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DESIGN SOFTWARE INTEROPERABILITY

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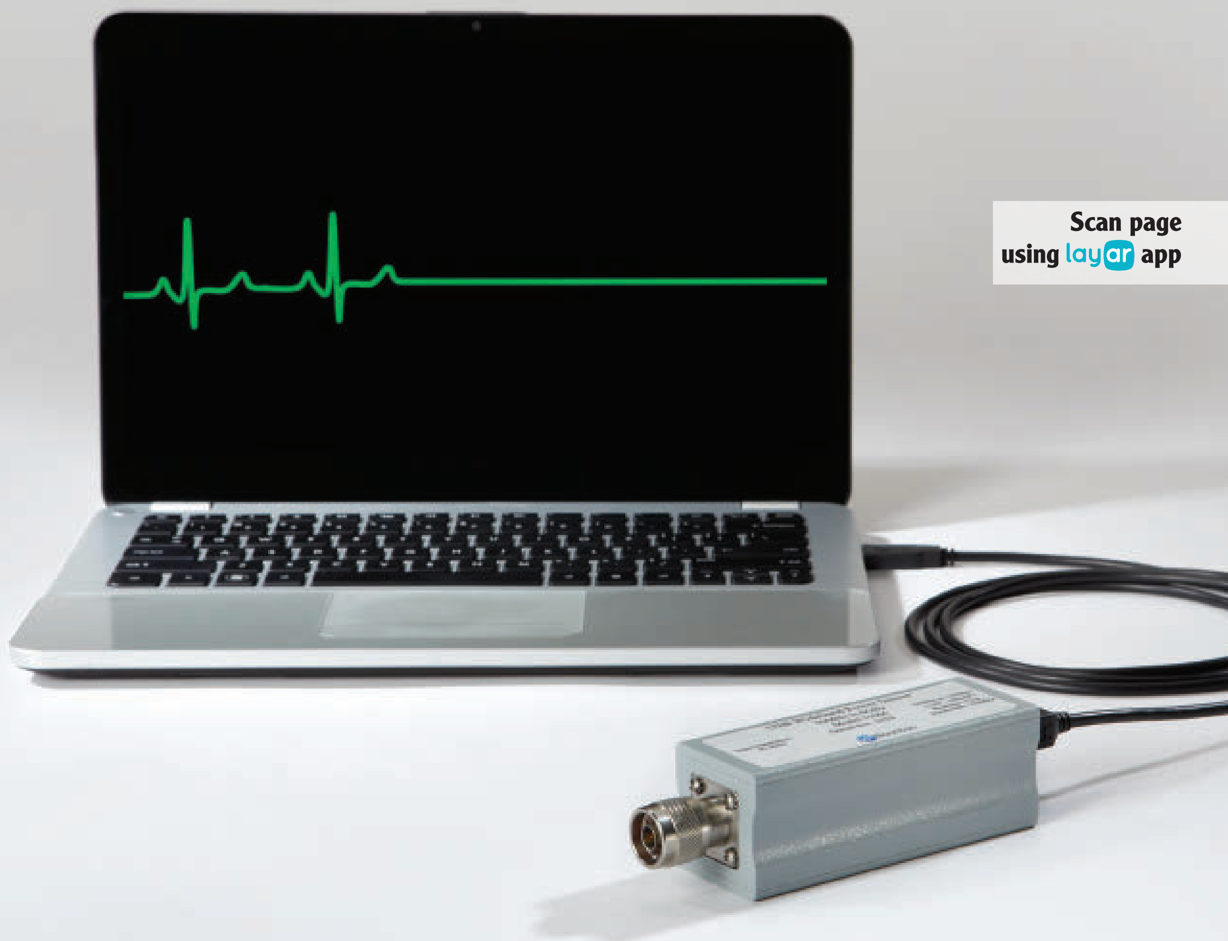

