.

FEKO's Method of Moments (MoM) and its extensions to solve dielectrics are well suited to the design and optimization of mobile antennas.

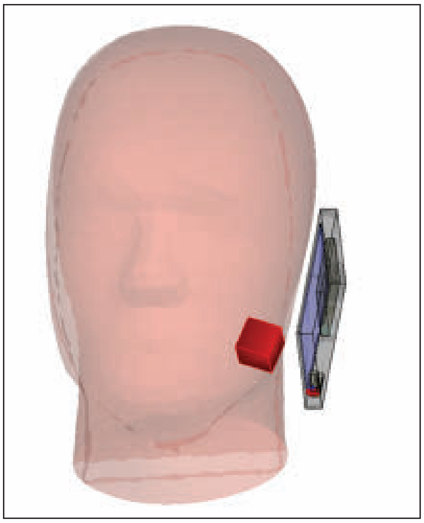


Fig. 4 Localized peak SAR when using phone near head.

Planar Green's functions, the Surface Equivalence Principle (SEP) and Volume Equivalence Principle (VEP) extensions to the MoM are all available in FEKO, providing designers with simulation methods to solve a wide range of different mobile antenna topologies.

The Finite Element Method (FEM) has also been fully hybridized with the MoM in FEKO, providing users with the ability to blend the strengths of these simulation methods to solve complex dielectric antennas. The FEM-MoM hybrid also provides users with the ability to estimate SAR for new devices in close proximity to humans (see ***Figure 4***). Localized peak SAR (1 and 10 g cubes) or whole body average SAR levels can easily be computed. In situations where the entire body or other electrically large objects have to be included in simulations of mobile antennas, the Multilevel Fast Multipole Method (MLFMM) may be used to accelerate the solutions methods that have already been mentioned here.

FEKO also incorporates a technique called Characteristic Mode Analysis

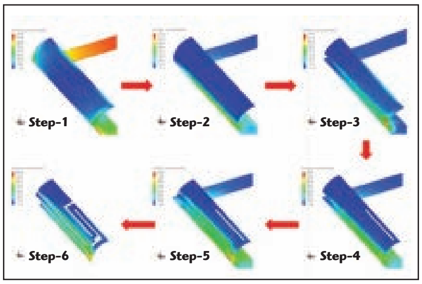


Fig. 5 LTE antenna is designed by modifying the metal sheet systematically based on the modal current distribution.

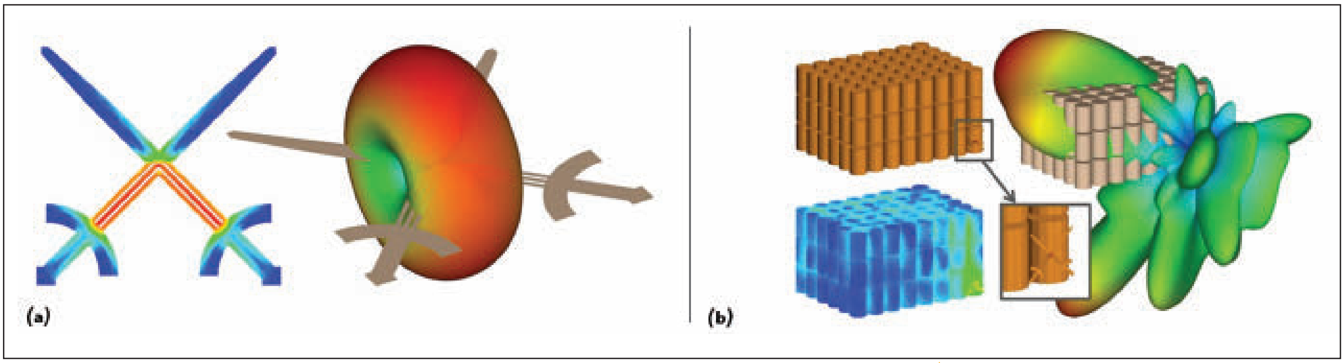


Fig. 6 Excalibur tag antenna current distribution and radiation pattern (a) and surface current distribution and radiation pattern of tag antenna on a pallet of metal canisters (b).

(CMA) that helps designers follow a systematic, intelligent approach rather than a brute force method, by looking at the eigen-value spectrum and the eigen-vector distribution. CMA is used to design a mobile antenna operating in the LTE 1.8 GHz band (see ***Figure 5***). A predefined surface area is assumed on which the antenna will be etched, in this case a curved metal sheet on the outer edge of the PCB. CMA is then used to calculate the modal currents on the surface for the dominant modes at 1.8 GHz. The advantage of this approach is that it is more intuitive than standard optimization algorithms and therefore the optimum design requirements can be met in less iterations.

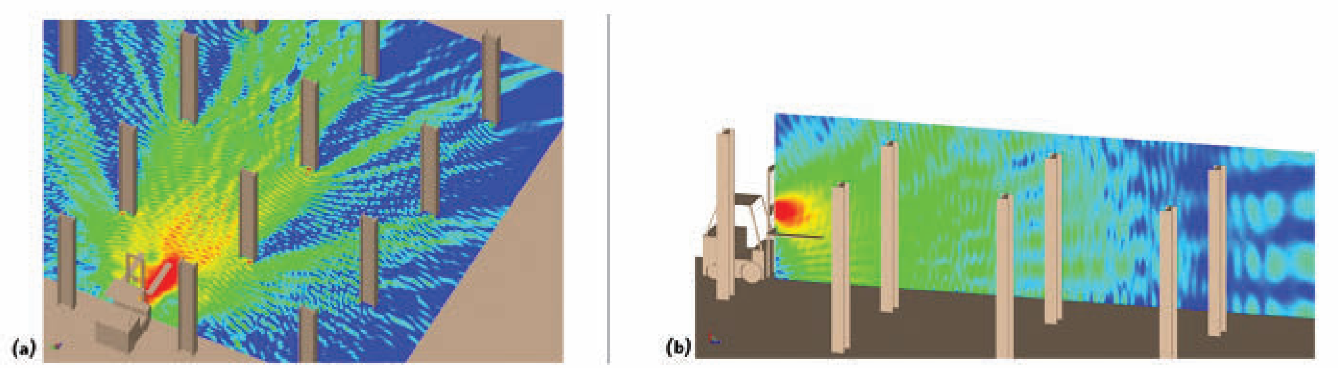
CMA can also be used to find the optimum placement of the battery connector with respect to the antenna and the spacing of the battery from the PCB. The combined performance including display frame and battery are shown previously, compared to the original antenna and PCB only. An improvement of 5 percent in radiation, 5 dB in coupling and up to 1 dB in MEG where achieved.

The major advantages that CMA offered in this study were two-fold: namely the CMA simulations are fast (on the order of a few minutes) and bring valuable insight through the modal currents, which helped improve an antenna design during the integration process.

Design Examples

Examples show application of advance simulation technologies in FEKO for 4G/LTE applications, but they can also be effectively incorporated for 5G antenna designs for mobile devices and base stations.

One of the main aspects of IoT is



▲ *Fig. 7 Near field pattern in a warehouse environment from RFID reader antenna mounted on a forklift (20 dB visualization range) (a) and vertical near field cut in front of a RFID reader antenna (30 dB visualization range) (b).*

the requirement for key components to enable communications between devices and objects. Objects need to be augmented with an Auto-ID technology, typically an RFID tag, so that each object is uniquely identifiable. Also, an RFID tag allows the object to wirelessly communicate certain types of information, which leads us to another requirement – the ability to monitor data. Truly smart objects will be embedded with both an RFID tag and a sensor to measure data. The sensor may capture fluctuations in the surrounding temperature, changes in quantity, or other types of information. FEKO is being used effectively in characterizing RFID tags, optimization of RFID tag placement as well as the operating environment within which the reader antenna communicates with the tag (see ***Figure 6***).

FEKO not only offers the numerical methods such as MoM, MLFMM, FEM, FDTD, etc., but also asymptotic, ray-based method such as the uniform theory of diffraction or ray launching geometrical optics (shooting and bouncing rays) that are used for electrically extremely large RFID problems such as long distance indoor propagation (see ***Figure 7***). On the other hand, for electrically small but dielectrically complex problems, such as tag-reader interaction in the presence of the human body, the finite element method (FEM) or Finite Difference Time Domain (FDTD) can be employed. The FEM can either be used by itself or in hy-

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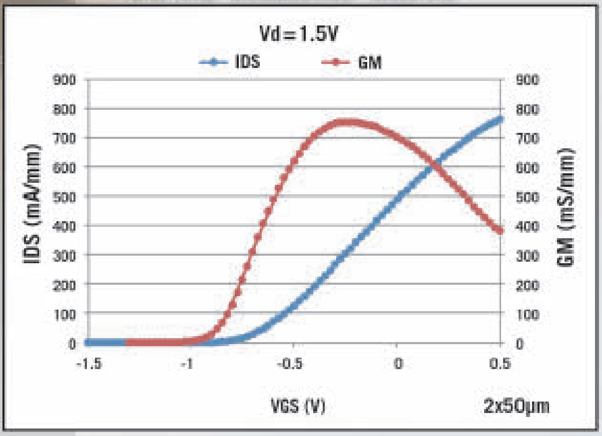

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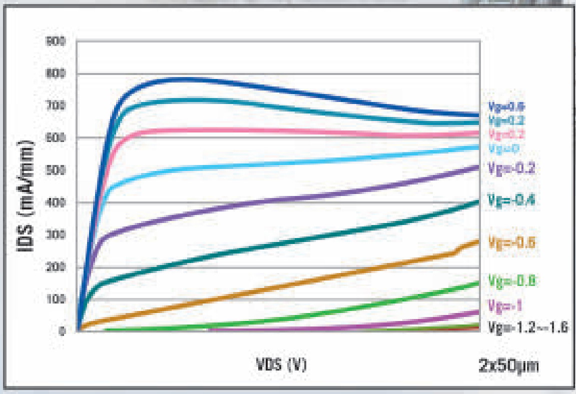
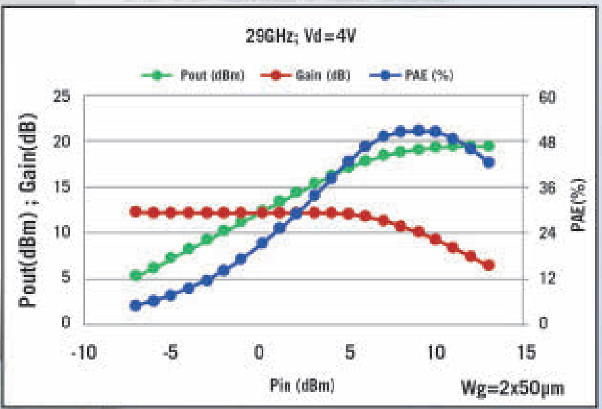


PP10 Load Pull Data



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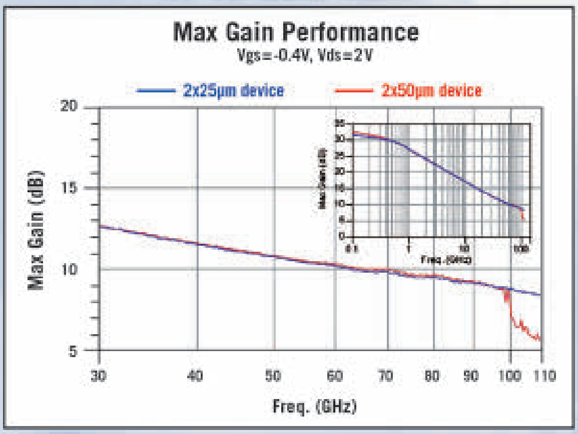

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brid coupling with the MoM (e.g., the reader antenna is modeled with the MoM, while the human body is being modeled with the FEM in order to combine the strong points of the two methods). FEKO, with its advanced and comprehensive computational techniques, is playing a major role in 5G systems as well as Internet of Things.

Enabling 5G and IoT Development

Keysight EEsof EDA
Santa Rosa, Calif.

Over the next five years, 5G and IoT design engineers will be facing familiar trends: increasing design size, higher integration and design complexity, movement from single IC designs to multichip modules, integration of multiple technologies (e.g., GaAs, GaN, SiGe/Si/SOI and CMOS), and more challenging standard specifications. Smaller design teams with tighter budgets will also continue to be a key trend, and this will drive efficiency improvement initiatives designed to improve design flow efficiency.

While these trends bring a number of key benefits, they are also forcing 5G and IoT design engineers to face new challenges, many of which are an extension of those the industry has been working to address and solve over the last 10 years. Some of the key challenges include maximizing power efficiency, managing electro-thermal effects and dealing with the increasing circuit simulation issues that come from more complex designs, while simultaneously handling the increased electromagnetic coupling that arises from more compact designs. Other challenges include integration, evaluating and choosing the "right" technology mix, and verifying performance to industry standard specifications across a wide frequency spectrum.

To stay at the forefront of these trends and overcome these challenges, today's design engineers require flexible and powerful design solutions that keep pace with emerging trends and standards. Keysight EDA focuses on solving communication system design challenges, especially IC and PCB design and simulation of applications including 5G and 802.11xx wireless networking, as well as Bluetooth Low Energy (BLE), ZigBee and Wi-SUN for the IoT. Keysight's customers are leading the industry with their 5G and IoT products, and they have relied on Keysight EDA software to get them there.

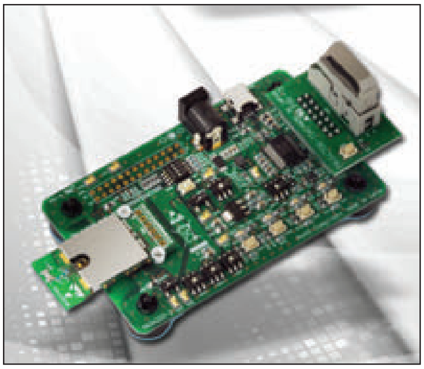
Design Examples

Renesas Electronics: BLE Smart Wireless Solution for IoT Applications:

Many IoT applications require small, battery-powered devices intended to operate over extended periods of time—for months or even years on just a button power cell. As a result, minimized power consumption is a key design constraint for IoT applications.

Renesas recently announced a new technology and group of microcontrollers that integrate a BLE RF transceiver capable of operating up to two years or more on a CR2032 button cell. The design utilizes an integrated Tx/Rx switch, DC/DC converter and matching network/filter reuse to reduce chip size and power consumption. High efficiency DC/DC converters typically require fast switching rates and compact silicon spirals, which produce RF frequency components and undesired electromagnetic effects.

Hisayasu Sato, Renesas design team manager and Keysight Certified Expert, successfully designed the transceiver in a single design iteration using Keysight GoldenGate Silicon RFIC and Momentum simulation software. Boasting the industry's lowest current drain, the transceiver will serve as a core technology for short-distance wireless communication in wearable devices and other IoT applications. This enabled Renesas to accelerate its use of embedded devices in IoT applications and recently led to its release of the new RL78/G1D microcontrollers (see ***Figure 8***).



▲ *Fig. 8 Renesas' Bluetooth Smart Wireless Solution will enable designers to more easily develop Bluetooth Smart applications for the IoT.*

Plextek RF Integration: 28 GHz, 4-channel, Phase Adjustable PA for 5G:

5G wireless is expected to give users the perception of near infinite capacity for "everything, everywhere and always connected." To achieve this vision, devices will require significantly faster data rates and operation at mmWave frequencies with sufficient bandwidth. Signal propagation at mmWave; however, is much more challenging than at typical mobile wireless frequencies.

To address this challenge, Stuart Glynn and Liam Devlin, CEO, Plextek RF Integration and Keysight Certified Expert, used Keysight's Advanced Design System (ADS) software to develop an innovative 4-channel, 28 GHz, 5G phase adjustable PA IC design for use in 5G radio front-ends (see ***Figure 9***). It was designed using a commercially available 0.15-µm GaAs PHEMT process and is intended to be housed in a low cost SMT package suitable for volume production. The IC can be used in either 5G mobile devices or base stations.

What makes the Plextek RF Integration IC unique is that each of its channels has a PA with an integral 4-bit, digitally controlled phase shifter, which provides a compact means of beam steering. Innovative components like this are critical to enabling the design of hardware suitable for mmWave frequencies with sufficient bandwidth.

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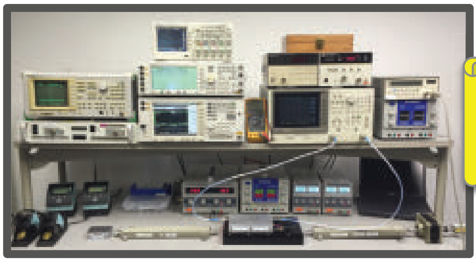
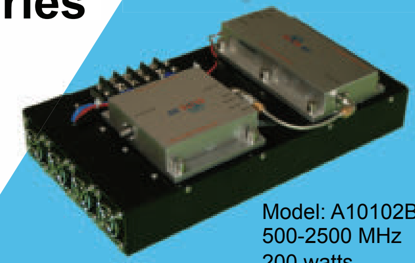


Typical RF System
Projected Cost
> $200,000



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S100GMA	X			X	X	X
S100GSTMA	X	X	X	X	X	X

Model	Class	Freq - min	Freq - max	Power	Gain	Supply
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A10102B3Q	AB	500	2500	200	45	50 vdc
A10102A3Q	A	500	2500	50	45	50 vdc
A10024B3Q	AB	100	1000	150	45	28 vdc
A10041B3Q	AB	2500	6000	50	45	28 vdc
A10066P2Q	AB	7000	9000	500	45	40 vdc
A10067P2Q	AB	8000	11000	100	45	28 vdc

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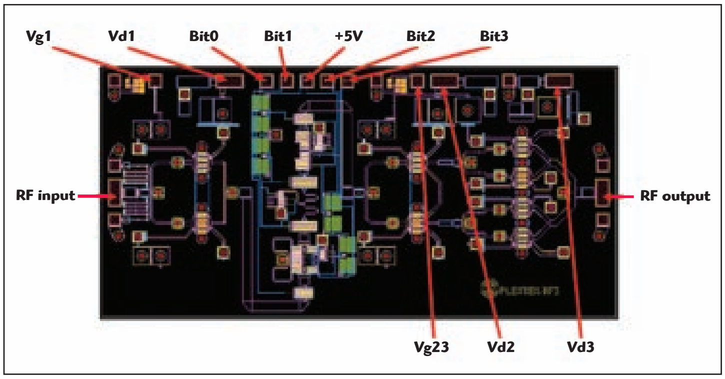

Fig. 9 Layout of one channel of the Plextek RF Integration transmitter IC modeled in ADS.

As 5G wireless communication systems and the IoT continue to evolve, EDA tools will be crucial to advancing their ecosystems and transforming the promise of these industries into reality. Renesas and Plextek RF Integration are just two examples of leading-edge companies that have successfully used Keysight EDA's solutions for 5G and IoT development. In addition to supporting its customers' efforts, Keysight works closely with industry consortia, partner companies and academia. Plus, its R&D and application engineers—industry experts in their own right—play a critical role in developing the design software, bench instrumentation and manufacturing solutions to advance 5G and other emerging standards, as well as the IoT. It is this combination of leadership, application expertise and industry leading design tools that is enabling Keysight customers to solve even their most difficult design challenge.

Is the IIoT (Industrial IoT) Waiting on 5G?

NI (formerly AWR Corp.)

The introduction of highly functional smart devices, such as the Apple iPhone and Android-powered devices, along with all of those cool apps has ignited the global demand for wireless data, and it has no indication of slowing down anytime soon. Mobile broadband data's impact on our lives is unquestioned, yet faster data is just part of the larger picture. Applying reliable wireless service to industries such as transportation, construction, manufacturing, medicine and healthcare, and energy and smart grid can spur unprecedented economic growth. For example, 85 percent of the billions of embedded devices sold in 2014 were not connected to a network. But what if they were? Analysts predict that global networks must accommodate over 50 billion embedded devices by 2020. A collection of low power sensors connected to the Internet forms the foundation of the IoT. Many of these devices will be autonomous, embedded units powered by batteries or by small solar panels. Defining 5G networks has created a lot of excitement, and much of that

attention has centered on faster data. However, 5G has a broader agenda. In addition to faster data, 5G will accommodate significantly more connected users and devices (100× or more) and will aim to address the challenge of network latency. Solving these less publicized challenges is the key to unlocking the IoT's enormous potential.

IoT devices may not need the high data rates of today's smartphones or tablets, but many IoT applications require faster and more deterministic response times to expand the IoT's reach—from transforming older localized applications to using connected apps for creating new applications. Latency or network response time has not been a priority for standardization bodies such as the 3GPP or 802.11 because these entities have primarily focused on the increase in data rates. Consequently, latency in our current networks is unpredictable and nondeterministic, and can span from milliseconds to several seconds. This unpredictability is a nonstarter for many commercial entities looking for ways to use the network for remote access and control.

Earlier cellular networks, where voice was the dominant (or rather the only) application, required a latency that was just good enough to satisfy the listener. The human ear can discern sounds on the order of 100 ms. More sensitive than the ear, the human eye perceives visual discontinuities on the order of 10 ms, which is a useful metric for multimedia applications. Enabling the tactile Internet or considering touch requires much more stringent latency (less than 1 ms) because human touch is more discernible than either the eye or ear.

Design Examples

These examples outline the use cases at a crude level between network responsiveness and human perception whether considering sight, sound or touch. Applications that involve machines talking to machines require factoring in additional application sets: monitoring and control.

The two types of "monitoring" IoT use cases are:

1. Human eye/visual
2. Sensor logging—storing video or sensor data for later retrieval and review

Human eye/visual IoT monitoring/surveillance applications require latency requirements similar to those for human visual perception—on the order of tens of milliseconds (that is, the delivering mechanism can be the same, and the requirements must scale up or down with the applications). Sensor logging latency requirements can actually vary quite dramatically depending on the application and the deployed sensor capabilities. To illustrate this point, consider the rather mundane task of measuring temperature. Temperature sensors are used extensively in a variety of applications. If the sensor measures the ambient temperature, then the latency can be on the order of seconds, hours or even days as temperature changes because of climate conditions, which tend to vary over a wider time constant. We see applications like this today that are quite functional. Conversely, a sensor measuring the temperature of a chemical pour or mixing

process might need to trigger an action if the temperature rises above a certain threshold to avoid damaging the end product or for safety reasons. This type of monitoring and economic benefit is directly tied to the capabilities of the network and is possible in localized proprietary implementations. This example introduces the concept of control that encompasses a round-trip response time for both uplink and downlink.

This type of control application cannot be performed with today's networks because service operators cannot guarantee a minimum latency specification (and for the most part, the latency may be out of their control). The holy grail of 5G networks in terms of latency is to provide industries with predictable or deterministic latency response that is ideally in the submillisecond range. If service operators can deliver predictable network response, perhaps even for a designated geographic region, then companies can develop viable businesses.

The concept of "control" over a cellular network is radical. Combining control with the computational and storage power of the cloud promises to improve our everyday lives and spur economic growth. To be clear, "remote control" in this context refers to software running in the cloud, monitoring sensor data or video, and controlling processes deployed at a remote location—perhaps the control software resides in the cloud. Examples include factory automation/smart factories, traffic control/smart cities, smart grid/energy conservation, and healthcare monitoring and medicine disbursement. In aggregate, these ideas form the Industrial Internet of Things (IIoT). IIoT applications change the control paradigm; rather than discretely duplicating a particular control process a million times around the world, 5G networks can make the IIoT possible by delivering a consolidated control experience that reduces costs, improves quality, increases performance, and spawns new industries.

NI is working with researchers today to create 5G networks capable of supporting the IoT infrastructure necessary to drive the broader agenda. There are several examples of 5G technologies researched today that hold much promise. An example of a promising 5G candidate technology is mmWave. Despite efforts by governments around the world to reallocate spectrum, free spectrum below 6 GHz remains scarce. However, spectrum in the mmWave frequency is plentiful. To simplify, more spectrum equates to more capacity and more bandwidth per device. NI has been closely collaborating with researchers at Nokia Networks to prototype a mobile access networks at 73 GHz. Through this collaboration, Nokia and NI were able to publicly demonstrate the world's first 10 Gbps mobile access link last April at the Brooklyn 5G Summit. Breakthroughs such as the Brooklyn 5G Summit demonstration hint that the 5G networks capable of providing a robust IoT infrastructure may not be that far away. ■

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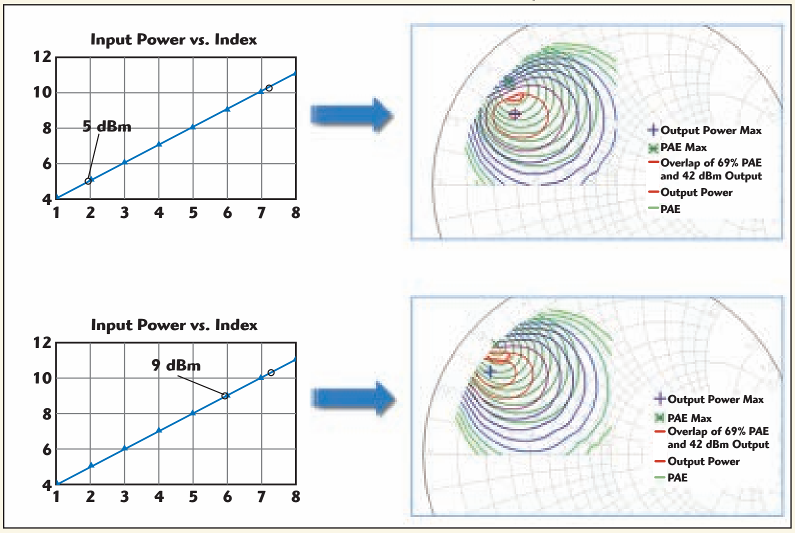
V12 Release Enhances Productivity for RF/μWave Designs

NI (formerly AWR Corp.)
El Segundo, Calif.

The wireless revolution that brought smart phones and Wi-Fi-enabled everything to consumers is largely thanks to our community of RF/microwave engineers as well as NI AWR software. NI AWR Design Environment™ – Microwave Office, Visual System Simulator™ (VSS), Analog Office, AXIEM and Analyst™ – is what RF and microwave engineers use to design wireless products, from base stations to smartphones to satellite communications.

NI AWR Design Environment software accelerates the design and product development cycle of high frequency integrated circuits (IC), RF printed circuit boards (PCB), and modules, as well as the communications and radar systems found within the aerospace and defense, semiconductor, computer, consumer electronics and telecommunications markets. NI AWR reduces the time to migrate a design idea or concept to prototype and manufacturing.

NI AWR software sprang forth from the principle of enabling RF and microwave design engineers to be more productive, by empowering them with robust yet easy-to-use and intuitive tools. Today, even with the addition of more and more sophisticated features over the years, ease of use continues to be the cornerstone of every software release. The NI AWR software advantage is simple: an intuitive use model that delivers an exceptional user experience as well as an open design flow that supports best-in-class third party tools, resulting in more compelling solutions.



▲ *Fig. 1 New load-pull formats give designers access to an extensive array of data.*

V12 EMPHASIS ON DESIGN FLOW/USER PRODUCTIVITY

With the release of V12, the NI AWR Design Environment platform once again emphasizes user productivity by focusing on the design flow process for designers of all types of high frequency electronic components, circuits and systems. With the addition of new amplifier, antenna and radar-specific features, with expanded third-party flows for EM, stability analysis and improved DRC/LVS and multiple speed and ease-of-use improvements, V12 makes it even easier for design engineers to streamline their design process, improve end product performance and accelerate time to market.

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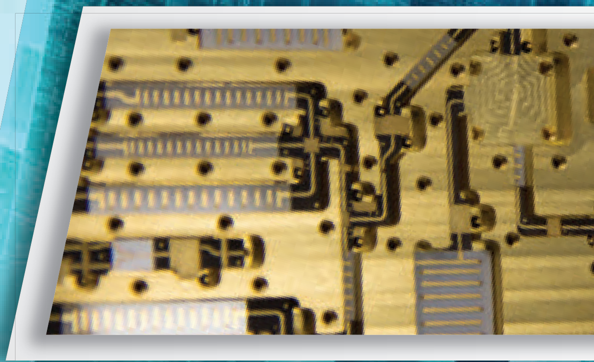

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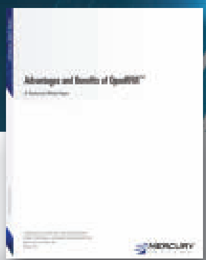


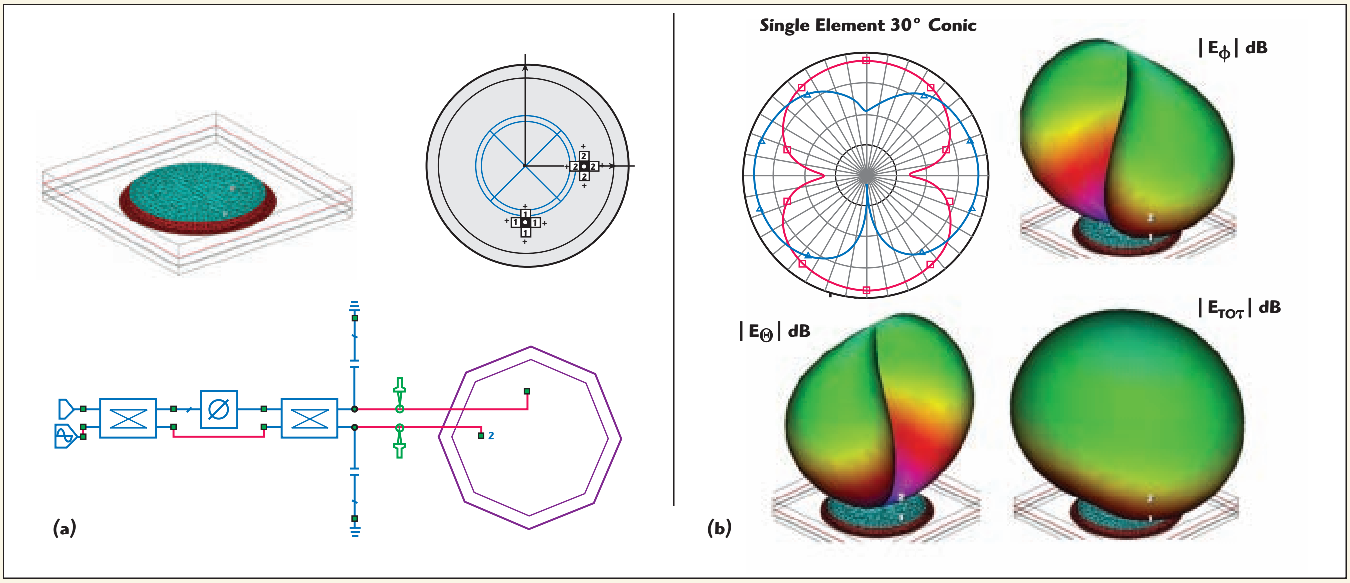


Fig. 2 Schematic (a) and radiation patterns (b) of a stacked circular patch with active electronic polarization diversity.

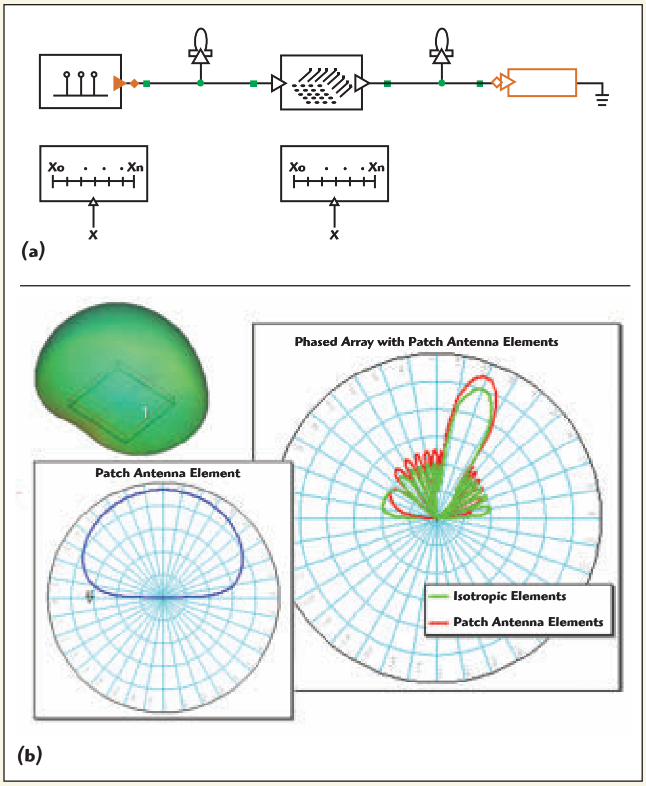
LPC files, to integrated stability analysis with AWR Connected™ for AMCAD STAN, V12 allows amplifier designers to view and analyze swept load-pull data more efficiently (see ***Figure 1***).

Load-pull simulation has been a valuable tool for the design of amplifiers for more than a decade, and recent advances in data file formats by load-pull measurement system vendors such as Maury Microwave and Focus Microwaves have significantly expanded the usefulness of load-pull characterization. These new file formats support sweeps of input power, DC bias or temperature, in addition to swept source or load impedances. The ability to visualize swept load-pull data, graphically control the sweep dimensions, and use the swept data with circuit simulation to design matching networks at fundamental and harmonic frequencies greatly speeds and simplifies the design process.

In addition to the enhancements to load-pull simulation, stability analysis has been expanded within V12 to include a connection to AMCAD Engineering's STAN tool. Because stability can be difficult to achieve in microwave circuits with gain and nonlinear behavior, such as amplifiers and oscillators, the ability to invoke STAN directly from NI AWR Design Environment Microwave Office helps designers locate and characterize the unwanted oscillations in components such as power amplifiers. This aids the development of networks that not only improve circuit stability, but maintain the performance goals of the original circuit design.

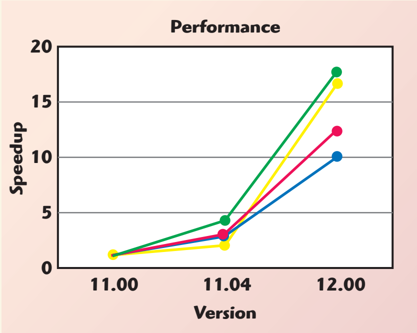
Antenna Design

With V12 of NI AWR Design Environment, antenna designers benefit from in-situ current analysis, which shows the impact of circuits on antenna patterns (see ***Figure 2***). Also, using real antenna data, whether EM simulated or measured, has been implemented directly within VSS for further system analysis of structures like phased arrays.



▲ *Fig. 3 VSS phased array test bench depicting a patch antenna element (a) and its radiation and antenna pattern (b).*

Configuration of the array hardware can be done interactively using the VSS GUI, entered as equations or imported as a data file. Beam forming algorithms involving current taper, phase shift and geometry may be implemented. A typical implementation will use discrete blocks, such as power dividers, attenuators, phase shifters and amplifiers. Each block contributes to the final definition of gain and relative phase for each antenna element. The entire system can be analyzed for optimum performance, assessed for the effects of hardware impairments, and evaluated in a complete end-to-end system (see ***Figure 3***).



▲ *Fig. 4 New features in V12 streamline and speed EM analysis, improves overall design performance and efficiency.*

Radar Design

These new antenna design features, coupled with VSS phased-array models, within V12 of NI AWR Design Environment makes the design and development of radar systems more efficient, across a host of industries. This new release supports the simulation of phased arrays with hundreds of elements directly within VSS.

EASE-OF-USE, SPEED AND THIRD-PARTY INTEGRATION

There is more to V12 than the features noted above. Ease of use across all facets of the software platform and speed improvements to harmonic balance and electromagnetic (EM) solver technologies, as well as new and expanded third-party flows for EM and DRC/LVS, further empower users of the NI AWR Design Environment platform to streamline design flows and improve productivity.

Whether editing a schematic or layout, constructing equations, exposing a ground node within a circuit, or adding a sticky note onto a measurement graph, dozens of usability features have been added or enhanced in V12. Details of all features are available within NI AWR Design Environment "What's New" documentation found at awrcorp.com/what-is-new/v12-preview.

A key objective for V12 was streamlining and speeding EM analysis. From EM setups to extraction flow support for Analyst to expanded 3D graphical editing and debugging, the overall efficiency of designers requiring EM analysis has been greatly improved. Additionally, new threading, adaptive mesh refinement and frequency sweep algorithms within Analyst enable designers to obtain EM simu-

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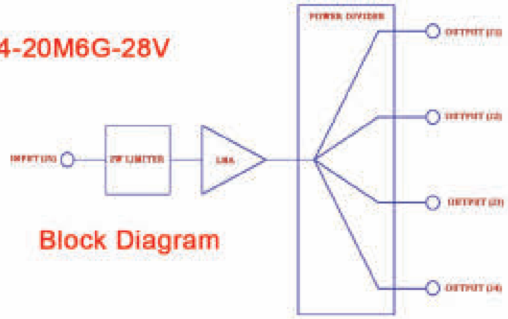
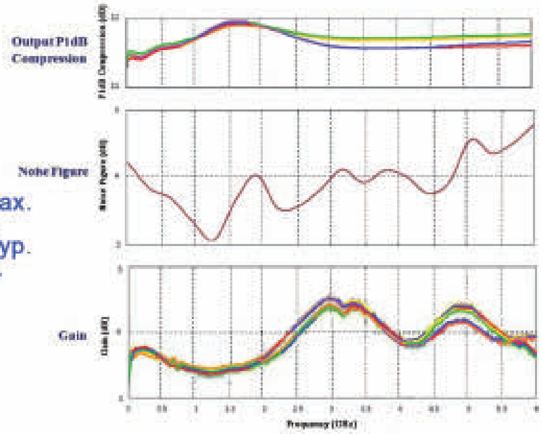


Block Diagram

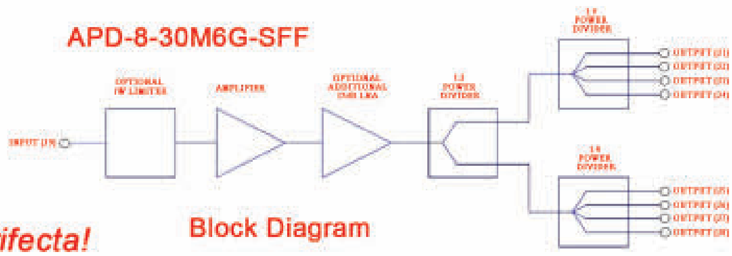
Quadfecta!

Quadport Device Balances Bandwidth, Low Noise, 3.5 dB Gain & 10 dBm Output Power



• Frequency Range:	20 MHz to 6.0 GHz
• Gain:	3.5 dB, ±2 dB max.
• VSWR:	2.5:1 max.
• Noise Figure:	5.5 dB (70 to 3000 MHz) max. 6 dB (20 to 6000 MHz) typ.
• Output P1dB:	10 dBm (20 to 3000 MHz) typ. 9 dBm (3.0 to 6.0 GHz) typ.
• Input Power:	33 dBm max (survival)
• Power Supply:	+28V @ +75 mA typ.
• Size:	2.00" x 2.00" x 0.40"

APD-8-30M6G-SFF

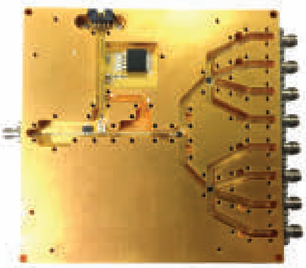


Block Diagram

Trifecta!

Octaport Device Balances Low Loss, Flat Frequency Response & High Reverse Isolation

• Frequency Range:	30 MHz to 6.0 GHz
• Reverse Isolation:	32 dB min. 36 dB nominal
• Insertion Loss:	4 dB min. 6 dB nominal 8 dB max.
• Loss Flatness:	±1.0 dB typ.
• Noise Figure:	6.5 dB typ.
• VSWR (In/Out):	2.0:1 max.
• Input P1dB:	-2.5 dBm typ.
• Input Power:	+10 dBm (+30 dBm Optional)
• Connectors In/Out:	SMA(F)
• DC Voltage:	+12 to +15 VDC @ 50 mA typ.
• Size:	4.50" x 4.30" x 0.50" (miniature option available)



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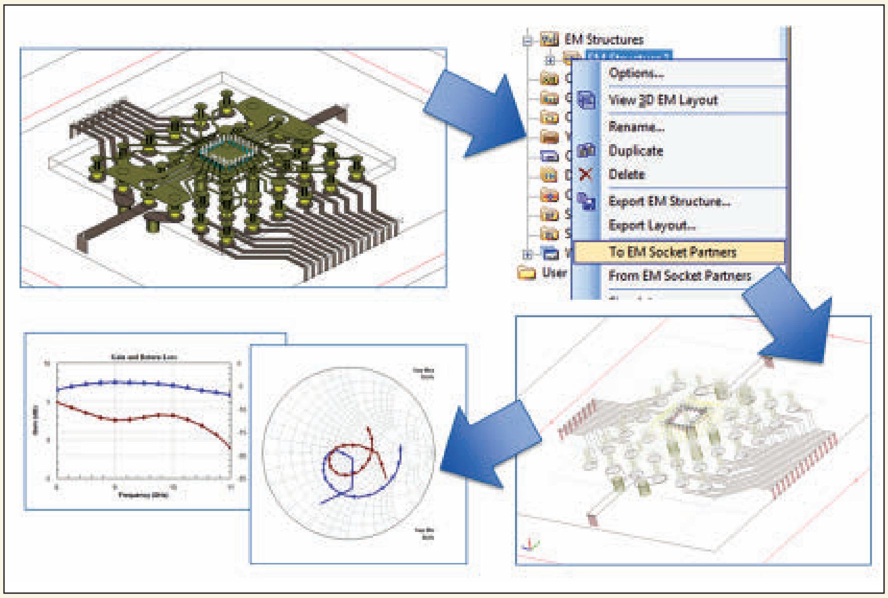

▲ *Fig. 5 AWR connected flow for EM socket partners ANSYS HFSS.*

lation results even faster (see ***Figure 4***). Tuning and optimization technique improvements inside the APLAC harmonic balance engine decrease simulation wait times even further.

AWR Connected for AMCAD, ANSYS and DWT all serve to provide designers with best-in-class design flows that can be tailored to needs and preferences. An expanded AWR Connected flow provides a seamless two-way link between ANSYS HFSS and NI AWR Design Environment, enabling designers to seamlessly tie HFSS extracted S-parameters back into NI AWR software. This expanded flow leverages the latest implementation of NI AWR Design Environment EM Socket architecture (see ***Figure 5***), which permits users to access a broad range of third-party electromagnetic (EM) products from within the Microwave Office framework.

AWR Connected for DWT enables seamless integration with Design Workshop Technologies' (DWT) design rule checking (DRC) and/or layout vs. schematic (LVS) tools for PCB and module design. These new DRC/LVS flows can run one of two ways: in the DWT full view/UI mode or transparently from within Microwave Office. The DRC module performs a series of measurements to identify areas of the design that exceed preset limits for a particular manufacturing process. These design rules also ensure that the layouts will not interfere in non-permissible ways, providing a very flexible means for data selection and measurement accuracy to perform complex design rule checks. The LVS module provides designers with an efficient tool for detecting network mismatches occurring in the physical layout. It consists of a layout extractor component that outputs a netlist based on extracted hierarchical and generic devices, including their parameters and values. The LVS component compares two netlists that report errors found between the schematic netlist and the extracted netlist from the layout.

NI AWR Design Environment still holds true to its roots more than a dozen years after its first release as a design tool, delivering productivity and ease-of-use to its users. Numerous customer testimonials convey that NI AWR Design Environment provides accurate results and a flexible framework – putting the emphasis on valuing the time of design engineers regardless of their domain of expertise, from systems to circuit or EM.

VENDOR**VIEW**

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- **I-Tera® MT** materials are suitable for both high-speed digital and RF/microwave designs. A full compliment of cores and prepregs allowing flexibility in design is available in core thicknesses from 0.002" to 0.018". I-Tera MT has been used in designs up to 24 GHz.
- **TerraGreen®** halogen-free, very low-loss, thermoset materials are available in a variety of laminate and prepreg offerings. This material is inexpensive to process – improving your company's bottom line, as well as the environment.
- The revolutionary **Astra® MT** ultra low-loss thermoset laminates are a replacement for PTFE. Astra MT is available in core and prepreg for double sided, multilayer and hybrid designs using isola 185HR, 370HR or IS415. Astra MT has been used in designs up to 77 GHz.

	RF/MICROWAVE MATERIALS				
	IS680	I-Tera® MT RF	I-Tera® MT	TerraGreen®	Astra® MT
Tg	200°C	200°C	200°C	200°C	200°C
Td	360°C	360°C	360°C	390°C	360°C
Dk @ 10 GHz	2.80 - 3.45	3.38, 3.45 & 3.56	3.45*	3.45*	3.00
Df @ 10 GHz	0.0028 - 0.0036	0.0028, 0.0031 & 0.0034	0.0031*	0.0030*	0.0017
CTE Z-axis (50 to 260°C)	2.90%	2.80%	2.80%	2.90%	2.90%
T-260 & T-288	>60	>60	>60	>60	>60
Halogen free	No	No	No	Yes	No
VLP-2 (2 micron Rz copper)	Available	Available	Available	Standard	Standard
Stable Dk & Df over the temperature range	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C	-40°C to +140°C
Optimized global constructions for Pb-free assembly	Yes	Yes	Yes	Yes	Yes
Compatible with other Isola products for hybrid designs	For use in double-sided applications	Yes	Yes	Yes	Yes
Low PIM < -155 dBc	Yes	Yes	Yes	Yes	Yes

* Dk & Df are dependent on resin content NOTE: Dk/Df is at one resin %. Please refer to the Isola website for a complete list of Dk/Df values. The data, while believed to be accurate & based on analytical methods considered to be reliable, is for information purposes only. Any sales of these products will be governed by the terms & conditions of the agreement under which they are sold.

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- Isola's **Design Review Service** can facilitate your conversion to Isola's RF/microwave products and get you to market faster with the newest, ultra-low-loss materials.
- As part of this new service, Isola's technical staff will provide turn-key calculations, testing, characterizations and material recommendations to assist PCB fabricators and OEMs in converting to Isola's RF-materials, which will help overcome the current material shortages of other vendors and accelerate time-to-market. The design review service also addresses the perceived conversion issues when migrating from a currently used material to an Isola material.

http://www.isola-group.com/conversion-service

FREE! Impedance and Power-Handling Calculator

- Isola's free **Impedance and Power-Handling Calculator** predicts the design attributes for microstrips and striplines based on the design's target impedance and dielectric properties of the company's RF, microwave and millimeter-wave laminate materials.
- This software tool provides a design or an equivalent dielectric constant to facilitate modeling for PCB designers to predict impedance and other design attributes. The software computes changes in the effective dielectric constant due to dispersion at higher frequencies. The software then computes the total insertion loss—a measure of power lost through heat for power handling calculations, including the dielectric loss, conductor loss, and the loss due to the surface roughness. The main factors affecting the typical power-handling capability of a material are its thermal conductivity, the maximum operating temperature, and the total insertion loss.

https://isodesign.isola-group.com/phi-calculator

www.isola-group.com/RF

L-3 Awarded $81.8 M to Supply SATCOM Terminals to the ADF

L-3 Communications recently announced that it has been awarded an $81.8 million contract from Raytheon Australia to supply the Australian Defence Force (ADF) with 236 Very Small Aperture Terminals (VSAT), additional support equipment, and training as part of Joint Project 2008 Phase 5B1. This program will further enable the ADF to utilize the Wideband Global SATCOM (WGS) system, significantly increasing their satellite communications capabilities. Two L-3 business units, Global Communications Solutions (GCS) and Linkabit, will perform on this contract, with hardware deliveries expected to be completed this year.

> This further enables the ADF to utilize the Wideband Global SATCOM system, significantly increasing their satellite communications capabilities.

The contract will deliver L-3 GCS's Hawkeye™ and Panther™ family of VSAT terminals, integrated with L-3 Linkabit's MPM family of modems, and includes the option to purchase additional terminals and equipment. These terminals will enable ADF troops on the ground to benefit from increased data rates and a higher level of network performance. This award comes as a follow-on to the $35 million Joint Project 2008 Phase 3H contract awarded to L-3 in 2013 for 54 Hawkeye III Lite VSATs and support equipment.

Air & Missile Defense Radar Sails Through Critical Design Review

VIEW VIDEO

The U.S. Navy and Raytheon Co. have completed the AN/SPY-6(V) Air and Missile Defense Radar (AMDR) critical design review. The outcome confirms Raytheon's design and technologies as mature, producible and low risk; on track to meet all radar performance requirements, on schedule and within cost.

The CDR assessed all technical aspects of the program, from hardware specifications, software development, risk mitigation and producibility analysis, to program management, test and evaluation schedules, and cost assessments. The review concluded with Navy stakeholders impressed with the radar's progress to date and confident in the program's path forward to on-time delivery.

The Engineering and Manufacturing Development (EMD) phase of the program continues and is now more than 40 percent complete. Raytheon attributes its exemplary performance to the implementation of an agile development and management methodology for AMDR. This approach supports the ongoing hardware and software design verification, technology maturity, producibility, and risk-reduction imperatives – yielding benefits across all program elements in productivity, quality and affordability.

All aspects of the AMDR EMD phase are progressing according to plan, from software development to pilot array testing. The first Engineering Development Model production-representative Radar Modular Assembly (RMA) is currently undergoing testing in the risk-reduction pilot array at the company's Near Field Range in Sudbury, Mass.

The team has also delivered the first external combat system interface definition language increment to the Combat System Integration Working Group – the government-industry team comprised of Raytheon, Navy and Lockheed Martin experts that is focused on AMDR integration with the DDG 51 Flight III's AEGIS combat system.

About SPY-6(V) AMDR

SPY-6(V) is the 21st century integrated air and ballistic missile defense radar for the U.S. Navy, filling a critical capability gap for the surface fleet. It is the first truly scalable radar, built with radar building blocks (Radar Modular Assemblies) that can be grouped to form any size radar aperture, either smaller or larger than currently fielded radars. All cooling, power, command logic and software are scalable. This scalability could allow for new instantiations, such as back-fit on existing DDG 51 destroyers and installation on aircraft carriers, amphibious warfare ships, frigates, or the Littoral Combat Ship and DDG 1000 classes, without significant radar development costs.

> It is the first truly scalable radar, built with radar building blocks that can be grouped to form any size radar aperture...

Leveraging gallium nitride (GaN) technology to optimize power in a smaller size and using less space, power and cooling than older technology would require for the same performance, AMDR is a key enabler for the capability and performance enhancements of the new DDG 51 Flight III ship. SPY-6(V) for DDG 51 Flight III is designed with high operational availability and reliability to minimize overall ownership cost.