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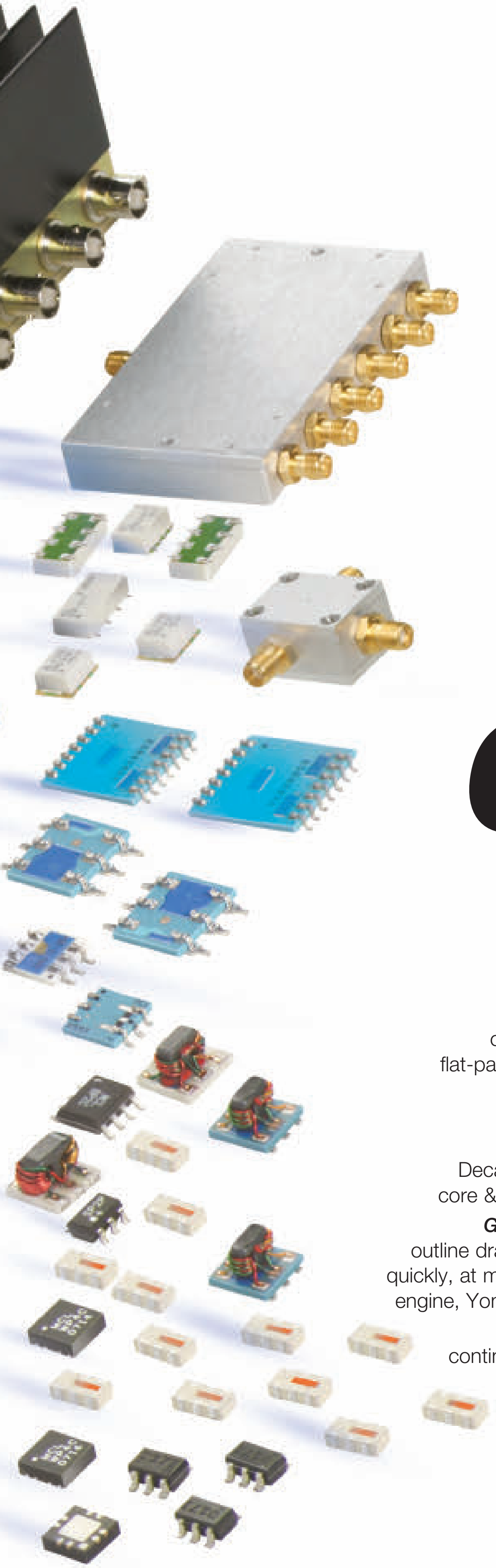

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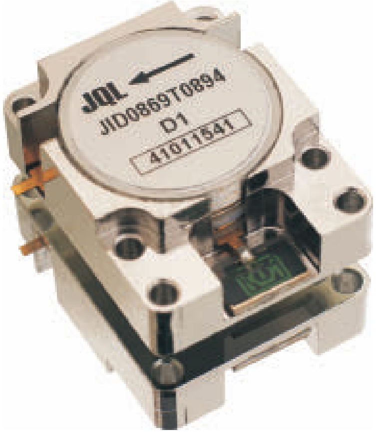

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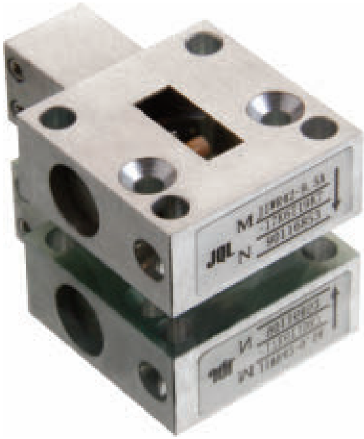

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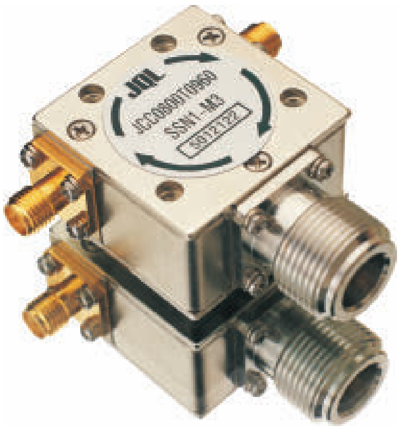

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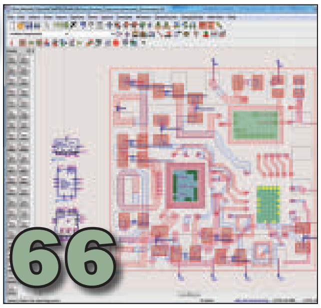