Exelis and FAA-Designated Test Sites to Research the Safe Integration of UAS into the National Airspace System

VIEW VIDEO

Exelis has signed agreements with four Federal Aviation Administration (FAA)-designated unmanned aircraft systems (UAS) Test Sites for airspace situational awareness and research. The research will focus on using

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Source: Exelis

the Exelis Symphony® RangeVue™ sense-and-avoid tool towards safe integration of unmanned aircraft into the national airspace system.

Under the terms of the agreements, the Test Sites will gain valuable real-time and historical situational awareness of the range airspace via Symphony RangeVue, while Exelis gains critical product feedback through operational usage. The participating Test Sites are the Pan-Pacific UAS Test Range at University of Alaska Fairbanks, Alaska; the Northern Plains UAS Test Site at University of North Dakota, N.D.; the Northeast UAS Airspace Integration Research Alliance at Griffiss International Airport, N.Y.; and the Mid-Atlantic Aviation Partnership at Virginia Polytechnic Institute, Va.

> Test Sites will gain valuable real-time and historical situational awareness of the range airspace via Symphony RangeVue, while Exelis gains critical product feedback through operational usage.

Symphony RangeVue enables UAS operators and test range personnel to have access to both real-time and historical aircraft surveillance information via a web-hosted platform, helping to manage mission operations across multiple locations. Symphony RangeVue can be used as command center decision support and post-event analysis tool, or in the field as a sense-and-avoid addition to UAS ground control stations. Flexible geo-fencing tools alert operators when a UAS approaches airspace boundaries or other aircraft are in the vicinity.

Additionally, Exelis is pursuing research and development opportunities with the Test Sites exploring detect-and-avoid algorithms; non-cooperative target tracking; command and control systems; infrastructure inspection and monitoring; big data analysis for air traffic; and integration of non-FAA surveillance sources. Exelis will leverage capabilities across multiple test sites for a wide range of operational testing and collection of safety data.

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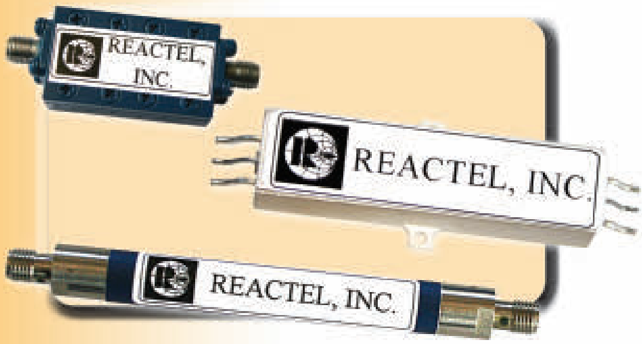

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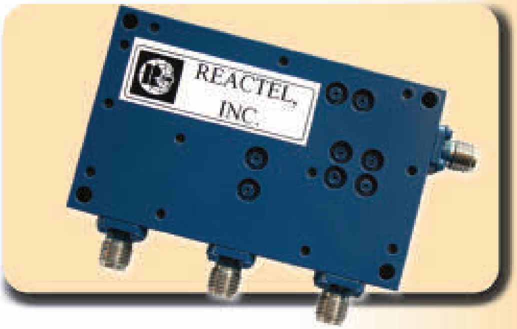

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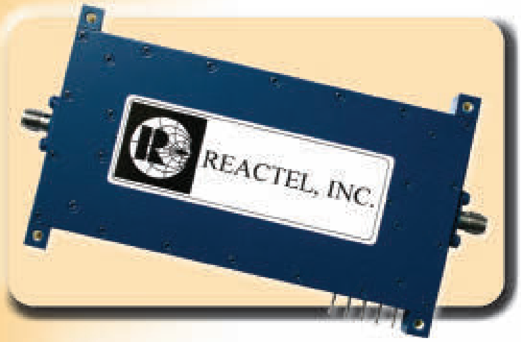

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The 2015 Defence, Security and Space Forum

At European Microwave Week

EuMA | Microwave Journal — Frequency Matters.

Wednesday 9 September – Palais Des Congrès, Paris – 10:50-18:45

A focused Forum addressing the application of RF integrated systems for UAVs.

The emphasis of the 2015 EuMW Defence, Security and Space Forum will be on RF systems and technology for UAVs, covering specifics such as: Synthetic Aperture Radar (SAR) for UAVs, ESM and EW for UAVs, operational use of integrated RF systems for UAVs, along with Airborne SARs. It will feature executives from industry, academia, the military and from space agencies, be held in combination with the opening of EuRAD and will conclude with a round-table discussion.

Programme:

10:50-12:30 EuRAD Opening Session

12:40-13:40 Strategy Analytics Lunch & Learn Session
This session will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of market.

13:50-15:30 *Microwave Journal* Industry Panel Session
The session offers an industrial perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2015, the Panel will address: RF and microwave development for UAVs.

16:10-17:50 EuMW Defence & Security Executive Forum
Speakers from leading European defence industries have confirmed their participation. These high-level speakers will present their view on RF microwave technology trends for the next generation UAV platforms and systems. The industrial speakers are complemented by speakers from government, agencies and research organizations who will offer their perspective of military/security needs, programmes, budgets and scientific research for next generation systems.

18:00-18:45 Cocktail Reception
The opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

Registration and Programme Updates

Registration fees are €10 for those who have registered for a conference and €50 for those not registered for a conference.

As information is formalized, the Conference Special Events section of the EuMW website will give further details and will be updated on a regular basis.

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Infineon and Google ATAP Develop Advanced Radar Technology

Infineon Technologies is working with Google's Advanced Technology and Projects group (ATAP) to develop a sensing solution. Potential applications include wearables, the Internet of Things and automotive applications.

First implementations which provide gesture recognition and presence detection capability for a range of future devices were demonstrated by Google ATAP at its Google I/O Developers Conference in San Francisco in May.

> ...applications include wearables, the Internet of Things and automotive applications...

The sensor provides Google ATAP and its developer community with a compact and low power implementation suitable for integration and use in both mobile and fixed devices. It is based on Infineon's advanced 60 GHz transceiver technology while integrating RF transceiver, antenna and control electronics in a single package.

"Infineon is a recognized leader in radar-based sensor ICs, providing component and system-level solutions for consumer, automotive safety, industrial and commercial sensing and machine vision applications – markets that are expected to grow significantly in the coming years," said Philipp Schierstaedt, VP and general manager of the Business Line RF & Sensors of Infineon Technologies.

EU and Japan Step Up Cooperation on 5G Mobile Technology

The European Union and Japan have agreed on a new 5G agreement whereby the EU will join forces with Japan to cope with the increasing need for wireless Internet and complement current efforts to create a Digital Single Market in Europe.

The agreement will allow EU and Japan to work towards a common understanding and standards of 5G, identify new harmonised radio band frequencies for 5G spectrum and cooperate on future 5G applications in areas like connected cars or e-health. Together, the partners will also invest €12 million during the next two years in 5G-related projects to help develop the Internet of Things, Cloud or Big Data platforms.

Günther H. Oettinger, European Commissioner for Digital Economy and Society said, "5G will be the backbone of our digital economies and societies worldwide. This is why we strongly support and seek a global consensus and cooperation on 5G. Our agreement with Japan is a milestone on the road to a global definition of 5G, its service characteristics and standards. It shows that our countries are ready to take leadership in building our digital future."

In parallel, the EU and Japan have also agreed to deepen their cooperation on Research and Innovation (R&I), based on a joint vision. The partners will also set up a joint funding mechanism that will make it easier to finance common R&I projects and collaborate more closely on policy aspects. In addition, an agreement to stimulate scientific exchanges has also been signed between the Japan Society for the Promotion of Science (JSPS) and the European Research Council (ERC).

> "Our agreement... is a milestone on the road to a global definition of 5G, its service characteristics and standards."

TSDSI India Signs Cooperation Agreement With ETSI

The Telecommunications Standards Development Society, India (TSDSI) has signed a cooperation agreement with the European Telecommunications Standards Institute (ETSI), strengthening relations after the establishment of a first Letter of Intent to cooperate in November 2014.

Collaboration between the two standards organizations now happens at the level of the Global Standards Collaboration (GSC) initiative where TSDSI is a full member. GSC fosters cooperation among standards organizations from different regions of the world to facilitate the exchange of information on standards development, build synergies and reduce duplication of work.

This enhanced relationship is all the more important as 'Make in India' and 'Digital India' are Indian policies, where reinforced collaboration is needed to enable and ensure joint efforts between EU and India market players. TSDSI has also signed agreements with 3GPP and oneM2M partnership projects, of which ETSI is a founding member.

> ...facilitate the exchange of information on standards development, build synergies and reduce duplication of work.

With a leadership and technical organization in place, TSDSI is fully operational and has developed its own IPR policy, making sure that the respective IPR Policies of TSDSI and ETSI were aligned. The collaboration between the two standards bodies will facilitate exchange and work on identified common areas such as M2M and IoT, energy efficiency, and mobile terminal safety. As TSDSI wished to use ETSI standards, recognized as high quality and globally implemented standards, the cooperation agreement grants TSDSI the right to adopt ETSI standards.

For More Information — Visit mwjournal.com for more international news

ETSI is supported in India by the Seconded European Standardization Expert for India (SESEI) project. This project is established by the European Standards Organizations CEN, CENELEC and ETSI, the European Commission and the European Free Trade Association (EFTA).

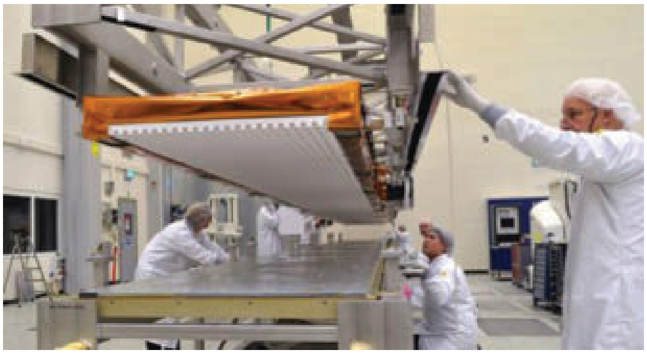
Airbus Defence and Space Delivers Sentinel-1B Radar

The Airbus Defence and Space built C-Band radar instrument for the Copernicus Sentinel-1B satellite has 'met' its spacecraft at Thales Alenia Space (TAS), Italy, the prime contractor for this program.

After integration and testing, the satellite is scheduled for launch in 2016 to join Sentinel-1A, an identical twin of Sentinel-1B, which has been in orbit since 3 April 2014 and to date more than 6,000 users have registered to access its online data products. The heart of the Sentinel-1 mission, the synthetic aperture radar (SAR), has an active phased-array antenna measuring 12.3 × 0.9 m including 560 C-Band T/R Modules developed by TAS Italy. The C-Band radar beam it produces can – as only one of many capabilities – determine changes in the Earth's surface with extreme accuracy.

Airbus Defence and Space is a key player in Copernicus, an operational program led by the European Commission (EC) in partnership with the European Space Agency (ESA). The Sentinel-1 mission has been specially designed for a wide range of environmental tasks including surveillance of the maritime environment. It will assist in reconnaissance and operational support activities in response to natural disasters, for which the latest data is required as rapidly as possible.

Airbus Defence and Space will also operate the SpaceDataHighway system (EDRS) that will provide secure and fast laser communication services for the Sentinel-1 and Sentinel-2 satellites.



Source: Airbus Defence and Space

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7.7 Million Truck Platoon Systems to Ship by 2025

VIEW VIDEO

Truck platoons are the most imminently anticipated application of highly automated driving in commercial vehicles. A fusion of forward-looking radar and V2V communication enable fleets of trucks to safely maneuver with a short distance between vehicles. The reduction in aerodynamic drag for following vehicles, and buildup of pressure behind the lead vehicle yields impressive fuel efficiencies, with various tests reporting convoy savings of between 5 and 10 percent. "With most fleet operators attributing some 30 to 40 percent of their operating costs to fuel expenditure, the savings presented by platooning are significant," comments James Hodgson, research analyst, ABI Research.

"The emerging market for platooning is promising; in no small part due to its relevance across a considerable spectrum of vehicle automation..."

As technology progresses and regulations adapt to accommodate greater vehicle automation, further benefits to fleet operators will come in the shape of labor productivity gains and better asset utilization. Currently, solutions from pioneers such as Peloton Technology require active intervention from the following driver to keep the vehicle within the lane of travel, but in the future the driver of the lead vehicle could be in sole control of all vehicles in the convoy; allowing following drivers to rest, or eliminating the need for them altogether.

"The emerging market for platooning is promising; in no small part due to its relevance across a considerable spectrum of vehicle automation. The premise stretches all the way from a platoon comprised of two vehicles whose drivers seek to narrow the interval between them in a safe manner, through to scenarios which involve more vehicles than they do drivers," Hodgson explains.

Recent high-profile investments in platooning technology have been made by the likes of Denso International America, Volvo Group Venture Capital, Magna International, Intel Capital and the UPS Strategic Enterprise Fund, among others.

Multimodal In-Car OEM Navigation System Shipments to Exceed 18 Million by 2020

With mounting traffic congestion and increasing concerns about environmental issues, the focus of both public and private companies in the automotive and transportation industries is shifting to multimodal/intermodal transportation solutions. Traveler information systems providing real-time public transport timetable information, multimodal journey planners and smartphone-based pedestrian guidance applications are geared at facilitating knowledge of and seamless access to a wide range of mobility solutions. "This is prompting car OEMs such as BMW, Jaguar Land Rover and Ford to offer solutions beyond the narrow context of the vehicle itself, realizing their products will become part of an integrated intermodal system, offering a range of mobility modes," says VP and practice director Dominique Bonte.

Key suppliers of multimodal in-car navigation solutions and journey planners include HERE (Jaguar Land Rover), Google (Android Auto), and INRIX (BMW i brand). Real-time parking space availability content providers, some of which rely on crowd-sourced data, are also important actors, playing a critical role in removing the friction points between different modes of transportation. Parking Spotter, one of Ford's 25 smart mobility projects (co-developed with Georgia Tech) is based on ADAS sensors, allowing information about open street-side parking spaces identified by roaming vehicles to be shared with other drivers via the cloud. Telematics-enabled public transport allows integrating real-time transit-schedule information into journey planners.

The multimodal transportation environment is set for a dramatic shift driven by a wide range of disruptive technologies...

However, the whole multimodal transportation environment is set for a dramatic shift driven by a wide range of disruptive technologies with smart watches accelerating a seamless in and out-of-the car experience (BMW i Remote Apple Watch application) and car sharing starting to blur the boundaries between public and private transportation. Uber car sharing, including ETA information, is already offered as an option in multimodal journey planners by Google and mxDATA.

In-Building Wireless Market Heads Towards $9 Billion by 2020

The market for in-building wireless equipment and deployments will more than double the current market by 2020. North America will continue to be the region with maximum distributed antenna system (DAS) spending with sports venues, transportation and healthcare remaining the verticals which attract the most DAS investment with shopping malls and hospitality coming in a close second place. Together, these verticals in North America account for just under half of DAS spending. North America is followed by Asia-Pacific and then Europe, respectively, for market size.

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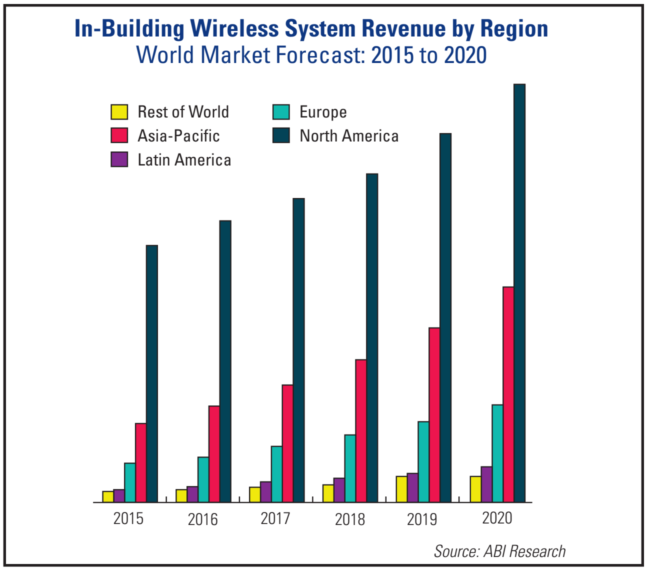
"While the Asia-Pacific region accounts for just one-fifth of the total market, we forecast it to be the fastest growing region and to represent over 25 percent of the market by 2020," says Nick Marshall research director at ABI Research. "China dominates the activity in the Asia-Pacific region and we believe that while CAPEX today is targeted to TD-LTE and 4G macro deployments, in-building wireless deployments will turn the corner in 2016 when the market returns to growth and active DAS systems are deployed for better data coverage."



China Drives RF Power Amplifier Sales for Wireless Infrastructure to Nearly $5B

The year 2014 was strong for wireless infrastructure hardware—especially RF power amplifiers—and prospects look good for growth through 2020. The Asia-Pacific region, including Japan, continues to account for the majority of RF power amplifiers that are sold into the mobile wireless infrastructure segment. According to ABI Research's research director Lance Wilson, "The Asia-Pacific region, particularly China, will remain the most important region and focus for RF power amplifiers for wireless infrastructure."

LTE and TD-LTE have become increasingly important factors in this business and will continue as the engines of growth for the future. "Although up until 2014, LTE had not significantly impacted RF power amplifier sales to the degree some would have wished," says Wilson, "that has changed now and as 2014 demonstrated, it is going to drive RF power sales in the wireless infrastructure space from 2015 onward." The continuing overall need for wireless data remains an important driver for the overall market for RF power amplifiers for wireless infrastructure.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Avago Technologies Ltd. and **Broadcom Corp.** announced that they have entered into a definitive agreement under which Avago will acquire Broadcom in a cash and stock transaction that values the combined company at $77 billion in enterprise value. Upon completion of the acquisition, the combined company will have the most diversified communications platform in the semiconductor industry, with combined annual revenues of approximately $15 billion.

Intel Corp. and **Altera Corp.** announced a definitive agreement under which Intel would acquire Altera for $54 per share in an all-cash transaction valued at approximately $16.7 billion. The acquisition will couple Intel's leading-edge products and manufacturing process with Altera's leading field-programmable gate array (FPGA) technology. The combination is expected to enable new classes of products that meet customer needs in the data center and Internet of Things (IoT) market segments. Intel plans to offer Altera's FPGA products with Intel Xeon® processors as highly customized, integrated products. The companies also expect to enhance Altera's products through design and manufacturing improvements resulting from Intel's integrated device manufacturing model.

Anite announced the completion of its acquisition of the trade and assets of **Setcom Wireless Products GmbH**, providing Anite's customer base with a more enhanced device application test offering for Wi-Fi offload, VoLTE, RCS and other application and IMS based services. The addition of Setcom's solutions to Anite's portfolio enables users to access an extensive range of test cases for a variety of requirements from a single test vendor, including interoperability, conformance, performance and application testing.

COLLABORATIONS

The National Radio Astronomy Observatory (NRAO), headquartered in Charlottesville, Va., and **Mini-Circuits**, headquartered in Brooklyn, N.Y., have entered into a licensing agreement to permit the use of NRAO-developed technology in a new suite of commercial electronics products. This newly signed agreement, which covers a part of the NRAO portfolio of radio frequency filters known as cascadable absorptive filters, will foster the development of new radio-frequency-based technologies in a wide range of commercial applications. The underlying technologies for this class of filters were developed by NRAO's Central Development Laboratory, where some of the world's most sophisticated radio astronomy technologies are engineered.

NEW STARTS

Rogers Corp., a global technology leader in the development of high performance printed circuit materials, announced that its division previously known as **Advanced Circuit Materials** is changing its name to **Advanced Connectivity Solutions** (ACS). This name change represents an important philosophical shift in how Rogers approaches printed circuit materials segment by expanding its potential areas of business beyond existing material sets into new areas of RF/microwave and digital connectivity.

MECA Electronics announced an expedited online service center, the source for RF Components on Demand (RFPOD) when you need them. RFPOD offers an expedited online service that processes orders and has them available for pick up at will call or shipment within two hours from order placement to pick up time. Will call pick up hours are 9 a.m. to 5 p.m. (ET) (earlier hours are available by calling customer service in advance). Orders are accepted 24 hours a day, 7 days a week and shipments are made same or next business day.

ACHIEVEMENTS

Orbel Corp. has been honored with a Small Business ImPAct Award as part of Pennsylvania's third annual Governor's ImPAct Awards, recognizing businesses that create jobs and generate an economic impact within the state. The Small Business ImPAct Award is given to a small business (100 or less employees) that is an innovator within its industry, demonstrated revenue/profit growth, increased its workforce, and is committed to the growth and development of its employees and community. Orbel's EMI/RFI shielding technology has helped to usher in automation to nearly all industries, promoted the viability of manufacturing within the Lehigh Valley and continuously pushed the envelope in the EMI/RFI marketplace.

United States Patent 9,007,125 B2, recently awarded to **Empower RF Systems**, validates the uniqueness of the hardware architecture in use on Empower's high power, next generation amplifiers. The ability to deliver 1 kW CW broadband power in an air cooled, 5U chassis (and other combinations of power and chassis sizes utilizing this architecture) requires innovation and engineering breakthroughs that are described and protected in this patent award. The patent was submitted and authored for Empower RF Systems by Paulo Correa, Don Wike and Leo Mogilevsky.

Anokiwave Inc., an innovator and leading supplier of semiconductors enabling mmWave and AESA markets, announced the completion of a Series B round of funding. The round was led by JP Carney, CEO and co-founder of Revolabs, Lamberto Raffaelli, and COM DEV International Ltd. Anokiwave will use the funds to continue to expand its engineering team, launch development laboratory facilities and expand rapidly innovative products for mmWave, 5G and complementary markets.

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Around the **Circuit**

CONTRACTS

L-3 Communications announced that it has been awarded an $81.8 million contract from **Raytheon Australia** to supply the Australian Defence Force (ADF) with 236 Very Small Aperture Terminals (VSAT), additional support equipment, and training as part of Joint Project 2008 Phase 5B1. This program will further enable the ADF to utilize the Wideband Global SATCOM (WGS) system, significantly increasing their satellite communications capabilities. Two L-3 business units, Global Communications Solutions (GCS) and Linkabit, will perform on this contract, with hardware deliveries expected to be completed this year. The contract will deliver L-3 GCS's Hawkeye™ and Panther™ family of VSAT terminals, integrated with L-3 Linkabit's MPM family of modems, and includes the option to purchase additional terminals and equipment.

GigOptix Inc. announced the booking of a $7.9 million order with a large aerospace and defense contractor to deliver ASIC products.

PEOPLE

▲ Larry Gross

Delta Electronics Mfg. Corp. welcomed **Larry Gross** as business development manager. Gross has spent over 25 years in the electronic component distribution field, building his product knowledge, covering a variety of interconnect products. Since the Mid 90s, Gross has focused his efforts more specifically around RF, microwave and millimeter wave coaxial connectors and related assemblies. His background has afforded him an opportunity to work with most of the top organizations in our industry, from all aspects of the supply cycle. He has worked in sales/applications engineering functions, and rose to the ranks of general manager.

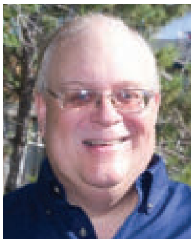
▲ Bruce Yolken

Pasternack Enterprises Inc. announced the appointment of **Bruce Yolken** as the company's quality assurance manager. Yolken joins Pasternack with more than 30 years of Quality Assurance experience in the aerospace and defense sector. Prior to joining Pasternack, Yolken held multiple management positions with McDonnell Douglas and The Boeing Co. supporting both aircraft and spacecraft programs and ranging from development and test to production activities. Yolken holds a bachelor's degree in industrial technology with a quality assurance option and two master's degrees, one in quality assurance and one in systems management.

At the **IEEE International Frequency Control Symposium** recently held in April in Denver, Co., **Dr. Ulrich L. Rohde** was awarded the I. I. Rabi Award, recognizing his outstanding contributions related to the fields of atomic and molecular frequency standards, and time transfer and dissemination. The citation read: "For intellectual leadership, selection and measurement of resonator structures for implementation in high performance frequency sources, essential to the determination of atomic resonance." At the same event, **Dr. Ajay K. Poddar** was awarded the W. G. Cady Award, recognizing his outstanding contributions related to the fields of piezoelectric or other classical frequency control, selection and measurement; and resonant sensor devices. The citation read: "For the analysis, design, and development of a host of frequency control products exhibiting state-of-the-art performance, including the development of extremely low noise crystal oscillator circuitry." Congratulations to Drs. Rohde and Poddar for winning these prestigious awards from their leadership in the industry.

▲ Dr. Ajay K. Poddar and Dr. Ulrich L. Rohde

▲ Bill Anklam



▲ Lee Barford

Keysight Technologies Inc. announced the selection of two new Keysight Fellows, a designation reserved for the highest level of achievement for an individual contributor in the company. **Bill Anklam** and **Lee Barford** each received the prestigious promotion through a rigorous selection process led by Jay Alexander, Keysight's chief technology officer and vice president. The Fellow designation is reserved for those who have distinguished themselves through enterprise-level technical and strategic contributions. They serve as external company ambassadors and role models who exemplify technical excellence and extraordinary values.

REP APPOINTMENTS

RFMW Ltd. and **XMA Corp.** have announced a worldwide distribution agreement effective April 1, 2015. XMA Corp., powered by Omni Spectra®, offers a complete line of RF coaxial passive components that range from DC to 50 GHz and offer power handling up to 500 W.