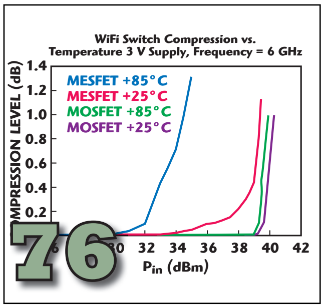

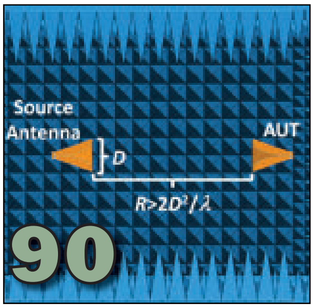

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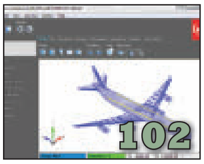

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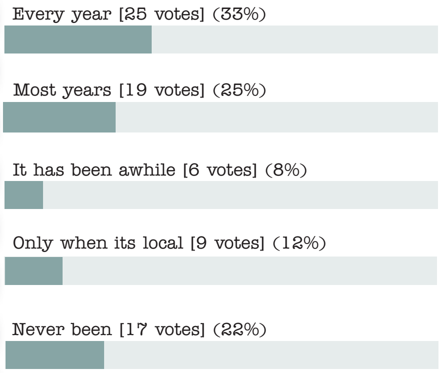

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2014 Design Software Review: Interoperability

Editor's Note: The quest for interoperability between RF/microwave EDA tools goes back to at least 1987 and the DARPA program known as MIMIC. This program launched a study to find the best way to produce reliable, high performance MMICs through the "development of computer-aided design capabilities." CAD companies teamed with IC manufacturers to develop standards for file formats allowing the exchange of data across platforms and design environments. Today, interoperability extends to nearly all software-based design tools including circuit/system schematic-based environments, physical layout, EM simulation, multi-physics, manufacturability and test systems, taking into account software from multiple vendors and supporting enterprise design flows. A new age is upon us whereby EDA providers are collaborating with each other to streamline design flows through interoperability and design automation. This improved functionality allows engineers to be more productive than ever before. The following is an update on the latest developments in interoperability and the impact on design.

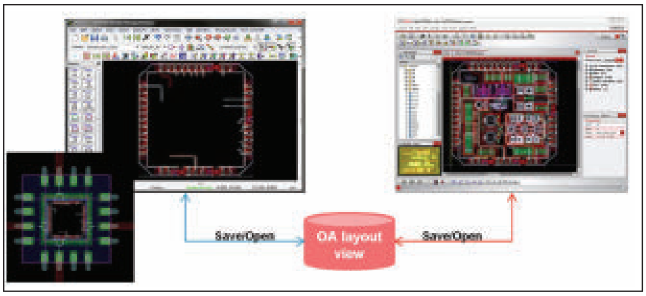
Agilent Technologies

Agilent's workflow environments provide a way to simulate, measure and analyze components and systems in a variety of applications. This is made possible by focusing on software interoperability across electronic design automation (EDA) tools as well as measurement application software for specific test needs. As a component or device moves through its lifecycle—from early design all the way to volume manufacturing—customers can achieve greater confidence in their designs, products and schedules.

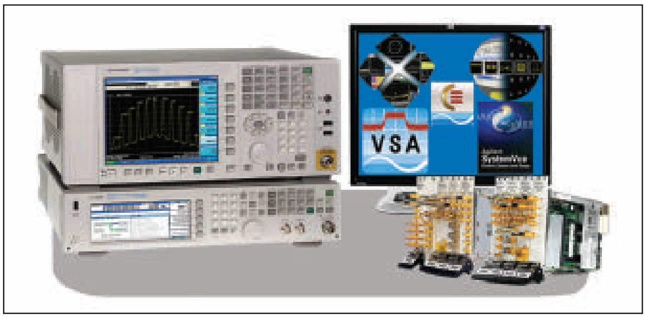
In recent years, the need for greater interoperability between design tools has intensified due to two main trends. The first is a general movement from single-technology designs to those that incorporate multiple technologies within ever-smaller enclosures. This leads to many challenges, and one of the most difficult is the potential for coupling between the subsystems within the device. Solving these problems quickly and efficiently depends on circuit simulators, electromagnetic (EM) simulators and layout tools that are designed to work together.

This leads to the second trend: the need for greater efficiency in the design flow. In many industries, headcounts and budgets are shrinking as competitive pressures drive shorter design cycles. If team members are using differing tools, they may need to convert or translate designs from one format to another—and this may cause inefficiency and errors.

Several years ago, Open Access was introduced as a common database for custom IC design. Agilent adopted this database in its flagship simulation platform, Advanced Design System (ADS), and its EM simulation tools. Today, ADS 2014 provides several new features that increase interoperability and address the two main trends described above. As an example, ADS 2014 goes beyond the use of a common database for circuit and EM simulation. To help designers save time—and eliminate hundreds of mouse clicks—the software includes automatic EM simulation set-up and design partitioning. This automates the process of removing SMD and IC active devices and replacing them with EM ports in the design layout.



▲ *Fig. 1 Advanced Design System 2014 uses the Open Access database, enabling bidirectional schematic interoperability with Cadence Virtuoso.*



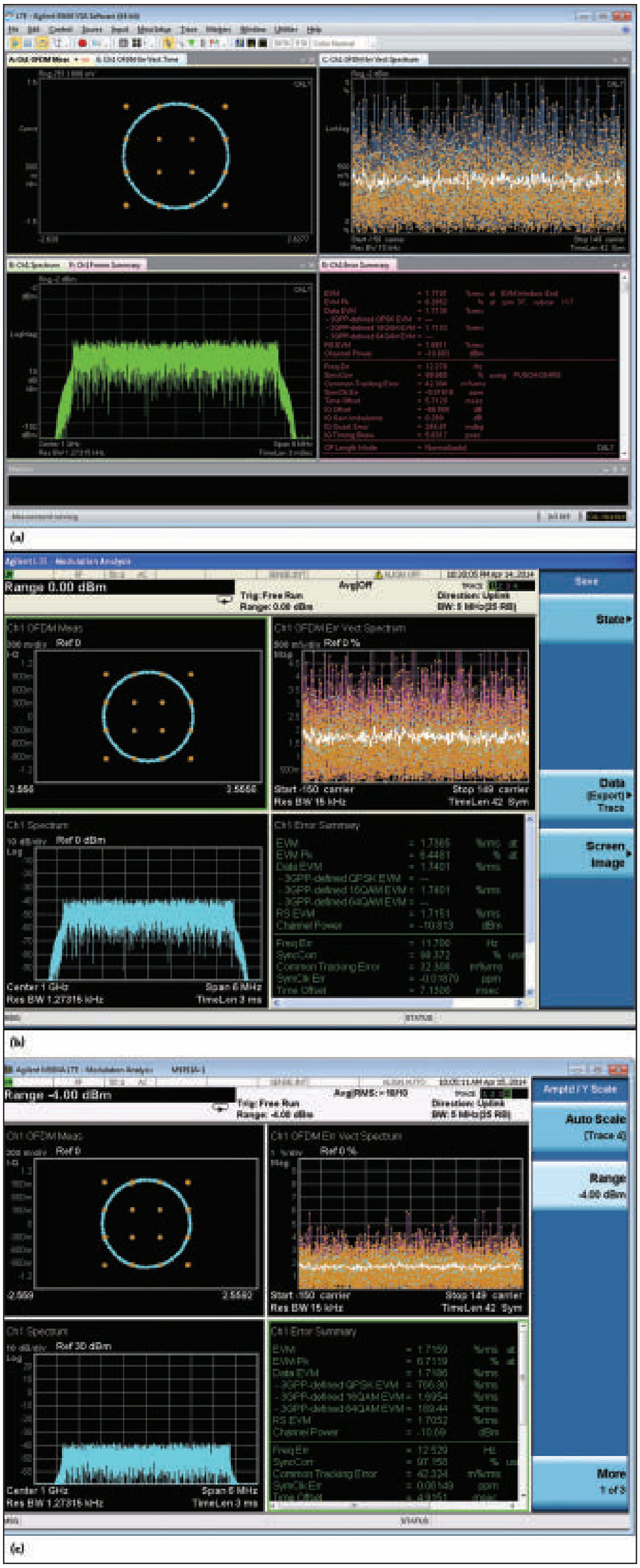
▲ *Fig. 2 Benchtop and modular vector signal generators and analyzers leverage common measurement algorithms that represent building blocks in their measurement.*

Another addition is a next-generation PCB integration solution – the ADS Board Link (ABL). This provides a bidirectional interface to enterprise PCB tools, enabling ADS to import layouts, schematics and libraries. ABL also enables easy transfer of RF schematic and layout designs started in ADS, to enterprise PCB environments for integration into a larger design for floor planning, modification to accommodate physical design constraints, and exportation back to ADS for verification.