Sivers IMA and Boston-based **East Coast Microwave** (ECM), announced that they have signed a reseller and distributor agreement for the U.S. and Canadian markets. ECM will represent the whole Sivers IMA product range including converters and customized transceivers, radar sensors and signal sources such as VCOs and synthesizers. With over 25 years in the radio frequency and microwave business, ECM has developed a broad network of industry contacts all over the North American continent. Together with its network of sales reps in the U.S. and Canada, ECM ensures that Sivers IMA will have local presence and improve support to customers in the region.

INVITED PAPER

3D Electromagnetic Simulation vs. Planar MoM

Robert O'Rourke
Remcom Inc., State College, Pa.

The technical comparison of 3D planar MoM EM simulation with fully arbitrary 3D EM simulation helps illustrate how both formulations work and informs users as to which may work best for a given application.

Several full-wave electromagnetic (EM) simulator software products solve Maxwell's equations in three dimensional detail, using different EM formulations and approaches in order to address high frequency applications such as signal integrity, microwave circuits and antennas.[1,2] 3D planar formulations, such as Sonnet from Sonnet Software (see ***Figure 1***), Momentum from Keysight Technologies (formerly Agilent) and Axiem from Applied Wave Research (part of National Instruments), are sometimes referred to as 2.5D or "two and a half D." Other products such as Remcom's XFdtd (see ***Figure 2***), Ansys' HFSS, and CST's Microwave Studio (MWS) are fully arbitrary 3D.

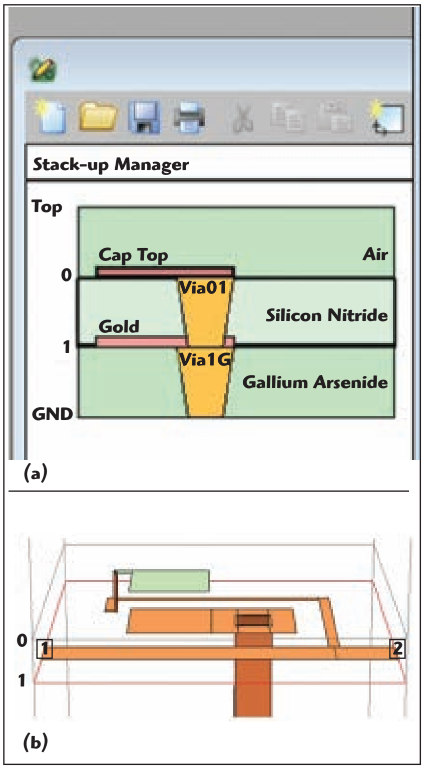


Fig. 1 Sonnet layout example including vias (a) and stack-up cross section (b).

Both 3D planar and fully arbitrary 3D EM simulations are full wave, capturing all metal coupling in all three dimensions, but the 3D planar formulations limit what dielectric and metal shapes can be modeled and simulated. Fully arbitrary 3D EM simulation accommodates any dielectric and any metal shapes. The term "fully arbitrary" 3D comes from the ability of EM simulators like XFdtd, MWS and HFSS to model and simulate any shape or configuration of metals and dielectrics that one needs. Fully arbitrary 3D EM simulation can simulate three dimensional metal shapes including car body sections, coaxial connector SMA launches, printed circuit board edge connectors, horn antennas, curved wire bonds and flexed MEMS switches.

3D Planar method-of-moments (MoM) formulations are based on parallel, uniformly thick dielectric layers with parallel metal layers in between. The dielectric layers generally extend horizontally to the end of the simulation

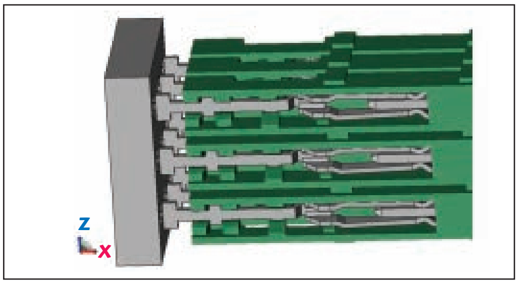


Fig. 2 XFdtd connector example of a 3D model.

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TABLE 1

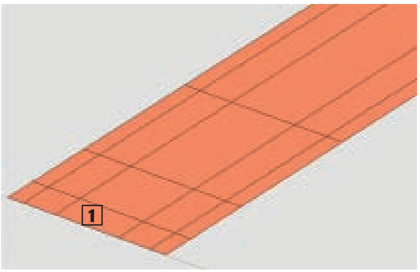
COMPARISON OF MESHING, PLANAR AND FULLY ARBITRARY 3D EM SIMULATION

Fully Arbitrary 3D EM Simulation	Planar Method-of-Moments EM Simulation
3D volumetric mesh elements	2D planar mesh elements
Meshes the entire simulation space	Meshes only flat metal surfaces

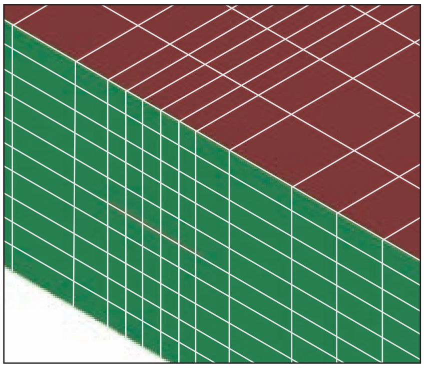
space. Planar MoM finds widespread use in electronic design flows because many circuits consist of multiple layers of planar, parallel circuit traces connected vertically by vias. This includes both printed circuit board and integrated circuit technologies.

MESH ELEMENTS AND WHAT GETS MESHED

One of the fundamental differences between planar MoM and fully arbitrary 3D EM simulation is meshing: 1) the nature of mesh elements and 2) what parts of the structure get meshed. Meshing, sometimes called sub-sectioning or gridding, characterizes full-wave EM simulators and distinguishes them from closed-form, equation-based modeling found in circuit simulations. But 3D planar and fully arbitrary 3D EM simulators mesh a design structure very differently from one another (see ***Table 1***). Fully arbitrary 3D EM simulators use a three dimensional mesh element, perhaps a hexahedron (six-sided brick) shape or a tetrahedron (four-sided) shape (see ***Figure 3***). These three dimensional elements are also referred to as volumetric mesh elements because they occupy three-dimensional volumes. By comparison, planar method-of-moments (MoM) simulators such as Sonnet, Momentum and Axiem, use two dimensional mesh elements (see ***Figure 4***). These flat 2D elements can be rectangles or triangles.



▲ *Fig. 3 Sonnet planar 3D MoM stripline sub-sectioning.*

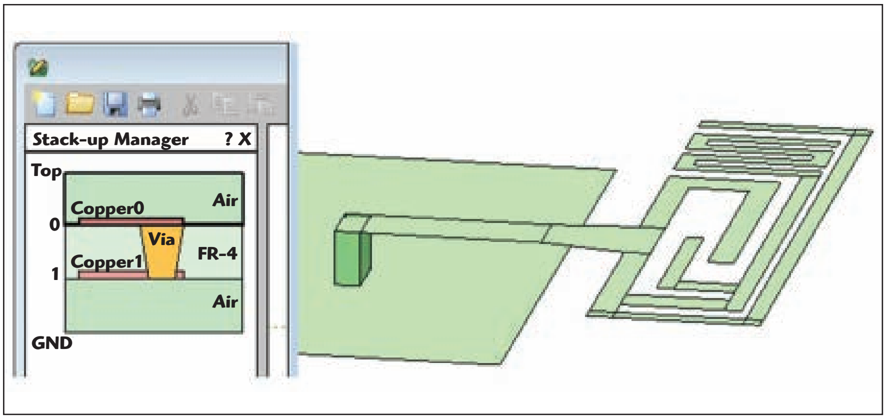


▲ *Fig. 4 Remcom XFdtd 3D stripline grid.*

While fully arbitrary 3D simulators mesh the entire volume of the simulation, planar MoM simulators mesh only the flat/planar metal conductor surfaces. Using a microstrip transmission line as an example, a fully arbitrary 3D EM simulator meshes the substrate, the metal signal conductor and the air above the microstrip. By comparison, a planar MoM meshes only the flat metal planar conductor (including vertical vias). In planar MoM, the effects of the substrate dielectric and the air above the microstrip are taken into account through the Green's function.

Note that both approaches are full-wave EM simulations; both solve Maxwell's equations in three dimensions and provide highly accurate results. Both capture all coupling among all conductors in all three dimensions of the entire simulation space. A two dimensional mesh element in planar MoM simulation in no way implies a two dimensional simulation; planar MoM captures all of the coupling among all of the metal including coupling in the vertical (third) dimension – hence the name "planar 3D." By contrast, a two dimensional simulation is more often associated with static solvers for printed circuit board vertical stack-up cross sections. These are not discussed here.

In all approaches, meshing/gridding/sub-sectioning is critical to simulation success and demands attention and understanding. The geometric features of the structure being simulated, including both size and spacing, influence the size or density of the mesh; this in turn influences the simu-



▲ *Fig. 5 Sonnet planar antenna example.*

lation time or problem size or both. Generally, one wants to have three to five mesh elements in the cross section of transmission lines in order to simulate impedance and current density (and therefore coupling) accurately. Also, one wants to have at least one mesh cell between two nearby metal conductors in order to differentiate them. Inspecting the mesh before simulation helps ensure that these minimum requirements are met. Automation of meshing in EM simulator software can help reduce the number of required steps, but do not rely on automatic features to replace engineering judgment. These meshing concepts are very similar among all types of EM simulation.

VERTICAL METAL AND VIAS

Planar MoM modeling and simulation is limited in the vertical direction. Planar MoM simulators can simulate horizontal metal with arbitrary shapes in parallel horizontal planes, but planar 3D MoM can only simulate limited configurations of vertically oriented metal, typically based around vias. Fully arbitrary 3D EM simulators can model any shape of vertical metal including slopes and curves and can simulate currents and fields in all three dimensions anywhere around this metal. Generally, planar MoM vertical metal vias carry vertically directed currents. Some planar MoM simulators simulate only uniform currents between adjacent metal layers, while others can simulate variation of vertical current with distance along the vias.

Antenna structures can be used to illustrate the distinction between arbitrary vertical metal and planar metal. Patch antennas, where the metal lies on a flat plane parallel to the dielectrics, are well modeled by planar MoM simulators (see ***Figure 5***). A via might feed signal to the metal patch surface from below, perhaps representing a vertically oriented coaxial cable center conductor. A helical or horn antenna, on the other hand, clearly requires the generalized 3D metal and dielectric modeling capability of a fully arbitrary 3D EM simulator. (Note that there is another class of EM simulation not considered here; some 3D surface MoM or wire-based EM methods work well on these types of antennas.)

VIA FENCES AND LATERAL CURRENTS

When spaced closely together in a fence-like manner, planar MoM vias can be used to approximate vertical metal walls, though there may be some limitations on the diagonal flow of currents in those walls. Each via may carry a certain (vertical) current and the amount current varies among the many vias. In fully arbitrary 3D EM simulation, metal can take the form of a via, a metal wall or any other shape. Fully arbitrary 3D can simulate currents and fields in all directions in and around metal walls.

In some sense, the treatment of vias represents an important distinction between the strength of planar MoM and fully arbitrary 3D. If the circuit consists of generally horizontal metal dominating the circuit behavior and vias taking a minor role, then planar MoM may work well. When one needs to see the details of individual vias, such as exact current densities in three dimensions within one via or a metal wall, then perhaps fully arbi-

trary 3D may work better for the application. Understanding exactly how an EM simulator models current flow, current variation and field strength is important in applying an EM simulator to a structure with vias.

SIMULATION SPACE BOUNDARIES

Planar 3D and fully arbitrary 3D EM simulators all have some form of simulation space and boundaries surrounding the structure being simulated. Fully arbitrary 3D EM simulation has a six-sided simulation space with a choice of boundary conditions including perfectly electrically conducting (PEC), perfectly magnetically conducting (PMC) and absorbing boundaries. Planar MoM simulation boundaries vary between the two main formulations of MoM. In shielded formulation MoM, such as Sonnet, the simulation space is a six-sided box where the four vertical side walls are always perfectly conducting. The top and bottom of the Sonnet box can be set to PEC, lossy metal material, or 377 ohms simulating open. Unshielded formulations of MoM, such as Axiem from AWR/NI and Momentum from Keysight Technologies, have an infinite ground plane and unbounded open upper and lower hemispheres.

It can be important to match the simulation boundary specification as close as possible to the real boundaries around the physical structure. A PEC boundary on the end of a simulated transmission line dielectric will cause a reflection to signals incident on the boundary. If the physical structure does not have that same PEC or conductive metal boundary, the simulation will not match the hardware measurements. In the simulation of patch antennas, there can be surface wave energy moving laterally in the substrate above the ground plane and below the patch. A PEC simulation boundary would reflect the surface wave energy back through the substrate. As a comparison experiment, changing lateral simulation boundaries on the patch antenna substrate from open/absorbing to PEC in a fully arbitrary 3D EM simulator should indicate how this surface energy bounding affects the antenna's behavior. In an unshielded formulation of MoM, there is no lateral boundary; surface wave energy goes horizontally away from the patch forever.

It is also possible to use simulation boundaries to represent part of the structure being simulated. The simulation of stripline, for example, has two ground planes, one above and one below a stripline center conductor. Instead of inserting metal ground conductors explicitly into the simulation model, one could use the PEC boundaries as ground conductors. Using PEC boundaries as ground planes decreases the size of the simulation mesh because that boundary metal is not getting meshed. On the other hand, one cannot usually see values for current or fields in boundaries like PEC metal.

Simulation boundaries can also become part of the simulated structure unintentionally; for example, PEC boundaries can easily become part of a ground return current path. Detailed studies of on-chip spiral inductor substrate currents have been done in Sonnet by comparing simulations with the box wall ground return paths allowed versus port configurations that don't allow the Sonnet box wall to be part of the ground return path.

PORTS AND DE-EMBEDDING

EM simulators all have a variety of port types and configurations available, but perhaps the main distinction between planar MoM ports and fully arbitrary 3D ports is the presumption of transmission line propagation in MoM simulators including an emphasis on de-embedding. Most MoM simulators have ports designed to attach to the edge of a stripline or microstrip conductor and they typically address differential port and coplanar waveguide (CPW) port configurations explicitly. By comparison, fully arbitrary 3D is completely general and no context can be presumed; one always needs to understand the physics and circuit theory of any port connection or excitation.

Most fully arbitrary 3D EM simulators, such as XFdtd, HFSS and Microwave Studio have both discrete ports and waveguide ports. A discrete component port consists of a voltage source or current source circuit element that is placed between two conductors, such as a microstrip conductor and a ground plane. A waveguide

port is a rectangular two-dimensional interface that is attached to the end of a structure and represents an infinite-length waveguide excitation. A discrete component port excites a structure at a specific point. A microstrip transmission line, driven by a component voltage source placed at the midpoint in the cross section of the conductor metal, may need some time and distance along the transmission line to establish a single-mode TEM wavefront.

Some unshielded MoM EM simulators use a point source exciting a transmission line but they also include a de-embedding arm between the source and location of the port. This is specifically to provide the port location with a TEM or quasi-TEM wave. Sonnet's shielded MoM formulation uses an infinitesimal gap voltage source between the ideal-ground box wall and a transmission line for a main port type. This voltage is evenly distributed along the transmission line offering an immediate TEM wave to the structure being simulated.

In contrast to the point-source nature of discrete component ports, waveguide ports in fully arbitrary 3D simulators incorporate dimensions and materials of the structure into the ports. They typically run a 2D EM simulation of the port area to determine modes and impedance. Waveguide ports are the preferred choice for microstrip and stripline structures versus discrete ports. Additionally, waveguide ports can drive coaxial cable structures and even actual waveguides with no center conductor at all. Waveguide ports can drive more than one mode in a transmission line as well. Planar MoM generally presumes single-mode propagation for a single line, at least for the purposes of de-embedding. Two coupled lines can have two modes. MoM port calibration, just like vector network analyzer calibration, assumes the port connecting lines are not over-moded.

De-embedding can be as simple as subtracting a uniform section of transmission line from a port and may even be done at circuit simulation level outside of the actual EM simulation structure. This is often thought of as phase rotation along the transmission line. Most EM simulators have some capability to de-embed, but planar MoM simulators' transmission line context might offer more accurate de-embedding because they generally focus on single-mode propagation. Sonnet, in particular, is well known for extremely accurate de-embedding. While related to shifting a reference plane as in network analyzer calibration, Sonnet also offers port calibration.

Fully arbitrary 3D EM simulators generally have plane wave sources and other external excitation that planar MoM EM simulators may not have. XFdtd from Remcom has Gaussian beams and plane wave excitations available. These external sources are often used for radar cross-section (RCS) simulation in antenna design, but they can also be used for photonic and other optical structure applications as well.

THICK METAL

In planar MoM simulation the default is generally infinitely thin metal. It can be useful to think of metal layers as the interfaces between vertically adjacent dielectric layers. Skin depth can be taken into account in an infinitely thin metal layer using equations for surface impedance. Most well-refined planar MoM EM simulators have thick metal modeling options available. In some cases the simulator may create a box model, something like the outside of a metal waveguide, in order to take into account the metal side walls of thick transmission line conductors. Sonnet, for example, has an automated capability for using multiple sheets of infinitely thin metal to model thick metal.

Fully arbitrary 3D EM simulation can model exactly the actual thickness of metal traces in applications like on-chip spiral inductors. 3D EM simulators can mesh the entire volume of the metal geometry where MoM cannot. This often leads to mesh cell sizes that are very small compared to the geometric features of the rest of the circuit such as transmission line length and dielectric thickness. Despite the completely general capability to mesh and simulate the exact dimensions of a structure, users of fully arbitrary 3D EM simulators often choose not to mesh the entire volume of thick metal traces due to large simulation sizes and long run times. Some simulators even

TABLE 2

COMPARISON BETWEEN FULLY ARBITRARY 3D AND PLANAR 3D MoM

Feature	Fully Arbitrary 3D	Planar 3D MoM
Dielectrics	Any shape	Uniformly thick parallel layers.
Metal Conductors	Any shape	Two dimensional flat metal layers plus vias.
Meshing/Sub-Sectioning	3D/volumetric mesh of entire simulation space including dielectrics	2D flat mesh of metal. Some simulators mesh vias vertically.
Boundaries	PML, PEC, or absorbing can be chosen for each or any of all six sides	Shielded MoM has four side walls always perfectly conducting. The top and bottom of the box can be adjusted in conductivity including 377 ohms for free space. Unshielded MoM has open hemispheres above and below infinite ground planes.
Ports	Discrete, waveguide and external plane or Gaussian wave	Transmission line ports, often explicit port types for differential signaling.
Thick Metal	Discrete metal thickness natively modeled and meshed; infinitely thin metal sheets available	Infinitely thin metal default, various thick metal modeling approaches available.
Dielectric Anisotropy	Anisotropy can be specified in any or all three dimensions	Uniaxial anisotropy (z-direction different from x and y) available in Sonnet.
Frequency Dependent Dielectrics	Debye-Drude models available	Generally not available.

offer GUI check box features for "do not solve inside" the metal.

SUBSTRATES AND ANISOTROPY

Because of the generality of the formulation, fully arbitrary 3D EM simulators generally offer an array of capabilities for dielectric anisotropy, frequency dependence and metamaterials. These features are generally not available in planar MoM, although Sonnet offers uniaxial anisotropy where the vertical (z-oriented) dielectric constant differs from the dielectric constant in the horizontal dimensions. XFdtd, Microwave Studio, and HFSS all offer Debye-Drude modeling for frequency dependent dielectrics.

CONCLUSION

Table 2 summarizes and compares the features of fully arbitrary 3D and planar 3D MoM simulation. While the capabilities and application areas of planar MoM and fully arbitrary 3D EM simulators overlap extensively in microwave circuit and antenna design, each has strengths and limitations beyond the basic dimensionality of the tools. Knowing the technical features of each formulation and how they can be applied to various designs and simulations is an important and valuable part of the engineering practice. ■

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INVITED PAPER

A Synthesis-Based Approach to Quickly and Easily Design a Class E Amplifier

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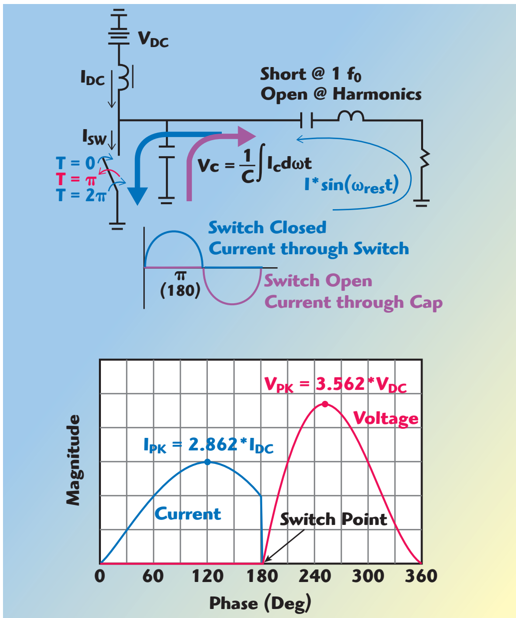
Power amplifiers (PA) are increasingly part of everyday life, used in everything from wireless and broadcast transmitters to hi-fi audio equipment. Due to its very high efficiency, the Class E PA topology is particularly advantageous for wireless communication devices. Unfortunately, that benefit comes at a price: a Class E PA circuit is difficult to design. It involves a number of design challenges and trade-offs that must be well understood in order to achieve a successful circuit implementation. Fortunately, a novel synthesis-based design process now promises to make designing a Class E PA faster and easier than before.

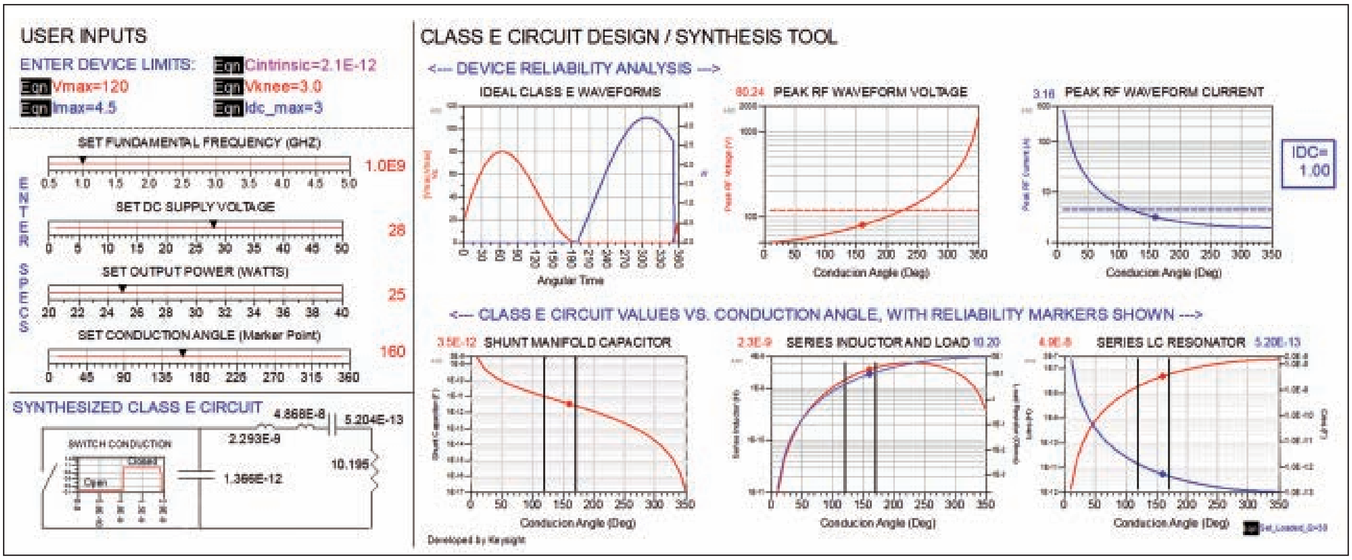
CLASS E THEORY

Before designing a Class E PA, it is critical to understand the basic theory behind the topology. As opposed to the conventional classes of operation, Class E amplifiers use a transistor like a switch that toggles on and off at the fundamental frequency (see ***Figure 1***). A series resonator added to the output acts like a short at the fundamental frequency and an open at the harmonics. This forces a single frequency (sinusoidal) current to flow through the circuit. When the switch is closed, AC current flows out of the resonator into the switch with the DC current from the supply. When the switch is open, current flows back into the resonator from ground through a capacitor. The voltage across the capacitor is the integral of the current.

If designed correctly, this switching mode circuit has the potential to be 100 percent efficient. The challenge, however, is that the voltage and current swings can be high multiples of the DC supply values. For example, when the switch toggles at the halfway point (50 percent duty cycle), the voltage peaks are several times that of the supply voltage. These swings can cause the signals to exceed the safe operat-



▲ *Fig. 1 Standard Class E topology. With this type of circuit, duty cycle is an important design parameter to ensure reliable operation, as current and voltage swings can push device limits.*



▲ *Fig. 2 The Keysight ADS Class E power amplifier synthesis utility[2] generates Class E voltage and current waveforms across a transistor and analyzes these vs. reliability constraints.*

ing limits of the transistor, and this has significant implications for reliability.

Designers want to avoid such swings; therefore, successful circuit design requires using equations that vary with duty cycle. Unfortunately, enumerating these equations is not easy. Circuit design equations that include duty cycle are not compact, meaning that the resulting values are usually expressed in graphical format or in the form of a polynomial fit. Designers often have to interpolate normalized values from these graphs manually, and that can jeopardize the accuracy of the design.

LOAD-PULL SIMULATION AND A LOT OF PATIENCE

In general, PAs are designed using load-pull simulation. This technique involves sweeping the output load over a set of impedances, generating various contours for power and efficiency and picking the load value that gives the needed performance. Unfortunately, load-pull simulation doesn't work well with a complex switching mode amplifier, like Class E.

In Class E, performance depends on presenting a very precise combination of fundamental and harmonic impedances to the intrinsic node of the device, along with an input signal drive level and bias point combination which set the switching duty cycle. To find such a specific combination of points using a brute-force technique like load-pull would require generating and sorting a huge volume of data. Even if it is feasible to take all the points, there would be no guarantee that the simulation would converge or remain stable over every possible combination of bias and impedance. There could be conditions where the model isn't intended to be used because the device is intrinsically unstable or the simulation just doesn't converge, which can result in interpolation errors. If designers arbitrarily follow this approach and rely too much on the device model without understanding circuit fundamentals, the results can be quite confusing and the device might even be damaged. For Class E, a more meticulous approach to the initial PA design is needed.

NEW SYNTHESIS-BASED APPROACH

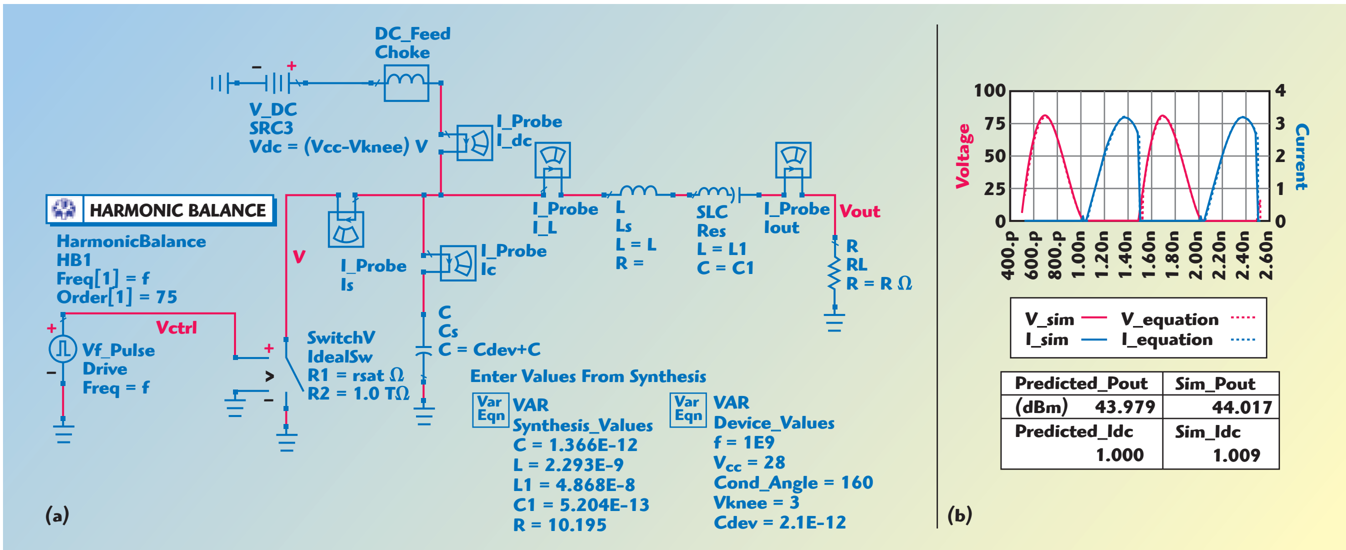
How can a Class E PA circuit be accurately designed without having to use load-pull simulation or manually interpolate plots of normalized equations? The key is an interactive circuit synthesis design process that relies on first principles to get an accurate prediction of the performance of an amplifier entirely from a starting set of equations and rules. This process enables PA designers to more quickly arrive at a predictable and understandable starting point.

The first step is to synthesize the circuit entirely from transient equations.[1] Second, the circuit is validated using an idealized switch/lumped circuit topology. Third, the voltage/current waveforms are converted from the time domain to a set of harmonic impedances in the frequency domain. Finally, design tools are used to optimize a more practical, realizable circuit topology to match the target impedance values for the first few harmonics.

Key to this approach is the choice of synthesis tool (see ***Figure 2***). Ideally, it should have a utility that allows the general Class E design equations to be encoded in an interactive manner so that circuit synthesis occurs in real-time based on design inputs. With this type of utility, the designer can enter the device parameters on the display (e.g., maximum voltage and current, knee voltage and the internal parasitic capacitance of the device) and set performance specifications (e.g., frequency, DC supply voltage, output power and conduction angle). The synthesis tool then uses this information to synthesize the ideal Class E circuit.

This type of synthesis tool offers the ability to plot circuit values against conduction angle and denote, with markers, the valid range under which the PA circuit can reliably operate. The conduction angles between the markers are valid, those outside the markers are not. When operation with any conduction angle is not possible, the designer is notified with a warning message. Such design flexibility is critical to ensuring the device operates reliably while meeting target performance specifications in the Class E circuit.

To see how this four-step process



▲ *Fig. 3 Ideal Class E circuit (a) and validation of the synthesized circuit (b). The solid lines in the graph are the simulation, while the dotted lines are predicted from the synthesis equations. This idealized large-signal simulation achieves about 99.9 percent efficiency.*

works, consider the example of a Class E PA design using a Cree GaN MMIC device and Keysight Advanced Design System (ADS) for synthesis. The device has a breakdown voltage of 120 V, an intrinsic capacitor value of 2.1 pF and a maximum AC and DC current of 4.5 and 3 A, respectively. The Cree model also allows access to the intrinsic current generator of the device, which is important because the target impedances achieved through the synthesis process must be presented across this node.

Step 1: Synthesize the circuit from transient equations.

To generate the design, the device's reliability limits and intrinsic capacitance are entered into ADS. The tool's sliders are then used to set the frequency to 1 GHz, the supply voltage to 28 V and the output power to 25 W. The tool outputs a range of conduction angles that can be used for the design. In this case, the valid conduction angles range from 120° to 170°. If the conduction angle goes below 120°, the RF current will exceed device limitations; if the conduction angle goes above 170°, the required value of shunt capacitor is smaller than the intrinsic device parasitic. The interactive nature of this process provides a more complete understanding of the tradeoffs and limitations involved, helping to avoid errors later. Selecting a conduction angle of 160°, an ideal Class E circuit is obtained as shown in ***Figure 3***.

Step 2: Validate the circuit using an idealized switch/lumped circuit topology.

The goal of the validation is to match the AC voltage and current waveforms, power and DC current, so that the circuit can be tried with the GaN device. It's a good idea to validate in an ideal environment before moving to implementation using a real transistor. In this case, the circuit is validated using a simple simulation bench. The transistor is modeled using a switch component, the circuit values are brought in from the synthesis tool and a harmonic balance simulation is run. Figure 3 shows that the simulation results agree very well with the predicted waveforms. This level of agreement with simulated results is typical for the synthesis tool.

Step 3: Convert the circuit's voltage/current waveforms from the time domain to a set of harmonic impedances in the frequency domain.

To make a realistic PA, the ideal circuit is translated to a more physical configuration. This is done by performing a Fourier transform on the simulated Class E voltage and current waveforms and then matching the resulting frequency-domain harmonic impedances in Step 4.

Step 4: Use design tools to optimize the impedances presented by a more practical circuit topology to match the target impedance values for the first few harmonics.

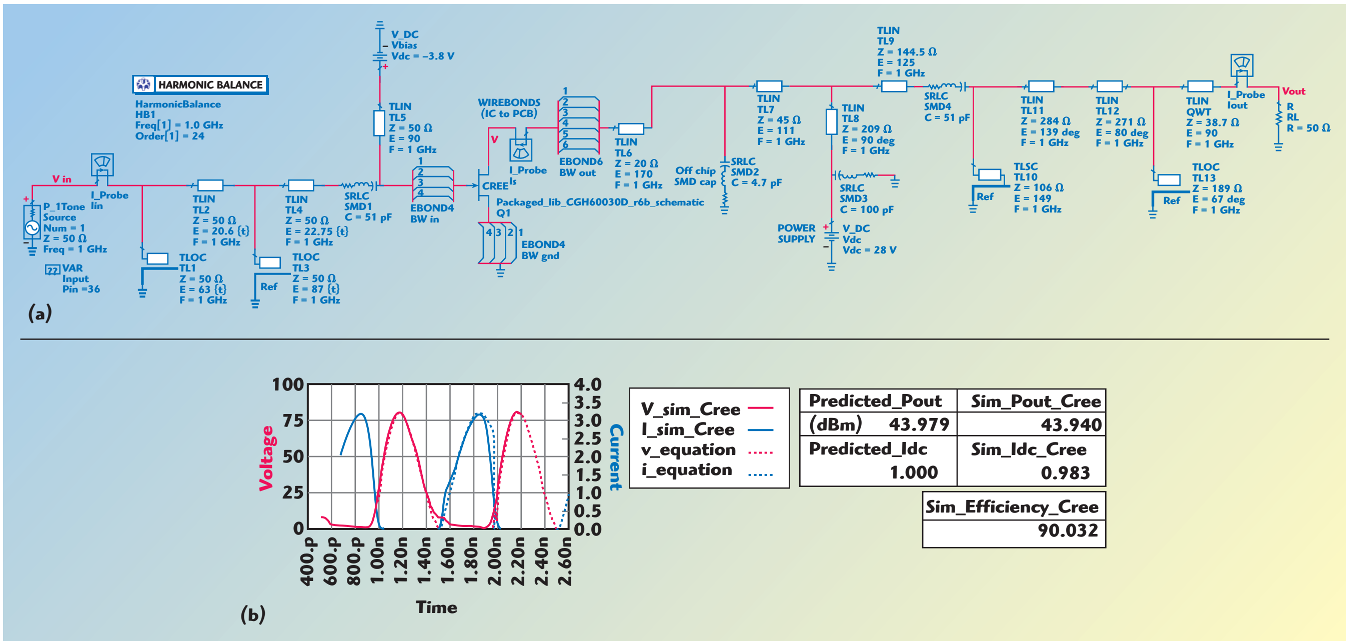
For the final step, any circuit topology that provides the right impedances to the harmonic frequencies will result in Fourier components that combine to deliver the necessary composite time-domain voltage and current waveforms. In fact, there are many circuit topologies that can potentially provide this combination of impedances.[3] Typically, the designer only needs to match the first few harmonics to get very close to the ideal waveforms.

Figure 4 shows the actual first-pass physical circuit design created by following these four steps. For the input and output connections to the IC, EBOND components were used to model bond wires, and SMT components were used for blocking and bypassing. Otherwise, transmission lines were used for the matching.

The design produces similar waveforms, output power and DC current as compared with the idealized case, with 90 percent drain efficiency. These results track closely with the original prediction from the design synthesis utility used in Step 1. There is excellent agreement in both the waveforms and also the power and DC current. This accuracy is especially helpful for designers who are trying to maximize performance without losing reliability. To watch a short video describing this design, go to www.keysight.com/find/eesof-how-to-pa-series.

CONCLUSION

While designing a Class E PA can be difficult, a novel design process offers a simpler and faster alternative to



▲ *Fig. 4 Initial physical Class E circuit design using a GaN device from Cree (a), which achieves good agreement between the predictions from the synthesis tool and the simulated waveforms on the device (b).*

the load-pull simulation technique. The process relies on first principles and allows designers to quickly get to a predictable and understandable starting point for the circuit. From here, designers can continue to make the models more accurate and physical and spend time on increasing bandwidth,[4] ensuring stability over various conditions and minimizing the sensitivity of the circuit to process and packaging variation. ■

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INVITED PAPER

Is Your Handset PA Ready for LTE Device-to-Device Proximity Services?

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With release 12, the third generation partnership project (3GPP) has taken on the challenge to enhance the LTE specifications to support features essential for critical communication systems. The two initial features to be standardized are LTE device-to-device (D2D) proximity services (ProSe) and group call system enablers (GCSE) for LTE. Both features are adding quite some complexity to the standard, including new types of signals with specific characteristics that have to be transmitted and amplified by the handset's power amplifier.

As these signals have a higher peak-to-average power ratio (PAPR) than the standard LTE uplink signals (such as PUCCH, PUSCH, DMRS), it is important for companies who design power amplifiers to verify that their products still comply with the standard and that recently developed digital predistortion (DPD) algorithms and shaping tables for envelope tracking (ET) are still valid. This article discusses the fundamentals of device-to-device communication, the newly introduced synchronization signals, their characteristics and how to ensure that the power amplifier is still working within the specification.

HOW LTE D2D PROSE WORKS

The objective for LTE D2D ProSe is to allow devices in close proximity to detect each other and to communicate directly. For this purpose, two functionalities have been standardized. First, direct discovery allows for a device to either announce or to monitor information of interest upon authorization and provisioning from the serving LTE network. Second, direct communication enables two or more devices to establish group communication. The latter is only intended for non-commercial public safety applications.

While integrating these two features into the standard, 3GPP (the standardization body behind LTE/LTE-Advanced) defined three different coverage scenarios: the 'in-coverage' case, where two devices are served by a LTE base station; the 'partial coverage' case, where only one device is served by a base station and the second one is 'out-of-coverage'; and the 'out-of-coverage' case, where both devices are

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LS-A112-XXXX[3]											47
LS-0212-1121											70
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LS-0118-XXXX[3]		DC-18.0		0.6	350						70
LS-A118-XXXX[3]											47
LS-0218-1121											70
LS-A218-1121											47
LS-0118-5161	N							300	355	-65/+70	105
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LS-A121-XXXX[3]											47
LS-0221-1121											70
LS-A221-1121											47
LS-0321-1121			1.31:1		500	35	0.6	236.7	290.5		30
LS-0170-1121			1.26:1	0.26	127	13.5	0.36	109.2	122.8		9
LS-S008-1121			1.50:1	0.4	155	10	0.6	118.6	135.1		20
LS-P140-KFKM	2.92 mm	DC-40.0	1.2:1	0.6	590	12	1.2	168	208	-65 to +65	51
LS-0140-KFKM			1.4:1								49
LS-P150-HFHM	2.40 mm	DC-50.0	1.3:1	0.8	400	7		172	195		55
LS-0150-HFHM			1.5:1								53
LS-P165-VFVM	1.85 mm	DC-63.0	1.4:1	0.8	600	8		167	195		55
LS-0165-VFVM			1.5:1								53

[1] div.: Connector Configuration available: SMA, male and female; N, male and female; TNC male and female
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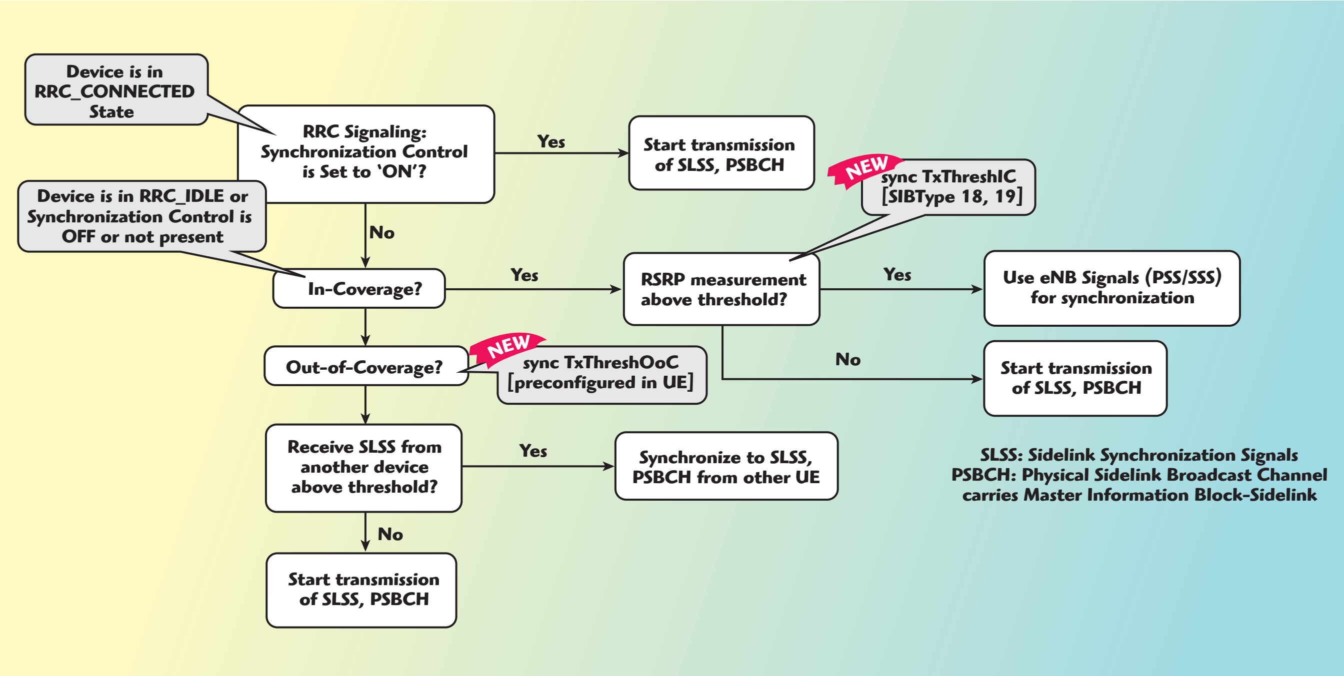

▲ *Fig. 1 Synchronization flowchart for direct communication.*

not in range of a base station. These three scenarios provide different challenges when realizing direct discovery and direct communication.

The first challenge is to define when and on what resources a device will be allowed to transmit and receive. Before taking on this challenge, 3GPP made a fundamental decision by deciding to (re)use the LTE uplink structure as much as possible for LTE D2D ProSe. This means that the underlying access scheme is single-carrier frequency division multiple access (SC-FDMA), and a device using direct discovery or direct communication transmits and receives using uplink frequencies for FDD-based systems and uplink subframes in TD-LTE.

The resource pools for transmission and reception for both direct discovery and direct communication are broadcast by two newly introduced system information blocks (SIB), Type 18 and 19, respectively. A device that is not served by the LTE network and found to be 'out-of-coverage' will use relevant parameters that were either stored on the UICC card placed in the device or that are hard-coded on the device itself.

SYNCHRONIZATION IN LTE D2D PROSE

The prerequisite before any communication can happen for all scenarios – in-coverage, partial coverage or out-of-coverage – is that the transmitting device and the receiving device have to be time-aligned. In standard LTE, synchronization is typically established based on synchronization signals that are embedded in the downlink signal provided by the LTE base station. There are two signals designed for this purpose: the primary and secondary synchronization signals (PSS, SSS). These signals are transmitted every 5 ms, twice per 10 ms radio frame. With the help of these signals a device gets frame synchronized and identifies the physical cell identity (PCI) of the serving cell. This identity is used to determine the mapping of the reference signals, which allows the device to fully synchronize in time and frequency.

Obviously, in the out-of-coverage case, there is no base station. Thus, no signals exist with which a device can properly synchronize. In such a case, one of the devices should assume this role and provide synchronization signals for other devices. Also, in the in-coverage and, especially, the partial coverage scenario, there might be the necessity for a device to transmit synchronization signals, even if it is considered under coverage. Therefore, 3GPP has defined a 'step-by-step' approach that a device undergoes to determine whether or not to transmit the newly defined synchronization signals, called sidelink synchronization signals (SLSS). ***Figure 1*** shows the related flow chart for direct communication. For direct discovery, the device would only transmit SLSS.

It is decisive whether the device has a passive (RRC_IDLE) or an active (RRC_CONNECTED) connection with the network. In the latter case, the network will inform the device via a signaling message to start transmission of SLSS and the newly introduced physical sidelink broadcast channel (PSBCH). In case of idle mode, the device first needs to determine if it is in-coverage by carrying out quality measurements on the downlink reference signals (reference signal received power, RSRP). If the measurement result is above a certain threshold, the device uses the synchronization signals provided by the base station. If not, it starts transmitting SLSS and PSBCH. The threshold is configurable and provided via system information to the device.

In the case where the RSRP measurement is below another threshold that is pre-configured in the device, the terminal considers itself out-of-coverage and starts looking for the SLSS issued by another device. If it detects these types of signals, the device has to carry out newly defined quality measurements known as sidelink reference signal received power (S-RSRP). The measurements are carried out on the demodulation ref-

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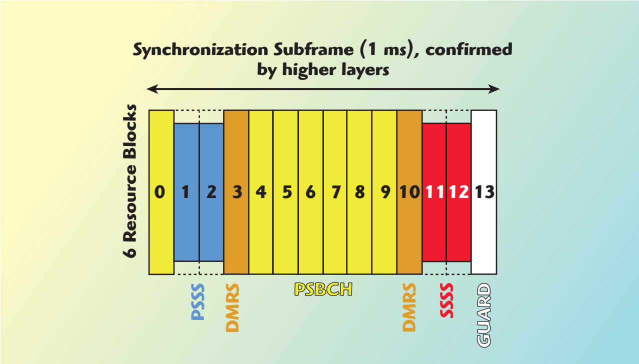


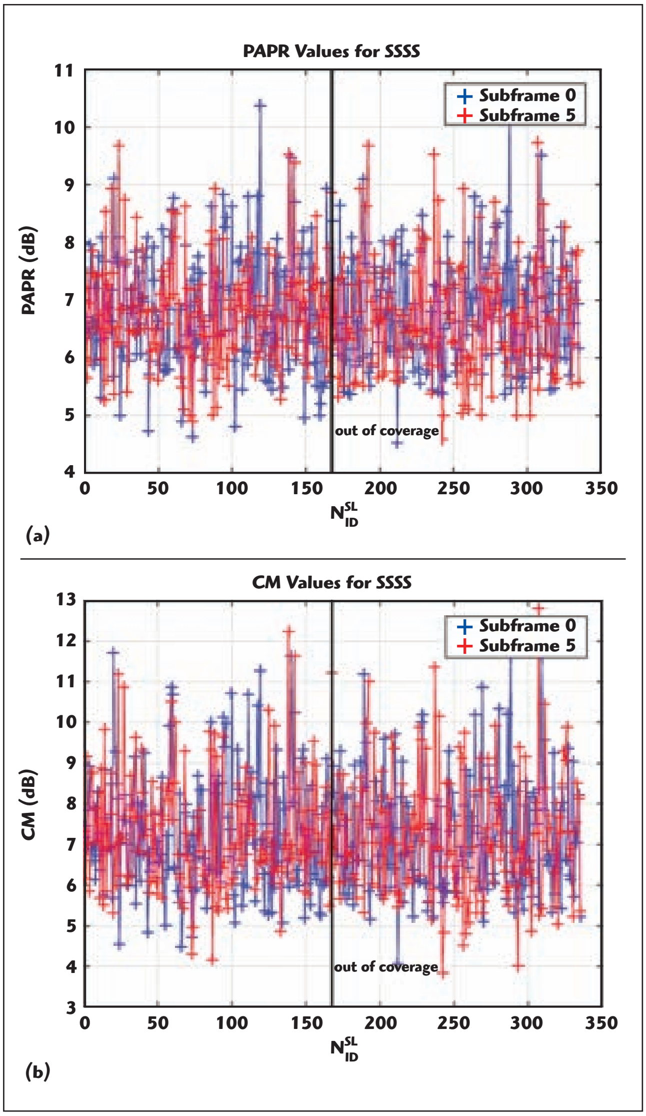
▲ *Fig. 2 Synchronization subframe for direct communication for normal cyclic prefix.*

erence signals (DMRS) embedded in the synchronization subframe (see ***Figure 2***). If the result is above a pre-configured limit, the terminal synchronizes to the SLSS issued by that device, otherwise it becomes a so called 'synchronization source' and starts transmitting SLSS and PSBCH itself.

ARCHITECTURE OF SLSS AND SUBFRAME MAPPING

Similar to the downlink synchronization signal architecture, the SLSS are comprised of two sequences: the primary sidelink synchronization signal (PSSS) and the secondary sidelink synchronization signal (SSSS). The latter is identical to the secondary synchronization signal used in the downlink. Also the PSSS relies on the fundamentals of the PSS in downlink. It is still based on a constant amplitude zero auto-correlation (CAZAC) sequence, specifically a Zadoff-Chu sequence.

However, for the purpose of LTE D2D ProSe, two new root indices were introduced: 26 and 37. The PSSS is therefore defined by two different sequences, compared to the three sequences in downlink for traditional LTE. Similar to the PCI in downlink, PSSS and SSSS are used to define the so called sidelink identity (N_{ID}^{SL} or SLSSID), that ranges from 0 to 335. The number of possible N_{ID}^{SL} is divided into



▲ *Fig. 3 PAPR (a) and CM (b) values for the SSSS.*

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NEW ZHL-5W-422+	500-4200	25	3	5	1670
ZHL-5W-2G+	800-2000	45	5	6	995
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two sets, where 0 to 167 are used for the in-coverage case and 168 to 335 for the out-of-coverage case. For the latter, the PSSS is generated using root index 37; in all other cases root index 26 is used. This enables a device which uses these SLSS as a reference to align its receiver to determine if the generating device (i.e., synchronization source or reference UE) is itself in-coverage or out-of-coverage.