Designers of silicon RFICs can now use ADS 2014 to simulate a design from Cadence Virtuoso with no importing or file translation required because both tools use the same database (see Agilent's article, p.66 in this issue for more about the benefits of this interoperability). For those making measurements with the latest Agilent instruments, ADS 2014 provides enhanced links through an upgraded Command Expert Mode in its Connection Manager (see ***Figure 1***).

In today's design cycles, interoperability extends beyond EDA tools to include information sharing between software and hardware as well as interoperability across multiple hardware platforms. Incorporating multiple radios into less space also adds new challenges to device testing. The difficulties grow when those radios use sophisticated multiplexing and transmission schemes such as MIMO, space/time coding, beamforming and carrier aggregation.

As a product moves along its lifecycle, testing requirements evolve from "unbounded" in R&D to "just enough" on the production line. Satisfying those needs while also addressing business drivers often requires an optimal combination of benchtop and modular test equipment. The benefits grow if the platforms are well harmonized and the associated measurement software provides consistent results.



▲ *Fig. 3 These three traces show the same LTE measurement made with the 89600 VSA software, (a) an MXA signal analyzer running X-App VSA software (b) and a modular PXI VSA with X-Apps software (c).*

The availability of compatible benchtop and modular solutions provides the fastest path to a completed design and the lowest total cost-of-test (see ***Figure 2***). It also reduces the risks inherent in the product lifecycle. As an example, Agilent offers a common suite of signal-generation and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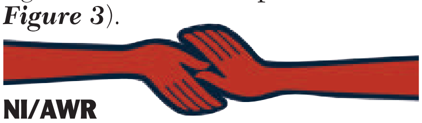
signal-analysis software that can be used across its benchtop and modular signal generators and signal analyzers. This enables engineers to easily correlate test results between the development and manufacturing phases.

Specific to signal analysis, Agilent provides a range of capabilities. This starts with basic functionality in the form of spectrum and "power suite" applications for all stages of product development and manufacturing. The next level comes from X-Series measurement applications, which offer capabilities such as power, harmonics, spurious and phase noise across benchtop and modular instruments. For advanced modulation analysis, the Agilent 89600 VSA software is compatible with—and provides consistent results from—a wide range of Agilent measurement platforms (see ***Figure 3***).



NI/AWR

AWR Corporation, a National Instruments Company and leader in high-frequency EDA software, has had a long-standing commitment to provide design engineers with access to best-in-class, third-party tools through integration with the AWR Design Environment™. The AWR Connected™ family of products supports the flow of data between high-frequency design software from AWR and products from third-party software and hardware manufacturers automating the exchange of design and simulation/measurement data from software-to-software and/or software-to-hardware design environments. Design domains addressed include printed circuit boards, test and measurement (T&M), as well as MMIC thermal and related synthesis technologies.

To keep pace with evolving engineering challenges and new tools on the market designed to address these issues, AWR has recently added several important interoperability links to its AWR Connected product line. These links provide interoperability to various tools for specific analyses (i.e. EM, thermal), complex physical structures and design flows and provide engineers with an opportunity to address specific engineering issues while utilizing existing design information.

In a significant development, AWR and ANSYS Inc. recently announced their efforts to integrate ANSYS® HFSS™, a leading 3D EM analysis tool, into Microwave Office. With this design flow, Microwave Office users can readily access HFSS for analysis of EM fields and coupling of 3D structures like bumps, bond wires, pins, tapered vias and ribbons, which are essential to successfully designing and realizing microwave circuits like monolithic microwave integrated circuits (MMIC), densely-populated RF circuit boards and multifunction modules.

The link between the two software tools is accomplished through the use of AWR's EM Socket™ open standard interface, which enables AWR users to access a broad range of electromagnetic (EM) tools from within the Microwave Office design environment. It is this same feature that also enables AWR Microwave Office users to essentially simulate EM structures with a single mouse click using either AWR's AXIEM® 3D planar method of moments solver or Analyst™ 3D finite element method EM software.

In addition to enabling ANSYS HFSS 3D EM simulation capabilities from within the NI/AWR Design Environment, the connection allows the resulting 3D layered format exported from the EM Socket interface to connect to the ANSYS multiphysics portfolio. That suite includes ANSYS SIwave® for signal/power integrity analysis and ANSYS Icepak® for thermal characterization.

High-power RF components not only produce high power—they also generate heat. This makes it important to not only understand the electrical performance of the end device but also the impact of its thermal profile. In addition to the link to ANSYS Icepak for thermal analysis, AWR Connected now provides interoperability to CapeSym's SYMMIC thermal FEM analysis software, which provides a co-simulation, software-to-software, electrical/thermal, MMIC design environment.

AWR Connected for SYMMIC is a unidirectional interface flow developed especially for high power monolithic microwave integrated circuit (MMIC) designers to enable them to easily take AWR's Microwave Office high-frequency circuit designs into CapeSym's SYMMIC software package for thermal analysis. Together, AWR & CapeSym provide high power RF designers with the ability to obtain optimal electrical performance with proper consideration given to thermal operating properties as well. This results in more robust and reliable next-generation RF and power systems.

In support of complex PCB layout design flows, AWR is also partnering with Cadence Design Corporation on a new and improved flow between AWR tools and Cadence's Allegro board solution. It is not uncommon that the RF functions on a board occupy only a small footprint on the final overall PCB design. While this RF area may be small, the importance of getting the design right is paramount. Unfortunately, is it also quite typical that the RF layout is designed in isolation and later placed into the final design. When this happens, the RF performance often suffers. Therefore it is very desirable and beneficial to perform a verification simulation using the actual layout from the full production PCB tool before prototyping.

AWR recognized this need several years ago and first partnered with Cadence in 2010 to provide the AWR Connected for Cadence Allegro design flow using Applied Computational Sciences (ACS) as the intermediary. This powerful solution is popular for an EM extraction flow taking data from Cadence and inputting it into AWR's Microwave Office circuit design tool, where it can also be leveraged using AXIEM® for 3D planar EM simulation.

As EM simulation has matured and become much more a part of the front end design process, mutual key customers have been requesting a tighter, more robust solution. In response, AWR and Cadence began working together in 2013 to ensure model compatibility across tools. The result is a 3D printed circuit board (PCB) flow that takes the RF schematic and layout from Microwave Office and exports the data into Cadence format such that it can be quickly and easily read in, plugged into the overall PCB design, and simulated/verified.

ANSYS

ANSYS is equally committed to providing open integration of HFSS, an industry leading electromagnetic field simulation technology, with third party microwave circuit simulation and EDA design software packages. Such interoperability allows companies to create customized design flows to fit their needs. The key enabling feature supporting this integration is the new 3D Layout interface. HFSS 3D layout is ideal for designers who work in layered geometry found in monolithic microwave integrated circuits (MMIC), densely-populated RF circuit boards and multifunction modules, or layout of high-speed components, including on-chip embedded passives, IC packages and PCB interconnects. These types of designs can be easily modeled in the HFSS electrical layout environment or imported directly from leading

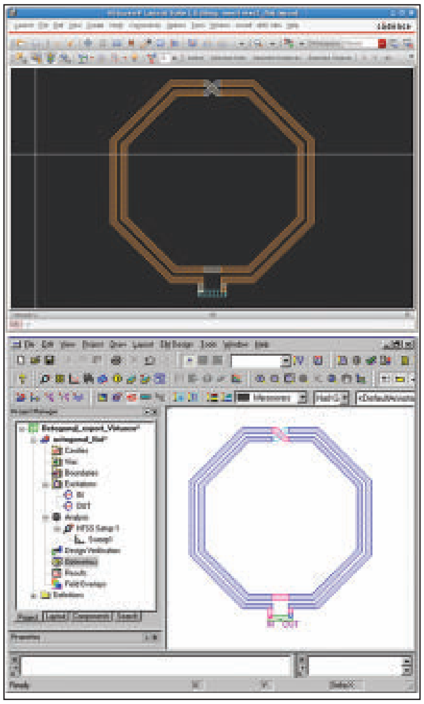
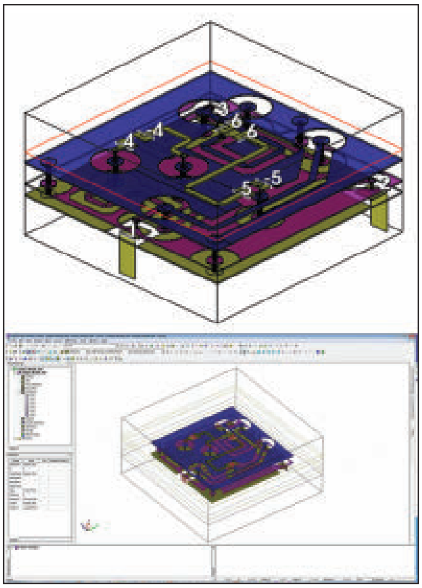