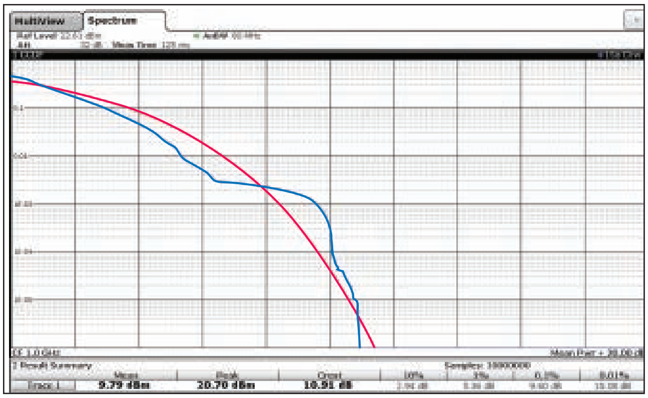
Likewise, in downlink the SLSS are mapped to the six inner resource blocks around the carrier frequency. Similar to the downlink synchronization signals, SLSS occupy 62 of 72 available subcarriers. For the case of normal cyclic prefix, PSSS occupies SC-FDMA symbols #1 and #2 whereas SSSS is mapped to symbols #11 and #12. Symbols #3 and #10 carry the demodulation reference signals (DMRS) that were mentioned earlier. The last symbol is used as a guard symbol. The remaining symbols are utilized by the physical sidelink broadcast channel. Figure 2 visualizes the described subframe mapping.

The radio frame where a terminal starts transmitting SLSS and PSBCH in subframe 0 and 5 is configured by higher layers by means of providing the system frame number (SFN). The periodicity of SLSS, PSBCH is 40 ms, which has been defined to save battery power.

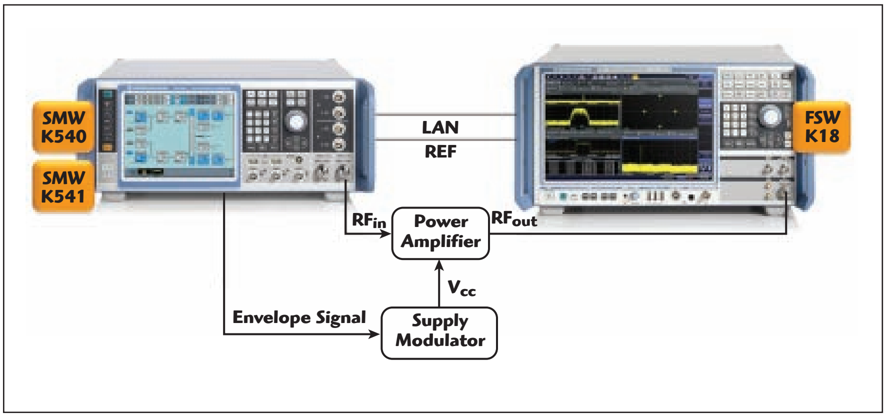
An interesting aspect is to examine the characteristic of these newly defined signals – they have to be generated, amplified and transmitted by a device that either has received the task by the network or has determined to transmit those signals following the flow chart outlined in Figure 1. Of particular interest is the SSSS. As it can be derived from simulations shown in ***Figure 3***, the PAPR and cubic m (CM) for SSSS varies greatly over the potential sidelink identities.

SIGNAL LEVEL CHALLENGES

As shown in Figure 3, there are cases for both in-coverage and out-of-coverage where the SSSS exceeds a PAPR of 10.5 and where the signal has a CM of up to 13 dB. This is even the case when SC-FDMA is used as the underlying multiple access scheme, which was introduced to overcome the unfavorable characteristics of a multicarrier scheme like OFDM. A high PAPR and CM is a tough design challenge for component manufacturers, especially handset power amplifiers. At this point, 3GPP has not decided on a way to overcome this challenge. Two options are in place: the first, a power back-off of up to 4 dB for SSSS while transmitting on maximum power. The value is currently discussed in 3GPP's relevant working groups RAN 4 and 5. The second option is restricting possible values that show a high PAPR and CM.



▲ *Fig. 4 CCDF measurement to determine PAPR for SLSSID = 288, made using the Rohde & Schwarz FSW signal and spectrum analyzer.*



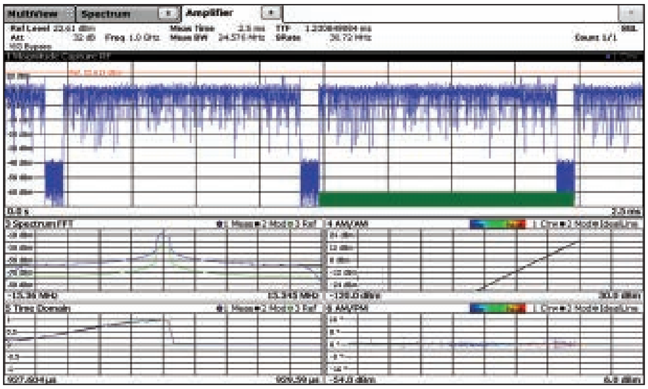
▲ *Fig. 5 Test setup for DPD and ET using Rohde & Schwarz SMW200A vector signal generator (left) and FSW signal and spectrum analyzer (right).*

However, this is currently not foreseen by 3GPP. Consequently, it is up to the respective network operator that deploys LTE D2D ProSe, direct discovery and/or direct communication, which SLSSID is being used. Depending on the coverage state (in-coverage or out-of-coverage), a pool of identities might be made available to the device as part of the broadcast system information. Here, the operator can influence the selected SLSSID. However, different circumstances exist for the out-of-coverage situation. It matters whether the terminal synchronizes to a device that sends out SLSS and this particular device is in-coverage or whether the device in question is not synchronizing to another terminal.

For the latter case, the device will randomly select an identity out of the available set of SLSSID's for the out-of-coverage situation (168 to 335) by applying a uniform distribution. This means a terminal can pick an SLSSID and thus an SSSS which has a high PAPR and CM. Such an SLSSID could be 288, for example (compare Figure 3). ***Figure 4*** shows the CCDF to determine the PAPR for a synchronization subframe with all relevant signals – PSBCH, PSSS, DMRS and SSSS that form a SLSSID of 288. This statistical measurement was carried out using a signal and spectrum analyzer.

PA CONSIDERATIONS

The new signals provide a new, challenging task to companies that design and manufacture components for modern handsets and tablets, in particular handset power amplifiers. Adequate test tools are required to test and verify that current and future products still fulfill the standard's requirements such as error vector magnitude (EVM) and adjacent leakage power ratio (ACLR) or spectrum emission mask (SEM),



▲ *Fig. 6 Arbitrary waveform where the signal represents SLSSID = 288 in the FSW-K18 power amplifier measurement option. The AM/AM and AM/PM conversions are shown in the bottom right display.*

while transmitting signals with a high PAPR and CM.

While the procedures and test tolerances to carry out the measurements for this new set of signals are still being discussed by 3GPP, the design engineer can already start to validate that recently developed DPD models and ET algorithms are still applicable for these signals on existing products or products currently under development. DPD and ET have been recently introduced to power amplifiers powering modern smartphones and tablets to optimize battery life and power consumption.

The same goals apply to a device that operates in direct mode using direct communication. One possible setup to carry out DPD and ET measurements is a vector signal generator in interaction with a signal and spectrum analyzer. The setup and required software options are shown in ***Figure 5***.

In this setup, the signal generator provides the waveform to the RF input of the power amplifier being tested. This can be a standard-compliant LTE signal generated by the LTE personality on the instrument or an arbitrary waveform coming out of a software simulation tool chain. The signal generator is connected via LAN to the signal analyzer and both references are tied together.

Figure 6 shows an arbitrary waveform where the signal represents SLSSID 288 in the power amplifier measurement software of the signal and spectrum analyzer. In the bottom right corner of the figure, the AM/AM and AM/PM conversions are visible. They are measures to characterize the power amplifier's nonlinearity. To perform these measurements, the signal analyzer needs to know the ideal waveform, which serves as a reference for the calculation of the distortion. For this reason, the setup is connected via a LAN interface, so the signal and spectrum analyzer is able to read the ideal waveform from the signal generator and stores it locally as the reference waveform.

The signal analyzer measures the output signal of the power amplifier, compares it to the reference waveform and calculates the distortion. Based on the measured distortion and the applied settings, the power amplifier measurement software of the signal and spectrum analyzer calculates a pre-distortion model that is transferred back to the signal generator. The signal generator applies the automatically calculated distortion model to the signal, and the effects are measured in real time on the signal analyzer.

CONCLUSION

With 3GPP release 12, a first set of features is added to enhance LTE to support the functionality for critical and tactical communications, such as direct mode (direct discovery, direct communication) and group communication. Those features, in particular direct communication in the case of being out-of-coverage, require a new set of synchronization signals that are periodically transmitted by a handset acting as a synchronization source. These signals can provide challenging signal characteristics to a handset power amplifier, since they can have a high PAPR and CM, higher than today's generic LTE uplink signal. The task of the power amplifier design engineer is to verify and validate that current and future products still fulfill the standard requirements and that lately derived DPD and ET models are still functional. ■

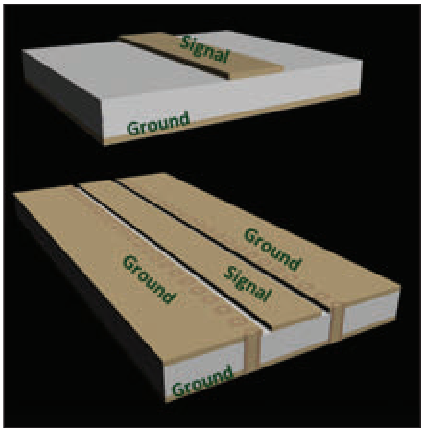
INVITED PAPER

Managing Circuit Materials at mmWave Frequencies

John Coonrod
Rogers Corp., Chandler, Ariz.

This article examines how different circuit material characteristics, configurations and fabrication influences can affect the performance of a printed circuit board at millimeter wave frequencies.

Millimeter wave (mmWave) frequencies are being used more and more, for short-range links and high data-rate near field communications (NFC) applications. Suppliers of mmWave integrated circuits (IC) are supporting this growth with more cost-effective components and improved performance. For circuit designers working with these higher frequency ICs, it is important to understand the limits and capabilities of the printed circuit boards (PCBs) and circuit materials that will be used at mmWave frequencies. Numerous PCB issues – insertion loss, dispersion, suppression of spurious wave propagating modes, signal launch effectiveness, fabrication methods – can affect the performance of a circuit at mmWave frequencies. This report will briefly review some of key PCB parameters and what to consider in a PCB material slated for use at mmWave frequencies.



▲ *Fig. 1 Microstrip (top) and GCPW (bottom) transmission-line circuits.*

MICROSTRIP VS. GCPW

mmWave circuits can be quite complex, performing transmit and receive functions with advanced modulation, and with frequencies through 77 GHz being used more routinely for short-range applications. However, all of these high frequency circuits share the need for transmission-lines to connect mmWave ICs to power supplies, antennas, input and output ports and other circuits. In general, microstrip and stripline transmission-line technologies are used in microwave circuits through about 30 GHz, while grounded coplanar-waveguide (GCPW) transmission-line technology is used for circuits above 30 GHz. ***Figure 1*** compares microstrip and GCPW transmission-line approaches for a single circuit dielectric layer with metalized ground and circuit conductors. In actual applications, a PCB is more likely to be multilayer, with microstrip or GCPW circuitry on the outer layers of the multilayer construction.

In general, microstrip circuits are susceptible to radiation at mmWave frequencies, where a well designed GCPW circuit is less likely to radiate or suffer radiation loss. Yet,

50 MHz to 26.5 GHz

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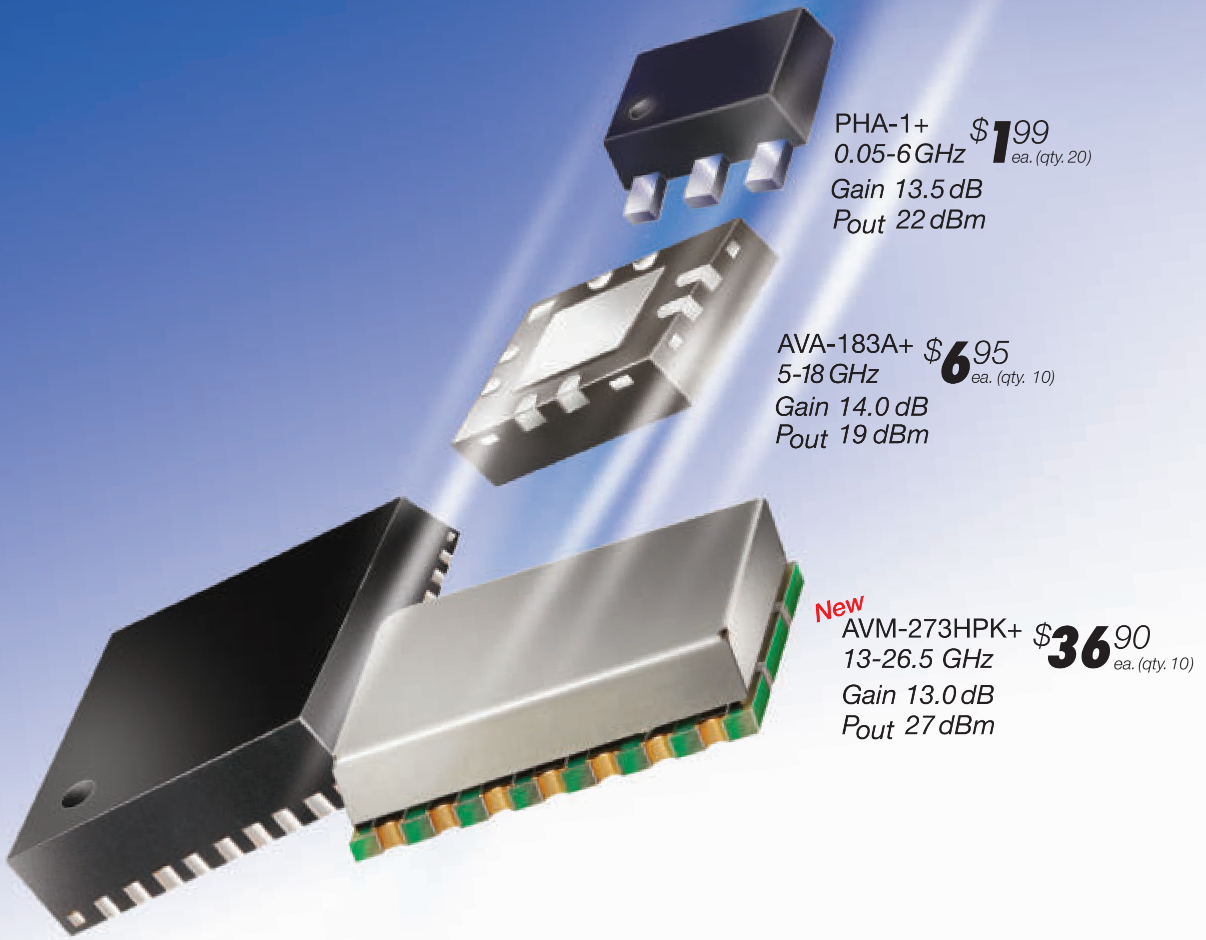

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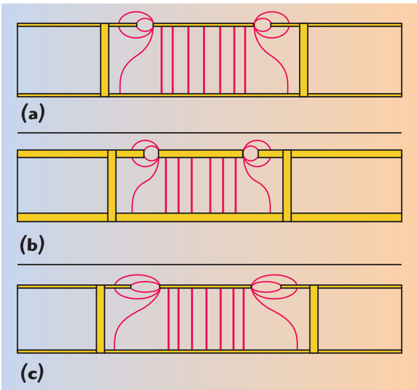
microstrip transmission-line circuits are less likely to have performance affected by PCB fabrication tolerances at mmWave frequencies than GCPW circuits. Fabrication tolerance issues can also be a function of frequency. Transmission lines used for 60 GHz communications backhaul can be affected less by fabrication tolerances than transmission-lines for automotive radar at 77 GHz (with their finer dimensions at higher frequencies).

EFFECTIVE DIELECTRIC CONSTANT

The comparison is not so much related to the frequency difference of these applications but to a critical circuit property that will change from circuit-to-circuit due to PCB fabrication effects. One circuit property that is prone to change more for a GCPW circuit than for microstrip, due to PCB fabrication effects, is the effective dielectric constant. This is the dielectric constant exhibited by an electromagnetic (EM) wave on the transmission-line due to the EM fields propagating through a combination of the dielectric substrate material (with a dielectric constant of greater than 1) and the air around it (with a dielectric constant of 1). Variations in the effective dielectric constant will affect signal phase through the circuit, causing phase variations. For the transmission-line used for 60 GHz backhaul, variations in phase are important but not as critical as for 77 GHz automotive radar. This may be one reason why 77 GHz automotive radar applications typically use microstrip structures.

One PCB fabrication parameter that causes circuit-to-circuit variation of effective dielectric constant and changes in the phase response is from the variation of copper plating thickness. When a PCB employs plated-through holes (PTH), e.g., for ground connections, the holes are drilled from top to bottom through the PCB. The holes are plated with conductive copper, resulting in lot-to-lot and even circuit-to-circuit copper plating thickness variations. The thickness variations have minimal impact on the effective dielectric constant of microstrip transmission lines. However, since GCPW transmission-line circuits have coupled features, plating thickness variation can cause significant variation in the coupled energy.[1] When considering the electric fields between the coplanar layer of a GCPW circuit, the amount of electric field energy between adjacent ground and signal conductors on the coplanar layer will be less with thinner copper and exhibit greater field intensity with thicker copper. Essentially, coupled conductor sidewalls are taller for thicker copper and shorter for thinner copper. Additionally, a small (tightly coupled) space between the adjacent ground conductor and the signal conductor will result in higher electric field intensity in the coupled area, with less coupled energy in loosely coupled areas (i.e., with wide spacing between conductors), as depicted in ***Figure 2***.

A simple study was performed using 10 mil thick (25.4 mm) Rogers RO4835™ laminate with microstrip and GCPW transmission-line circuits purposely fabricated with varying copper plating thickness. The GCPW circuits were tightly and loosely coupled, with thin and thick copper. The circuits were made on the same sheet of circuit material, cut in half with one half of the sheet containing thin plated circuits and the other half containing thick copper circuits. Evaluating circuits made from the same sheet of laminate helps minimize circuit material variables. The total copper thickness of the circuits, which included the base copper thickness of the laminate and the plated copper thickness from the fabricator, was 1 mil for thin



▲ *Fig. 2 GCPW E field intensity with a small space (tightly coupled) between the adjacent ground and signal with thin copper (a) tightly coupled with thick copper (b) and loosely coupled with thin copper, which will have the least E field coupling (c).*

copper circuits and 4.1 mils for thick copper circuits.

Figures 3a and ***b*** show a cross-sectional view of tightly coupled circuits with thin and thick copper plating respectively. The sidewalls of the adjacent coplanar ground-signal conductors will have more electric field intensity for a circuit with the thicker copper. The impact of air on the effective dielectric constant will be more significant on the circuit with thick copper plating, resulting in a lower effective dielectric constant, than on the circuit with thin copper plating. For loosely coupled circuits, the circuit experiencing the least impact on effective dielectric constant due to air will be the loosely coupled circuit with thin copper.

Wideband measurements were made on these fabricated circuits from 10 MHz to 110 GHz using a Keysight N5251A mmWave vector network analyzer (VNA). The effective dielectric constant was calculated using the differential phase length method.[2] The trends for the different circuits remain stable but did vary where return loss was better or worse. ***Figure 4*** shows the performance of the four circuit groups in the range of mmWave frequencies where all circuits had good return loss. The legend for Figure 4 denotes the nominal conductor width (w) and the adjacent coplanar space (s) of the design. For example, the tightly coupled GCPW with thick copper is noted as “w18s6 thick cu.” It has a conductor width of 18 mils and spacing of 6 mils. Of the four circuit groups, the w18s6 circuit should have the greatest electric field intensity in the coupled area, since it is tightly coupled and uses thick copper. This was verified for the circuits with the lowest effective dielectric constant. Since air has a dielectric constant of approximately 1, the more air used for electric field propagation in

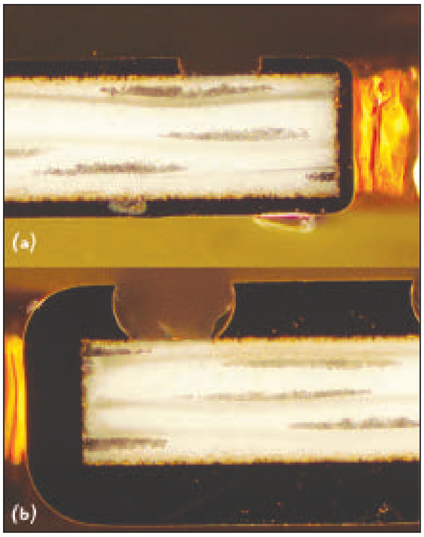


Fig. 3 Tightly coupled GCPW circuits with purposely thin (a) and thick (b) copper plating, using 10-mil thick Rogers RO4835 laminate.

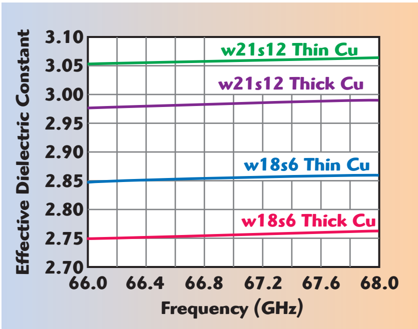


Fig. 4 Effective dielectric constant vs. frequency for four groups of GCPW with tight coupling (s6), loose coupling (s12) and thin and thick copper.

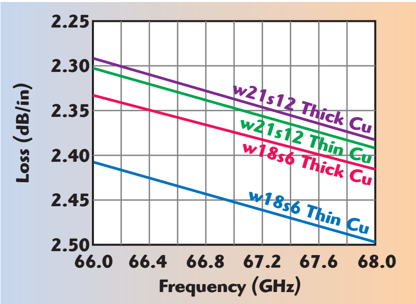
the GCPW circuit coupling, the lower the effective dielectric constant will be. In contrast, for the loosely coupled circuits with thin copper, the "w21s12 thin cu" circuit should have the lowest electric field intensity and the highest effective dielectric constant.

The microstrip circuits included in this study were not plotted in Figure 4, but those circuits showed a difference in effective dielectric constant of about 0.011 at 67 GHz for circuits with thin and thick copper. In comparison, for the tightly coupled GCPW circuits with thin and thick copper, the difference in effective dielectric constant was approximately 0.100. The loosely coupled GCPW circuits with thin and thick copper had a difference in effective dielectric constant of 0.075. Figure 4 shows that copper plating thickness variations that are part of PCB fabrication are more significant for tightly coupled circuits than for loosely coupled circuits and much less significant for microstrip transmission line circuits than for GCPW circuits.

The effects of copper plating thickness variation on effective dielectric constant will also apply to the phase response of a circuit. The resulting phase variations can be tolerated for some circuits, but not for others.

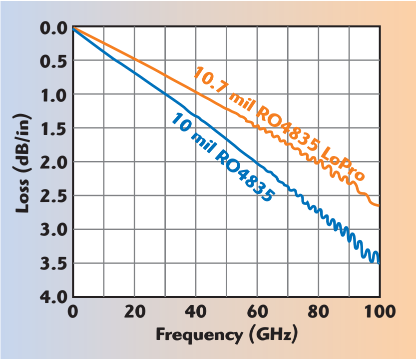
INSERTION LOSS

Insertion loss is another concern in addition to phase and effective dielectric constant variation due to copper plating thickness. As air is the lowest loss propagation medium, a circuit that uses air more effectively for propagation will suffer less loss than a circuit which propagates energy through circuit materials. ***Figure 5*** compares the insertion losses of the four GCPW circuits. The circuit with the highest loss is the "w18s6 thin cu" circuit, which has the narrowest conductor (18 mils wide) and the least propagation through air, due to its thin copper plating. The circuit with the least amount of loss is the "w21s12 thick cu" circuit, with a wider conductor, achieving lower conductor loss, and thick copper, which has greater propagation through air.

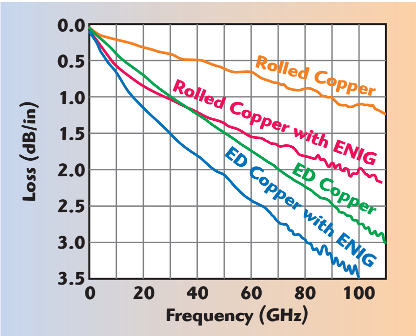


▲ *Fig. 5 GCPW circuit insertion loss vs. coupling and copper thickness.*

Copper surface roughness impacts insertion loss and phase propagation.[3] The copper surface of interest is the copper-substrate interface between the laminate copper and substrate. A smoother copper surface exhibits less conductor loss, resulting in lower circuit insertion loss for that material. Many mmWave applications are sensitive to insertion loss, and the previous information using 10 mil thick RO4835 circuit material is based on a circuit laminate with a relatively rough copper surface (although it is also available with smoother copper). The copper surface roughness for standard 10 mil thick RO4835 laminate is ap-



▲ *Fig. 6 Insertion loss vs. copper surface roughness, comparing Rogers RO4835 laminate and a similar laminate with smoother copper (LoPro).*



▲ *Fig. 7 Insertion loss vs. roughness using 5 mil thick RO3003 laminate and showing the impact of ENIG.*

proximately 2.8 µm root mean square (RMS), and that RMS roughness measurement is the same as the parameter that copper suppliers refer to as R_q. The 10.7 mil thick RO4835 LoPro® laminate uses the same substrate as standard RO4835 laminate, although with a much smoother copper surface of approximately 0.8 µm RMS. ***Figure 6*** shows differences in insertion loss from copper surface roughness. The circuits using RO4835 LoPro with smoother copper have lower insertion loss than those with rougher copper. The ripple in the insertion loss response is partly due to imperfect signal launch and spurious wave mode interference.