Fig. 4 Layout of spiral inductor defined in Cadence Virtuoso imported into HFSS for 3D full-wave analysis.

design software packages such as National Instruments/AWR (described previously) and Cadence Design Systems (see ***Figure 4***).

The HFSS 3D layout feature enables seamless integration with AWR's Microwave Office and Cadence® Allegro®, APD, SiP and Virtuoso® allows RF, SI and digital engineers to set up ready-to-solve chip, package and board simulations from within the host environment. The easy-to-use capability is ideal for engineers who are not familiar with 3D electromagnetic modeling but require the rigor, accuracy, and reliability that HFSS provides. All the necessary HFSS setup steps (geometry, material properties, port setup, and boundary conditions) are easily and quickly applied in the AWR or Cadence interface (see ***Figure 5***).

Engineers can easily perform a direct setup of a Microwave Office, Allegro, APD, SiP or Virtuoso layout design that can then be analyzed with HFSS. Users simply specify which regions, or connected regions, are to be solved by HFSS by specifying a cutout region in the layout tool. Once the region has been defined, the appropriate nets are selected and ports are automatically assigned to the nets or solder balls in the design. To complete the setup, the user specifies the solution frequency and sweep range.



▲ *Fig. 5 Layout of structure with defined ports originally designed in AWR imported into HFSS for 3D full-wave analysis.*

Once setup is complete, the 3D electromagnetic model is solved by the HFSS finite element electromagnetic solver. Since the solution region, nets of interest, excitation ports, and boundaries are automatically created and/or assigned in the layout, engineers do not need to be familiar with 3D modeling. Such integration provides access to HFSS while making model creation extremely simple and fast. Engineers obtain very accurate electromagnetic field simulations of high-speed differential pairs, via transitions, ball grid array transitions, package-to-PCB transitions, passives on silicon, RF circuits and more.

Once the imported geometry exists in HFSS, users can do further analysis beyond 3D full wave electromagnetics by leveraging the ANSYS® Workbench™. The Workbench framework allows users to perform detailed multiphysics analyses on the same imported geometry. For example, the design of an RF power amplifier must now consider how the device's thermal performance will impact the system's overall frequency response. Optimal designs can be accomplished only when both issues — electromagnetic and thermal performance — are considered in an interdependent manner. Moreover, today's microwave electronics systems are incorporated into demanding system-level environments. A power amplifier may be part of a phased array antenna that is mounted in a UAV that is expected to circumnavigate the globe. Vibration analysis is a critical component to this integration. What impact will in situ vibrations have on the antenna's beam steering capabilities? Only an integrated multi-physics solution can provide the answer. The ANSYS Workbench delivers an innovative project schematic view that ties together the entire simulation process, guiding the user every step of the way. Even complex multiphysics analyses can be performed with drag-and-drop simplicity.

COMSOL

Simulation enables faster product development by providing key information about how a design will perform prior to the manu-

facturing of physical prototypes. For electrical engineers, ever diminishing component sizes on printed circuit boards, integrated circuits, and MEMS devices demand that greater and greater accuracy be obtained to correctly predict device performance and characteristics. To achieve this, the interactions of multiple physics must be combined and analyzed within one and the same simulation.

Take power electronics, for example; analyses of the performance of solid-state electronic devices must include far more than just a single physics type. In these devices, it is crucial to understand heat management processes in great detail. This requires that current conduction be coupled to heat conduction as well as to structural simulations to check for stress and deformation. When designing flexible printed circuit boards, such as those used in wearable devices, it is beneficial to have both a fast development cycle and a reliable product that is ensured by simulation. This entails ensuring that the circuit board can deform as intended and does not break after repeated deformation, a truly multiphysics analysis.