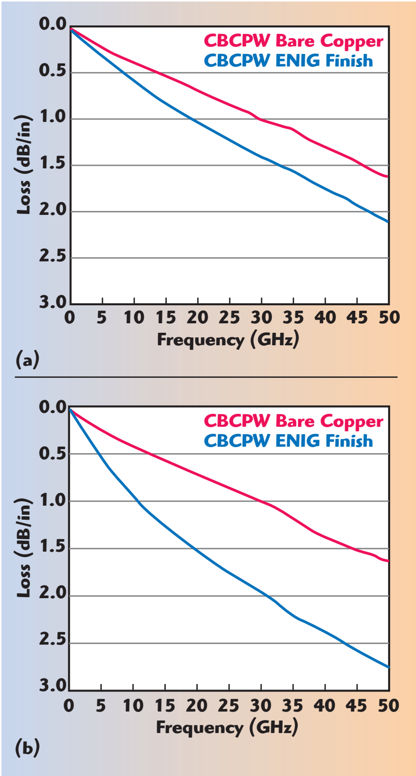
Suppression of spurious wave mode propagation is one reason why circuit designers use thinner substrates at higher frequencies. Thinner laminates are also beneficial for minimizing radiation losses, although the tradeoff is an overall increase in insertion loss. Thinner laminates tend to be dominated by conductor losses, so decreasing the copper surface roughness on a thin circuit laminate can provide much greater benefits in lowering insertion loss than decreasing copper surface roughness on a thicker laminate. A high frequency circuit material commonly used at 77 GHz is 5 mil thick Rogers RO3003™ laminate. The thin circuit material suffers less radiation loss than thicker materials, with better spurious mode suppression and easier signal launch optimization. However, it is more sensitive to conductor effects, such as copper surface roughness and plated finish losses.

The previous discussion is based on circuits with bare copper, but real world circuits usually incorporate a plated finish. When a plated finish is added to copper, it typically increases the copper conductor loss and ultimately the insertion loss. The increased conductor loss depends on substrate thickness: thinner circuits are dominated by conductor effects.

Figure 7 shows a combination of information for thin circuits at millimeter wave frequencies. The differences in copper surface roughness are 1.8 µm RMS for the circuits with electrodeposited (ED) copper and 0.3 µm RMS for the rolled copper. The differences in insertion loss are apparent for the two different copper types. The use of a finish will also affect insertion loss. With an electroless nickel/immersion gold (ENIG) finish, nickel has one-third the conductivity of copper, which increases conductor loss. Since the circuit is relatively thin, the increased loss due to ENIG is more significant than if the circuit were thicker. An ENIG finish increases conductor loss for microstrip because of the high current density at the edges of the conductor. With a GCPW circuit, the coupled fields actually use four layers of ENIG finish; because of these added layers, the insertion loss is more dramatically increased than for a microstrip circuit. ***Figure 8*** shows a comparison of microstrip and GCPW and the differences between bare copper and ENIG. GCPW suffers a much greater increase in insertion loss due to an ENIG finish than microstrip. The loss plots in Figure 8 represent 50 ohm transmission-line circuits; the GCPW circuits are tightly coupled. For a GCPW transmission line that was loosely coupled, the impact of ENIG is reduced, with less current density in the coupled area.

CONCLUSION

At mmWave frequencies, some standard circuit fabrication variables can affect the performance of certain circuit configurations more or less than others. For example, copper thickness variations can affect the performance of GCPW transmission-line circuits. Designers working with small coupled areas, such as GCPW launch or gap coupling, will also be influenced by this variable. Also, circuit substrate thickness can impact wideband insertion loss, as well as the copper surface roughness and the plated conductor finish used on a PCB. For optimum mmWave circuit performance, understanding these variables and how they affect circuit performance will benefit mmWave circuit designers. ■



▲ *Fig. 8 The effect of ENIG on insertion loss of microstrip (a) and GCPW (b) circuits using 8 mil thick RO4003C™ laminate.*

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Diminutive Duplexers: Big Rejection For Small Cells

CTS Corp.
Elkhart, Ind.

The latest generation of wireless picocells and chipsets impose challenging demands on duplexers. These cellular systems must increasingly support multiple band colocation, carrier aggregation, higher-order modulation, linearized power amplifiers or a combination of these requirements. The components used in these newer systems must achieve higher receive band rejection, extensive out-of-band rejection, higher peak power handling and improved reliability, with projected operating lifetimes increasing.

BETTER THAN SAW, BAW AND FBAR

The filtering requirements for these systems can no longer be fully satisfied by surface-acoustic-wave (SAW), bulk-acoustic-wave (BAW), or film-bulk-acoustic-resonator (FBAR) filters, which typically have operating lifetimes of less than eight years and out-of-band rejection of less than 58 dB. These filters have peak-power-handling of +31.5 to +33 dBm (2 W) – at most +36 dBm (4 W). This is not sufficient for wireless systems operating at peak power levels of +37 to +38 dBm, due to the higher-order modulation used in LTE-Advanced cellular systems.

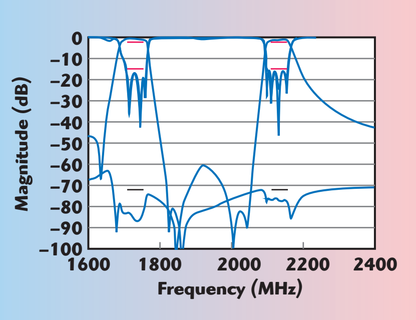
To address these challenges, CTS Corp. has developed three new families of ceramic surface-mount duplexers, offering three different tiers of performance and power handling: the UPD, USD and UMD duplexer families. Each family supports all the major frequency-division duplex (FDD) bands, from 698 MHz (band 12) to 2690 MHz (band 7). The filters have a universal footprint that enables a platform solution, using only a single printed circuit board (PCB) design and circuit layout.

The UPD family delivers more than 61 dB receive band rejection with less than 3 dB passband insertion loss (5 MHz average). This duplexer family handles average input power to 1.5 W and peak input power to 15 W. These duplexers are designed for multiple band picocells using linearized amplifiers, with 0.25 W typical at the picocell antenna.

The USD family of duplexers provides more than 71 dB receive band rejection with less than 2.6 dB insertion loss (5 MHz average). The USD family handles average input power to 6 W and peak input power to 60 W. These duplexers are well suited for power levels of 1 to 2.5 W at the antenna in outdoor small cells, indoor whole-band DAS or carrier-aggregation systems.

The UMD family of duplexers offers more than 80 dB receive band rejection with less than 2.2 dB insertion loss (5 MHz average). These duplexers handle 20 W average input power, 200 W peak. They are designed to support systems with 4 to 10 W power at the antenna, including outdoor metrocells, lower power indoor whole-band DAS or carrier-aggregation systems.

As examples, for a picocell using LTE Band

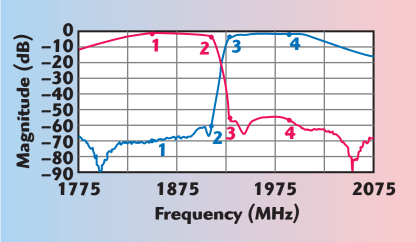


▲ *Fig. 1 The USD004A duplexer has low insertion loss in the receive band from 1710 to 1755 MHz and the transmit band from 2110 and 2155 MHz, with high rejection outside each passband.*

4, the model UPD004A duplexer covers the 1710 to 1755 MHz receive and 2110 to 2155 MHz transmit bands. Typical receive insertion loss is better than 1.2 dB over the full operating temperature range of -40° to +85°C; the transmit band insertion loss is also 1.2 dB or better. Rejection and isolation are greater than 63 dB over all operating conditions. The model UPD004A duplexer measures just 44.2 × 11.9 × 6.5 mm, including the shield. For the same LTE Band 4, the model USD004A is about 50 percent longer and taller than the model UPD004A, measuring 61.4 × 11.0 × 10.9 mm including the shield. This unit provides more than 72 dB isolation and rejection across the full set of operating conditions and supports the higher power levels necessary for applications with as much as 2.5 W at the antenna (see ***Figure 1***). The unit weighs 14.1 g. For more demanding LTE Band 2 coverage, the UPD002A duplexer operates at the 1850 to 1910 MHz receive and 1930 to 1990 MHz transmit bands. It achieves receive-band attenuation of more than 60 dB with insertion loss held to 3 dB (see ***Figure 2***). The duplexer measures 44.2 × 11.3 × 6.5 mm, including the shield.

COMPETITIVE WITH AIR CAVITY

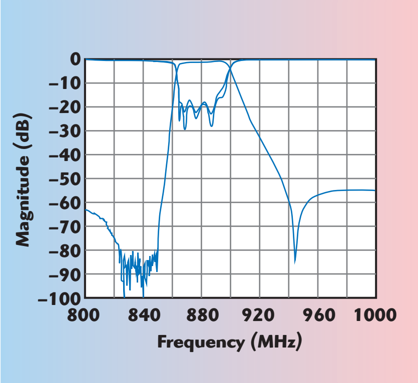
For applications requiring higher power-handling, such as outdoor metro cells delivering 5 W power at each antenna, these ceramic surface-mount filters can fill the roles once held by much larger and costlier air cavity duplexers. In Band 5, for example, the model UMD005A is a compact duplexer formed of a pair of bandpass filters, models UMBL05A and UMBH05A. The UMBL05A has a passband



▲ *Fig. 2 The UPD002A duplexer has low insertion loss from 1850 to 1910 MHz and 1930 to 1990 MHz with high rejection outside each passband.*

of 824 to 849 MHz with better than 2 dB passband insertion loss over -40° to +85°C. It measures only 56 × 15.8 × 14.5 mm, including shield. The other bandpass filter, model UMBH05A, has a passband from 869 to 894 MHz and better than 2 dB typical insertion loss across the same temperature range. It provides signal attenuation of 80 dB from 824 to 849 MHz (see ***Figure 3***) and measures 56 × 15 × 14.5 mm (including shield). Both bandpass filters handle 20 W average and 200 W peak power.

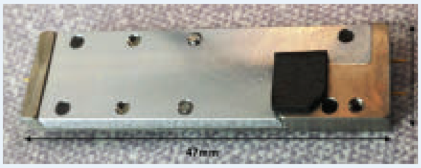
The UPD, USD and UMD duplexer families are designed and constructed to deliver their rated performance



▲ *Fig. 3 The UMBH05A bandpass filter has low insertion loss in the 869 to 894 MHz band, with high rejection from 824 to 849 MHz.*

across wide temperature ranges and long operating lifetimes, essentially for carrier-grade wireless infrastructure applications. In addition to saving space on PCBs, all of these filters are RoHS compliant. The technology can also be tailored to other market requirements and applications.

CTS Corp.
Elkhart, Ind.
www.ctscorp.com
RfFilters@ctscorp.com



2 to 20 GHz Broadband Splitter

Recent advances in high frequency sampling technologies have opened up a new range of solutions for traditional wideband receiver components, such as for ELINT applications. The capability to capture an RF signal's frequency and amplitude characteristics without employing traditional conversion techniques has led to simpler and lower cost receiver architectures, enabling more receivers per system and cross correlation between the outputs of those receivers. However, the receiver chipsets need to be driven by a balanced differential signal. This splitter can be a relatively large, costly component not supplied in a packaging solution suitable to be dropped into a stripline RF structure.

To address this issue, Linwave has developed a proprietary technology allowing wideband splitting of the input signal in a surface-mount package. The LW12-700176 splitter was originally developed as a sub-component for one of the company's multi-function microwave components. Due to its extreme decrease in physical size compared to other commercial off-the-shelf offerings – it is claimed to be over 90 percent smaller – and is now offered as a separate product.

The LW12-700176 provides two 180 degree balanced outputs with excellent phase and amplitude match from 2 to 20 GHz. Offered in a 47 × 12 mm drop-in package for easy interfacing; it is mechanically robust and has a wide operating temperature range.

Next-generation variants are now being developed to increase the upper frequency limit and provide multiple outputs, with hermetic packaging, connectorized and high power versions.

Linwave Technology Ltd.
Lincoln, UK
www.linwave.co.uk

Multifunction, COTS Programmable Test System Simplifies Testing

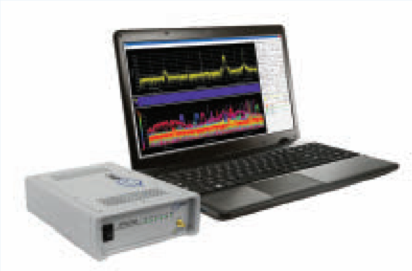
The RADX® LibertyGT® 1211B is a multifunction, programmable, software defined synthetic instrument (SDSI) that supports a broad range of real-time RF and microwave test and measurement applications from 100 kHz to 6 GHz. An "in-the-box" upgrade allows the measurement frequency range to be extended to 26.5 GHz. With a modular architecture, open-source programmability and intuitive touch screen interface, one bench-top LGT1211B can replace over a dozen "boxed" test and measurement instruments and components. Accordingly, the SDSI significantly reduces test system size, weight and power and total cost of ownership, while dramatically improving measurement throughput. The commercial off-the-shelf unit sets a new standard of value for R&D, repair depot and production test. The LGT1211B supports the testing needs for commercial and military radios, avionics, wireless communications, radar and other RF and microwave systems.

A fully configured LGT1211B provides the following test capabilities:

- Real-time vector signal generator (VSG), vector signal analyzer (VSA) and spectrum analyzer
- Two-channel digital storage oscilloscope (DSO)
- Bit error rate (BER) tester
- RF digitizer
- RF power meter
- Frequency counter and error meter
- Digital multi-meter (DMM)
- Two-channel real-time audio analyzer (SINAD, THD, AF Gen)
- Integrated radio tester (RF receiver, RF signal generator, modulator and demodulator and low frequency functions)

The LGT1211B features tightly integrated RADX real-time measurement science that includes patented synthetic instrumentation technology exclusively licensed by BAE Systems to RADX. The unit allows in-station calibration and alignment and has an API that is compatible with Python, LabVIEW, TestStand, C, C++, C# and Java.

RADX Technologies
Palo Alto, Calif.
www.radxtech.com/lgt1211b



PC-Controlled, Real-Time Spectrum Analyzer Family

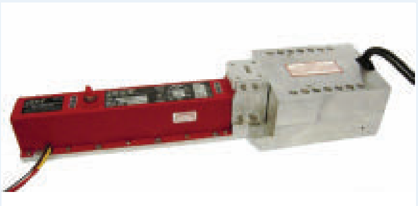
Berkeley Nucleonics offers a family of PC-controlled real-time spectrum analyzers (RTSA), with three frequency range options: 100 kHz to 8, 18 and 27 GHz. The BNC RTSA7500 has real-time bandwidth to 100 MHz, a probability of intercept as short as 1.02 µs and spurious free dynamic range up to 100 dBc. The elements of the RTSA7500 consist of the instrument, comprised of a software-defined radio receiver and a wideband digitizer, and the RTSA software that runs on a Windows 7 or 8 PC.

The RTSA7500 can be used anywhere in the wireless ecosystem, including R&D, education, manufacturing, deployment and monitoring. Anyone dealing with signals that may vary dynamically in amplitude or frequency can increase productivity with a real-time spectrum analyzer. Examples include fast intermittent, pulsed and frequency-hopping signals, signals hidden underneath signals and multi-signal environments that share the same spectrum in the license-free bands.

The BNC RTSA7500 solution provides the following real-time capabilities: spectrum graph, spectrogram view, power spectral density display (persistence), triggering, I/Q plots, and recording and playback. Users can choose between standard swept-tuned spectrum analysis and real-time spectrum analysis with 10, 40 or 100 MHz of real-time bandwidth. Users can also select the high dynamic range mode featuring 100 dBc of dynamic range for making critical IP3 measurements.

BNC utilizes industry-leading APIs and open-source code for easy customization and remote control. Python™, LabVIEW, MATLAB® and C/C++ programming languages are supported. Standard protocols and file formats include SCPI, VRT and CSV and GigE Ethernet for networking. With record and playback files, deeper analysis can be conducted on any PC or multiple PCs running the RTSA7500 RTSA software without the instrument being connected.

Berkeley Nucleonics
San Rafael, Calif.
www.berkeleynucleonics.com



High Power TWT Boosts Performance for DBS Market

A new high efficiency traveling wave tube (TWT) from CPI Microwave's Power Products division (CPI MPP) boosts power and efficiency in the DBS uplink band, which spans 17.3 to 18.4 GHz. The VTU-6398D9C provides 1250 watts peak (625 watts average) output power in a conduction-cooled amplifier measuring 16" × 2.8" × 4" and weighing just 9.7 lbs. Maximum prime power is 2500 watts. The unit has a coaxial input and waveguide output and focus electrode (FE) control line for turn on. The typical helix voltage is 15 kV, filament voltage is 6.3 V and filament current 1.4 A. Collector voltage 1 is typically 52 percent, and collector voltage 2 is 13 percent.

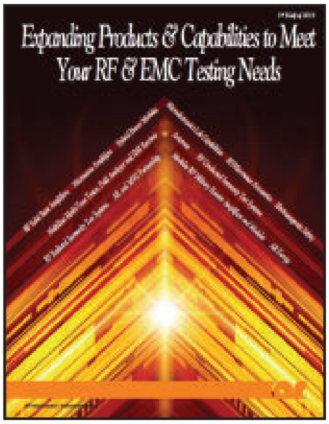
This VTU-6398D9C addresses the demand for higher power helix TWTs for the DBS uplink. The VTU-6398D9C can be customized to address unique requirements, including the mechanical configuration, electrical and RF connections, and dual-stage depressed collector.

CPI MPP has been a leader in vacuum electron device technology for over 50 years and is known for engineering expertise, reliable products and performance.

Communications & Power Industries LLC
Microwave Power Products Division
Palo Alto, Calif.
www.cpii.com/mpp

EMC & RF Testing Product Catalog

VENDORVIEW



A brand new edition (1st half of 2015) of AR's complete full line product catalog is now available. "Expanding Products & Capabilities to Meet Your RF and EMC Testing Needs," features new products, including their new line of electromagnetic safety products, refreshed page layouts, details on the company's new partnership with MVG and more. Please contact your local AR sales associate for a hard copy or visit AR's website at www.arworld.us/html/catalogRequest.asp for a free download, in full or by section.

AR RF/Microwave Instrumentation

www.arworld.us

Ku-Band Iso-Divider Family

VENDORVIEW

Crane's Microwave Solutions released the Ku-Band Iso-Divider product family brochure, featuring the integration of high performance power dividers (or combiners) with ferrite isolators into a single package, which provides enhanced product reliability due to fewer external components, interconnects and transitions. These 2-way, 4-way and 8-way units offer exceptional insertion loss and band flatness performance. Small size, low weight and high reliability are crucial features for passive space redundancy in both receive and transmit applications.

Crane Aerospace & Electronics

www.craneae.com/isodivider

MECA Issue 10 & mmWave Supplement

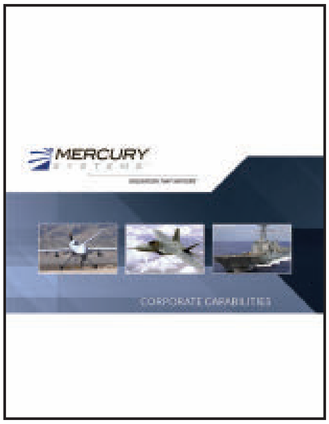
VENDORVIEW

MECA's latest publications include their new catalog (Issue 10) and mmWave supplement (Issue 1), featuring their low PIM & DAS equipment and components from 20 MHz to 40 GHz. Since 1961 MECA Electronics (Microwave Equipment & Components of America) has served the RF/microwave industry with equipment and passive components covering Hz to 40 GHz. MECA is a privately-held ISO9001:2008 Certified, global designer and manufacturer for the communications industry with products manufactured in the U.S. and 36-month warranty.

MECA Electronics Inc.

www.e-MECA.com

Corporate Capabilities



Mercury Systems is the better alternative for affordable, secure sensor processing subsystems designed and made in the U.S. Their robust, open standards solutions and program management teams are the gateway to best-of-breed solutions. The company's Advanced Microelectronics Centers enable them to produce integral, highly-repeatable devices, and their scalability seamlessly supports production from prototype to full rate; delivering modular open systems architectures that combine digital, RF and microwave technologies. Producing sophisticated solutions while optimizing affordability and accelerating time to market.

Mercury Systems Inc.

www.mrcy.com

Test Solutions Product Guide

VENDORVIEW

The Test Solutions Product Guide is an 88-page, full color publication featuring detailed information about Mini-Circuits' innovative line of RF test and measurement solutions including custom rack-mounted systems, user-defined modular racks and portable test devices. Comprising functionality ranging from signal source to amplification, routing, attenuation, distribution, signal measurement and more, Mini-Circuits' test solutions have significantly lowered costs and improved test efficiency for customers working in many applications from R&D to high-throughput automated test equipment.

Mini-Circuits

www.minicircuits.com

Air Traffic Control Rotary Joints

VENDORVIEW

The new second edition of SPINNER's Air Traffic Control Rotary Joints catalogue covers all rotary joints for civil and military ATC radars. This edition reflects the latest developments for this demanding market with high reliability. Starting from 3 channels up to 9 channels, S and L-Band solutions are available from Europe's leading system house of rotary joints. Customized solutions used for ATC Radar applications can be made available on short notice.

SPINNER GmbH

www.spinner-group.com

Components

NANO Series Wi-Fi Diplexer

VENDORVIEW

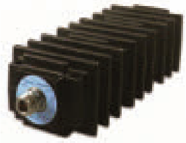
3H Communication Systems' new NANO series switch filter banks offer multiple switched channels (up to 8) from 50 MHz to 18 GHz. Switched filter banks are available in leadless surface-mount or RF pins. 3H's SFBs are designed and manufactured in accordance to the customers' electrical and environmental requirements and can be used for military or commercial application. The company utilizes its micro and nano filter technology to offer the smallest possible size for its switched filter banks.

3H Communication Systems

www.3Hcommunicationsystems.com

PIM Fixed Attenuators and Terminations

VENDORVIEW



Cobham Weinschel's low PIM products offer a rugged construction low profile design free of solder joints that covers DC to 6.5 GHz, with power handling up to 175 W average and IM3 levels as low as -150 dBc output and -120 dBc reflected dependent on dB value. Model 254 is available in 10, 20, 30 and 40 dB. Other features include quality connectors with special high temperature support beads and choice of Type N or SMK (2.92 mm).

Cobham Weinschel

www.ams.aeroflex.com/weinschel

Space Qualified Isolator

VENDORVIEW

DiTom Microwave released a new Ku-Band (10.70 to 12.75 GHz) space qualified isolator. The DS1009 is manufactured to meet or exceed environmental space-level reliability including thermal shock, sine and random vibration, temperature cycling and thermal vacuum survivability over a specified qualification and acceptance test plan. The company's current space level manufacturing process allows for delivery in as quickly as 4 weeks depending on the test requirements.

DiTom Microwave

www.ditom.com

Space Switch Matrix Assembly

Ducommun Inc.'s space switch matrix assembly 4 × 4 features pulse latching, suppression diodes (S Level), mechanical telemetry circuitry, vented holes, D-sub connectors and mounting brackets. Its size is 4.6 × 3.73 × 3. The weight is 725 grams (approximately) and the operating frequency is DC to 8 GHz. Ducommun Inc. RF product design engineers can create custom versions for your specific applications. Contact (310) 513-7256 for more information.

Ducommun Inc.

www.ducommun.com

Electromechanical Relay Switches

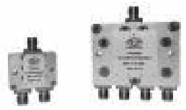
Fairview Microwave Inc. debuted a completely new portfolio of electromechanical relay switches that cover ultra-broadband and millimeter wave frequencies up to 40 GHz. These high-reliability RF switches are guaranteed to perform up to 2 to 10 million life cycles, which make them an ideal solution for demanding industries and applications related to defense and commercial aviation, radar, wireless communications, satellite communications, and test & measurement.

Fairview Microwave Inc.

www.fairviewmicrowave.com

Microwave/Millimeter Wave Power Dividers

VENDORVIEW

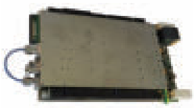


2 and 4-way, 30 W Wilkinson power divides are optimized for excellent performance across all microwave and millimeter wave bands from 6 to 26.50 GHz in (SMA). Also, resistive 2-way splitters covering DC to 26.5 GHz (2.92 mm) are available. Also available are attenuators, isolators, terminations and couplers. Their rugged construction makes them ideal for telecommunications, aerospace and test equipment systems. Made in the USA – 36 month warranty.

MECA Electronics Inc.

www.e-MECA.com

Activity Detector in a VPX Chassis



Norden Millimeter has designed and manufactured a channelized activity detector for EW, SIGINT, COMINT and ELINT applications. The Activity Detector operates in the 6 to 18 GHz frequency range and has 12 independent 1 GHz wide simultaneous detection channels. The channel outputs are DC voltages log linear to ±1 dB over a 60 dB dynamic range. The activity detector has the ability to process narrow pulses, with a pulse rise time of 15 nS and a 30 nS fall time.

Norden Millimeter

www.nordengroup.com

Power Divider

VENDORVIEW

For high power S-Band space qualified applications, REC has designed a 50 W 2-channel power divider that has low loss and high isolation. The design uses NASA compliant low outgassing materials with a housing/cover that can be laser welded for a truly hermetic seal.

Renaissance Electronics & Communications LLC

www.rec-usa.com

Cavity Filters

RLC Electronics has expanded its line of high frequency cavity filters with non-standard outlines/footprints. Custom requirements for package dimensions and connector orientation are often desired in system integration where space allocation and component arrangement have been pre-defined. One feature is for right angle or vertical connector launches with respect to standard filter configurations. This allows for integrated transitions without the need for external system transitions (e.g., jumper cables, microstrip) which often result in higher mismatch, potential spurious modes and additional cost.

RLC Electronics Inc.

www.rlcelectronics.com

Adjustable Low PIM Attenuator

VENDORVIEW

SPINNER's new low PIM attenuator reduces cost by ensuring much more flexibility during installation processes. The low PIM attenuator can be adjusted between 15 and 30 dB and performs with -160 dBc/-165 dBc in mobile carrier frequencies. First DAS outdoor installations have proven to save up to 90% of time during power adjustment. Site and in-building installations will be much faster and more efficient due to the flexibility provided by SPINNER's low PIM attenuator.

SPINNER

www.spinner-group.com

16-Way Combiner/Divider

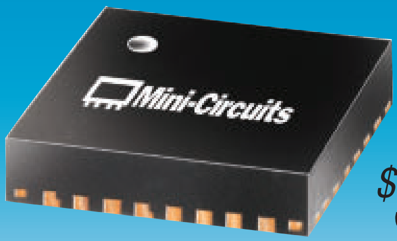
Werlatone is continuously expanding its line of high power radial combiners. Werlatone is currently adding to its S-Band products, with the Model D9706, a high power 16-way combiner, designed to cover the full 2700 to 3500 MHz bandwidth.

New!

MMIC PRODUCTS

Now Available for Immediate Shipment!

MMIC Splitter/Combiners
1.8 to 12.5 GHz

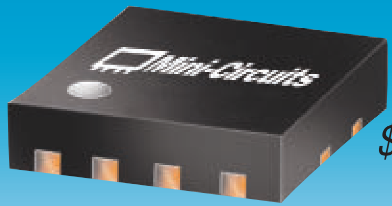


$5.56 ea. (qty.1000)

EP2C+

- ✓ 2-way 0°, 1.8 to 12.5 GHz
- ✓ 1.1 dB insertion loss
- ✓ Port-to-port isolation, 16 dB
- ✓ DC current passing up to 0.4A
- ✓ Tiny size, 4 x 4mm

MMIC Amplifiers
Noise Figure, 0.46 dB
1.1 to 4.0 GHz

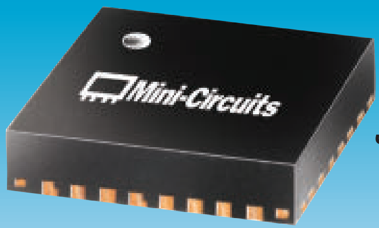


$2.76 ea. (qty. 1000)

PMA2-43LN+

- ✓ Ultra-low noise figure, 0.46 dB
- ✓ High gain, up to 23 dB
- ✓ P1dB up to +19 dBm
- ✓ High IP3, up to +33 dBm
- ✓ Low power consumption, +5V, 51mA
- ✓ Tiny size, 2 x 2mm

MMIC Mixers
2200 to 7000 MHz

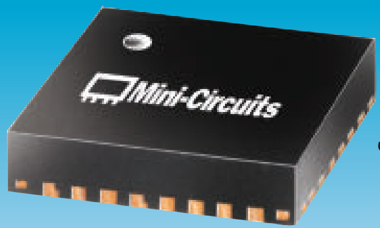


$2.74 ea. (qty. 1000)

MDB-73H+

- ✓ Low conversion loss, 8 dB
- ✓ High L-R Isolation, 39 dB
- ✓ High L-I Isolation, 46 dB
- ✓ IF bandwidth, DC to 1600 MHz
- ✓ LO power, +15 dBm
- ✓ Tiny Size, 4 x 4mm

MMIC Mixer-Amplifiers
2200 to 7500 MHz



$10.25 ea. (qty.1000)

MDA4-752H+

- ✓ Integrated mixer, LO amplifier, and IF amplifier in one package
- ✓ Conversion gain up to 9.7 dB
- ✓ High L-I Isolation, 61 dB
- ✓ Hi R-I Isolation, 51 dB
- ✓ LO power, 0 dBm
- ✓ Tiny size, 4 x 4mm

Visit minicircuits.com for detailed specs, performance data, free S-Parameters and off the shelf availability!
Place your order today for delivery as soon as tomorrow!

Mini-Circuits®

www.minicircuits.com P.O. Box 350166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

539 rev A

NewProducts

Rated at 6,000 W CW at the sum port, and 32 kW peak, the D9706 operates with less than 0.35 dB of insertion loss, and is designed to tolerate a wide range of environmental conditions.

Werlatone
www.werlatone.com

Cables & Connectors

Multi Lock Connector

Microwave cable used in connecting measurement instrument, such as vector network analyzer and DUT, is required to have phase stability against flexure and temperature change of environment. Junkosha offers the world's most phase stable cable, the MWX 0 series. The newest connector developed is called "multilock connect". It enables consistent precise coupling by either snap-on, hand screw or torque wrench.

Junkosha Inc.
www.junkosha.co.jp/english/item/cable/c001_mwx021multilock.html

Precision NMD-series Adaptors

Response Microwave Inc. announced the availability of its new series of durable between-series NMD adaptors to facilitate test applications. The new RMAD.BS.NMDxx series offers interface combinations in N18, 3.5 mm, 2.92 mm, 2.4 mm and 1.85 mm and covers the DC to 65 MHz band. The adaptors exhibit typical electrical performance of 0.20 dB insertion loss and 1.15:1 VSWR. Units are operational over the 0 to +85°C range and bodies are SUS303F stainless with gold plated BeCu center contacts. Custom combinations available upon request.

Response Microwave Inc.
www.responsemicrowave.com

Amplifiers

Single Band AR Amplifier

VENDORVIEW

Model 200S1G6 is a self-contained, air cooled, broadband, solid-state amplifier designed for applications where instantaneous bandwidth, high gain and linearity are required. The unit, when used with a sweep generator, will provide a minimum of 200 W of RF power from 0.7 to 6 GHz in a single amplifier and can be used in many RF applications such as: RF susceptibility testing, antenna/component testing and communication testing.

AR RF/Microwave Instrumentation
www.arww-rfmicro.com

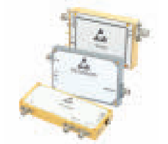
Solid-State Power Amplifier

Comtech PST released a solid-state Class "AB" linear amplifier that operates over the full 6 to 18 GHz frequency band and delivers a minimum of 50 W. The amplifier uses the latest gallium nitride (GaN) technology and is packaged in a standard rack mountable enclosure measuring 19" × 22" × 3.5".

Comtech PST
www.comtechpst.com

Log Video Amplifiers

VENDORVIEW



Pasternack introduced an all new line of broadband log video amplifiers covering multi-octave bandwidths from 0.5 to 18 GHz. The 5 models being released include 4 successive detection log video amplifiers (SDLVA), and one Detector Log Video Amplifier (DLVA), which offer a wide input dynamic range, high signal sensitivity, fast recovery times and excellent temperature stability.

Pasternack
www.pasternack.com

Portable Amplifier

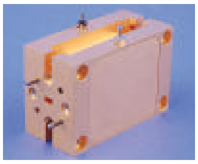
VENDORVIEW

PMI Model No. PTB-60-2040-5R0-10-115VAC-292-FF is a portable amplifier that operates over the 20 to 40 GHz frequency range.

This model provides 60 dB of typical gain with an OP1dB of +10 dBm minimum. This amplifier features an on/off switch that is located on the front panel and operates on 120 VAC.

Planar Monolithics Industries Inc.
www.pmi-rf.com

Medium Power Amplifiers



QuinStar Technology introduced series QAM, a new line of high performance broadband medium power amplifiers covering 26 to 110 GHz in full waveguide bands (Ka through W-Bands) in compact packages. With a nominal gain of 20 dB and power output ranging from 20 dBm at Ka, Q and U-Bands (altogether covering 26 to 60 GHz) to greater than 13 dBm over W-Band, these amplifiers are well suited as drivers for high power amplifiers, frequency multipliers and extenders.

QuinStar Technology
www.quinstar.com

E-Band High Power Amplifier

VENDORVIEW

Model SBP-7137632520-1212-E1 is an E-Band high power amplifier with a small signal gain of 32 dB and a P1dB of +23 dBm minimum in the frequency range of 71 to 76 GHz. The DC power requirement for the amplifier is +6 to +12

NewProducts

VDC/1,000 mA. The input and output port are inline configuration as shown in the photo with both WR-12 waveguides and UG387/U Flanges. SAGE Millimeter also offers many other low noise, ultra-broadband, power amplifiers in the frequency range of 1 to 110 GHz.

SAGE Millimeter
www.sagemillimeter.com

Semiconductors

Broadband Coaxial PIN Diode Switches

Amplical Corp. announced a new family of competitively priced high performance broadband coaxial PIN diode switches featuring low insertion loss, low VSWR, high isolation and fast switching speed. Standard configurations range from single-pole, single-throw (SPST) through single-pole, six-throw (SP6T), single-pole eight-throw (SP8T) and single-pole, twelve-throw (SP12T). All switches are available with either absorptive or reflective inputs in many broadband frequency ranges including 400 MHz to 6 GHz, 2 to 18 GHz, 500 MHz to 18 GHz and an ultra-broadband 100 MHz to 20 GHz.

Amplical Corp.
www.amplical.com

Digitally Controlled PIN Diode Attenuator

Model A0P-41N-3JJ is a digitally controlled PIN diode attenuator that operates from 2.3 to 2.5 GHz. It is capable of 19.922 dB range in monotonic 0.078 dB steps. The attenuation flatness is ±2 dB and the operating temperature range of 0 to +50°C with a coefficient of ± 0.03 dB/°C. This attenuator is available with a maximum VSWR of 1.7:1 and an insertion loss less than 2 dB. This device operates with power handling of +13 dBm CW, 1 W max.

G.T. Microwave Inc.
www.gtmicrowave.com

SPST PIN Switch Element

MPS4101-012S and MPS4102-013S are single-chip silicon monolithic series-shunt elements designed with minimal parasitic inductance to provide optimum insertion loss and isolation characteristics over the entire 50 MHz to 40 GHz frequency range. These products are ideal replacements for the conventional shunt mounted chip and series mounted beam lead PIN diode normally used in the manufacture of broadband microwave switches.

Microsemi
www.microsemi.com

Systems

Digital Receiver

The V602 digital receiver supports one or two plug-in XMC modules, each featuring 128 independent channels of DDC embedded in the Xilinx Virtex-6 FPGA. It supports capture and recording of wideband data directly from the ADCs or down-converted data from up to 256 channels modulated on the IF band. The receiver can do contiguous recording at 1600 MB/s until running out of disk space. Download data sheets and pricing now.

Innovative Integration
www.innovative-dsp.com

GaN SSPA Powers Ku-Band Block Up-Converter

VENDORVIEW

The model MFC147 from TRAK Microwave provides 13.75 to 14.5 GHz coverage for civilian and military aviation Ku-Band SATCOM applications, including In-Flight Entertainment (IFE) systems and UAV communications. The unit features a ruggedized design and innovative thermal management technique to withstand challenging airborne environments utilizing SMT construction with no open die. Input frequency to the block up-converter (BUC) is 950 to 1700 MHz, with Ku-Band output of +12 to +17 dBm.

TRAK Microwave
www.trak.com

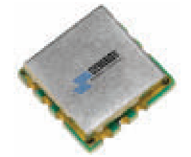
Sources

Voltage-Controlled Oscillator

Crystek's CVCO55CCQ-3500-3500 voltage-controlled oscillator operates at 3500 MHz with a control voltage range of 0.3 to 4.9 V. This VCO features a typical phase noise of -115 dBc/Hz at 10 KHz offset and has excellent linearity. Output power is typically +6 dBm. Engineered and manufactured in the USA, the model CVCO55CCQ-3500-3500 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is typically 5 V, with a typical current consumption of 27 mA.

Crystek
www.crystek.com

Miniature Footprint Fast Tuning VCO



This miniature size, fast tuning VCO model DCO5260-3 operates from 520 to 600 MHz over a 3 V tuning range with only a +3 V bias. Key features include a planar resonator construction, an output power of 0 dBm (minimum), a harmonic suppression of 10 dB (typical) and low phase noise performance of -105 dBc/Hz (typical) at 10 kHz and -125 dBc/Hz (typical) at 100 kHz offsets.

Synergy Microwave Corp.
www.synergymwave.com

Software

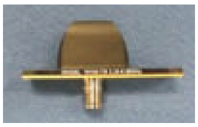
Three-Dimensional Solver

VSim is an electromagnetic, time-domain three-dimensional solver with particle and plasma simulation capabilities. VSim uses a package model to customize the powerful physics engine to meet customers' needs for electromagnetic, microwave device and plasma simulation capabilities. VSim 7 uses VMes™, a mesh generator that makes gridding up complex geometry easier and blazingly fast. VSim 7 supports STEP CAD files in addition to the STL and VTK formats. VSim 7 has improved ease of use, external circuit modeling, and new analysis and plasma modeling capabilities.

Tech-X
www.txcorp.com

Antennas

Broadband Blade Antennas



Haigh-Farr continues to expand its line of blade antennas with the introduction of its latest P/N 16100 Broadband Blade Antenna. The 16100 covers the 2.2 to 5.85 GHz frequency range and exhibits omnidirectional coverage in the azimuth plane and a filled-in null in the elevation plane. It is available in standard and metric versions with both TNC and SMA connectors.

Haigh-Farr
www.haigh-farr.com

Active Antenna

VENDORVIEW

Richardson RFPD Inc. announced the availability and full design support capabilities for a new active rugged antenna from Maxtena Inc. The M1227HCT-A2-SMA is designed for L1/L2 GPS and GLONASS bands, and specifically for applications requiring greater accuracy than L1 antennas can provide. It is built on Maxtena's Helicore® technology, which provides exceptional pattern control, polarization purity and high efficiency in a very compact form factor. The M1227HCT-A2-SMA features a screw-on design, with an integrated SMA connector.

Richardson RFPD Inc.
www.richardsonrfpd.com

Test Equipment

Vector Voltmeter Mode

VENDORVIEW

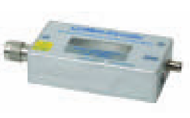
The Vector Voltmeter Mode (VVM) for its Microwave Site Master™ S820E – a handheld cable and antenna analyzer offering coverage up to 40 GHz – allows the S820E to be used as a drop-in replacement for legacy Vector Voltmeter instruments. With the ability to provide full A/B and B/A ratio capability without additional and expensive VNA options, the S820E with the VVM provides field engineers and technicians with a compact, durable, cost-efficient, single-instrument solution to make key field measurements to ensure the proper deployment, installation and maintenance of wireless networks.

Anritsu
www.anritsu.com

Integrated Frequency Counter and Power Meter

VENDORVIEW

Mini-Circuits' FCPM-6000RC integrated frequency counter and power meter is a pocket-sized (5.0" × 2.66" × 1.36") precision test device controlled via USB or Ethernet (HTTP and Telnet protocols) or operated as stand-alone test instrument. It simplifies test setups by enabling synchronized frequency and power measurements from a single device. The unit features an LCD display allowing convenient readings directly off the measurement head, while our user-friendly GUI software enables easy remote test management via USB or Ethernet.



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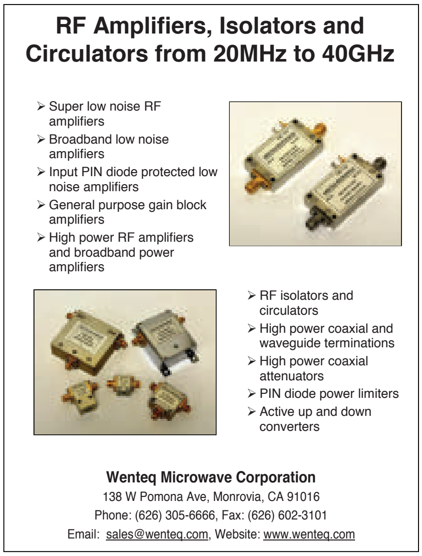
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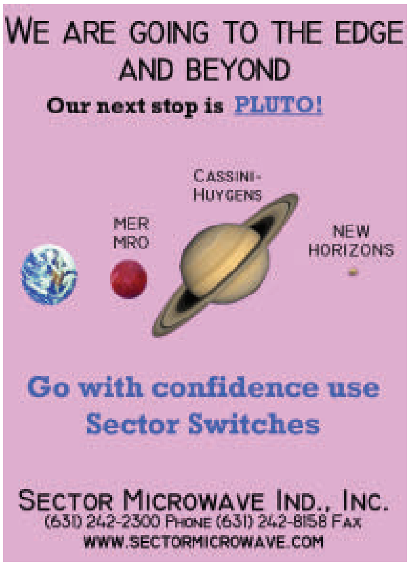
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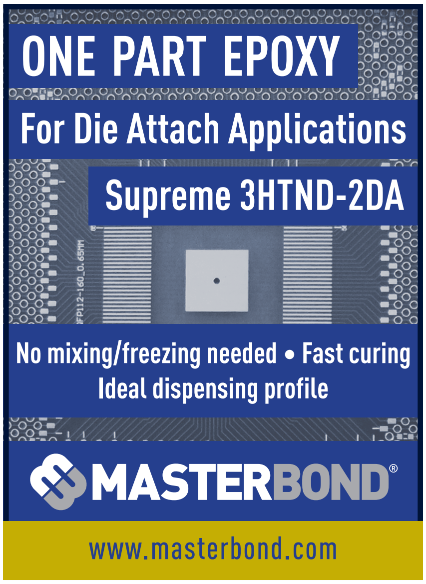
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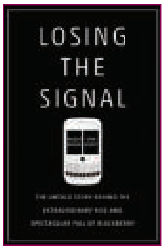
Losing the Signal:
The Untold Story Behind the Extraordinary Rise and Spectacular Fall of Blackberry



Jacquie McNish and Sean Silcoff
Reviewed by Gary Lerude

The expectation that we are always connected and always available has become so embedded in our culture that it's hard to remember when it wasn't so. The Blackberry launched this era with a handheld, oblong, black plastic case enclosing a small keyboard and screen. Using thumbs for typing – surprisingly easy to learn – email became mobile through an encrypted network established by Research in Motion (RIM), the name of the company that invented Blackberry. Corporate email often arrived faster on the Blackberry than it did on a desktop PC. Untethered from the PC, Blackberry email became addictive, spawning the nickname "Crackberry". Sitting at a conference table, hands and Blackberry in the lap, head bowed was a common scene in many corporate offices and became known as the "Blackberry prayer". A colleague said he had to leave his Blackberry outside the bedroom to preserve harmony with his wife.

RIM's success took almost 20 years after Mike Lazaridis and Doug Fregin formed the company in 1984. They were joined by Jim Balsillie, who invested and became co-CEO with Lazaridis. Balsillie led sales and marketing and Lazaridis was the technical visionary, heading product development and engineering. They were an unlikely pair, yet they perfectly complemented and respected each other – until the end.

Even while RIM was growing exponentially – Blackberry captured half the smartphone market in 2009 – the company was already unraveling. A patent infringement lawsuit, back-dated stock options, the introduction of the iPhone, the failure of the Blackberry Storm to counter the iPhone, Google's decision to license Android for free, and the deteriorating relationship between Lazaridis and Balsillie ultimately undermined the company. Fiscal 2015 revenue was $3.3 billion, compared to the peak of almost $20 billion in 2011.

"Losing the Signal" is the fascinating story of the company's dramatic rise and fall as well as the two men whose vision, persistence and single-minded devotion created the success – but failed to stem the downfall.

To order the book:

Publisher: Flatiron Books
us.macmillan.com/losingthesignal
ISBN-13: 978-1250060174
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FABS and LABS

National Research Council of Canada Offers GaN Foundry

Asked to list the world's GaN players, Canada probably wouldn't leap to mind. Yet the National Research Council of Canada (NRC) has been providing GaN foundry services for RF and microwave applications for five years, from a $150 million Canadian dollar ($121 million) wafer fab in Ottawa.

The National Research Council is the research and technology arm of the Canadian government. NRC invests in a wide range of industries important to the Canadian economy, from energy to health, to marine biology and aerospace. The mission of the 4,000 researchers and support staff of the CA$ 1 billion organization is to collaborate with industry and universities to enhance innovation and the competitiveness of Canadian industry. Nonetheless, many of NRC's projects cross Canadian borders and support international initiatives.

The National Research Council's exploration of GaN began in 1998, with material growth. The research was a partnership with Nortel, the Canadian telecommunications giant that was pursuing photonics integration. When the telecom industry imploded in the first half of the 2000s, NRC acquired Nortel's equipment and many of their staff and established the Canadian Photonics Fabrication Centre, which includes a 40,000 square-foot wafer fab with 11,000 square feet of Class 100 to 1000 clean room. GaN processes were added to the fab around 2010, and NRC began offering foundry services.

The National Research Council has released two GaN on SiC processes, with a third being developed. Design kits are offered for all three processes. The GaN wafer diameter is 3 inches, constrained by photonics processing. However, conversion to 4 inch wafers is planned in the near future. The two production processes include:

- 0.5 µm gate length, 40 V process with an ft of 13 GHz that achieves 5 W/mm power density
- 0.15 µm gate length, 30 V process with an ft of 35 GHz that achieves 7 W/mm power density.

A near enhancement mode process is being developed and is currently available as a beta release, with the full release planned for later this year. The 0.5 µm enhancement GaN HEMT presently has a threshold voltage of -0.2 V, 1 A/mm saturation current and an operating drain voltage of 30 V. The threshold voltage will be greater than zero in the full release. This process is suited for applications where only a single positive supply is available or power dissipation needs to be minimized.

Given the capacity of the fab, which runs two shifts, five days per week, NRC's foundry service is best suited for concept development and moderate production volumes. Most of their clients are working on aerospace and defense and satellite communications applications, creating MMIC designs for power or low noise amplifiers. The Canadian Space Agency has worked with NRC in the past to provide reliability qualification on an early version of the process. Qualification of the new generation of processes is in progress.

Supporting their business model to provide foundry services, NRC has a small design team that can consult with customers to refine their designs.

Jennifer Bardwell, leader of the GaN electronics program at NRC, says "We are very excited about the potential for GaN electronics, particularly about growing the ecosystem for this technology within Canada."

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Model QH10089

90° Hybrid Coupler

Excellent Amplitude Balance

This High Power 90° Hybrid Coupler covers the **full 800 - 2800 MHz bandwidth,** at 200 W CW. Incurring just 0.35 dB of insertion loss, while providing a minimum of 20 dB isolation, this compact, surface mount design, measures just 1.25 x 0.55 x 0.08". The QH10089 is ideal for extreme military or commercial environmental conditions.

Model D10262

2-Way 0° Combiner

Tolerates a Full Input Failure

The D10262 is a 2-Way Combiner rated at 600 W CW, and operates with full port - to port isolation of 17 dB minimum. This high power combiner is **designed to handle an input failure,** at rated power, while operating at a +70°C baseplate temperature. Ideal for coherent and non-coherent combining, the D10262 is suitable for multiple military applications.

Model H10125

180° Hybrid Combiner

SMT 180° Hybrid

Our newest 180° Hybrid Combiner / Divider **delivers best-in-class amplitude balance,** typically ± 0.2 dB, and operates with a maximum insertion loss of 0.5 dB. Supplied as a surface mount, stripline design, the H10125 is rated at 350 W CW, offers excellent phase tracking, and 30 dB typical port - to - port isolation.

Model D10118

4-Way Radial Combiner

Power Rating of 1,500 W CW

The D10118 is the newest addition to our full line of **Radial Combiners & Dividers.** Ideal for Radar, EW, and Telecom systems, this 4-Way design is rated at 1500 W CW, and combines or divides a single stage through a radial transmission line structure. The D10118 generates low loss and requires minimal heat dissipation.

Model D9623

4-Way 0° Combiner

Designed for MIL-STD-810

Werlatone provides several combiner designs, for high power applications, where the customer determines that port-to - port isolation is not required, or when an isolated design incurs too much loss. The compact and robust Model D9623, is a 4-Way Combiner, covers the full 1 - 3 GHz bandwidth, and is **rated at 500 W CW.**

Model H10253

180° Hybrid Combiner

Connectorized 180° Hybrid

The Model H10253 is the connectorized version of Model H10125. Rated at 350 W CW, and measuring just 2.31 x 1.21 x 0.25", this high power hybrid operates with **20 dB port - to - port isolation**, an amplitude balance of ± 0.2 dB maximum. Supplied with all N Female connectors, the H10253 is robust & compact.

Werlatone, Inc. 17 Jon Barrett Road Patterson, NY 12563 (845) 278-2220 www.werlatone.com sales@werlatone.com