How is this done? Computer aided engineering (CAE) software requires strong interfacing and interoperability capabilities in order to leverage the strengths of different software. With the ECAD Import Module, an add-on to COMSOL Multiphysics, ECAD files can be imported directly into the COMSOL® software, where 2D layouts can easily be converted into 3D geometries for further analysis.

Within the COMSOL environment, multiple physics interactions can then be combined and analyzed including the electromagnetic, thermal, and structural behavior of components and devices. One new feature introduced with COMSOL Multiphysics version 4.4 is the ability to import ODB++ files into the software (see ***Figure 6***). "With ODB++ import, the engineer is able to generate 2D or 3D geometry based on the layers of a circuit board. The geometry can be meshed and used together with any of the COMSOL modules for simulation," describes Lorant Olasz, product manager for the interfacing products available with COMSOL Multiphysics.

ECAD data can be imported using formats that contain layouts for the individual layers in a device such as a PCB or a chip. The ECAD Import Module, by recognizing the geometric components of a layout, will construct plane geometry objects from the files. These objects can then be extruded based on information (provided in the file or during import) about the layer stack-up. For IC and MEMS

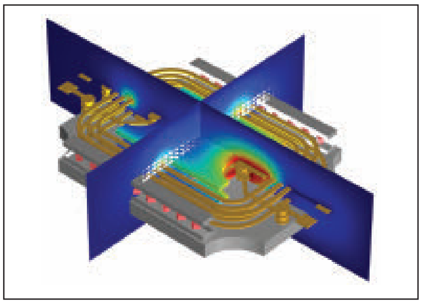


Fig. 6 COMSOL now supports the ODB++ file format for importing such files and performing analyses on the PCB components they represent.

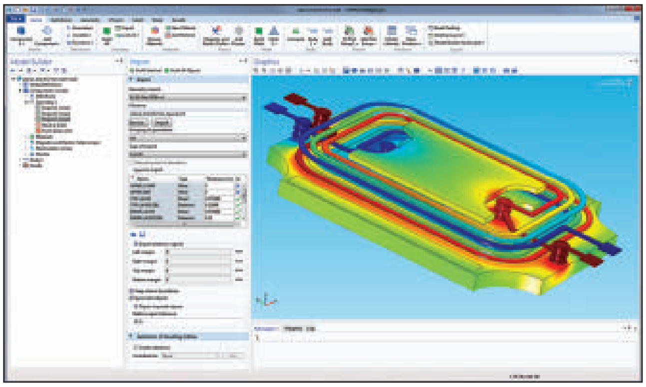


Fig. 7 The picture shows the electric potential on the surface of a planar transformer.

simulations, GDSII formats are supported. The NETEX-G, ODB++, and ODB++(X) file types can be imported for simulating PCBs. The NETEX-G format is the native file type for the program of the same name, which can extract connected metal traces from formats that are widely used for when PCB designs are sent for fabrication, such as drill and Gerber layout files. The layout in ***Figure 7*** is imported from an ODB++(X) file using the ECAD Import Module and is automatically converted to a 3D geometry model. The AC/DC Module is used to compute the capacitance and inductance parameters of the device.

CST

There is not, and never will be, a single tool that can do everything. Everything in the engineer's toolbox – whether it is a physical item or a computer program – represents years of research and development into solving just a subset of the tasks that come up over the course of the design cycle. CAD and EDA tools make it possible to create complex designs rapidly, simulation tools allow engineers to model and optimize the system, and CNC machinery and test equipment can then be used to construct and analyze prototypes. Each one covers a part of design cycle, but for a complete integrated workflow, there needs to be interoperability between all of these tools.

CST STUDIO SUITE® is a simulation tool that includes numerous electromagnetic solvers, which help engineers model, simulate and optimize their designs. Because of the range of different design workflows that require simulation, straightforward interoperability with a wide variety of tools is of CST's main goals when developing CST STUDIO SUITE, CAD and layout tools.

There are many CAD and EDA tools on the market, often focusing on different specific markets. The files these produce come in a wide variety of formats, with differing standards for model quality and shape representation. CST STUDIO SUITE includes import and export tools for general formats such as STEP, ODB++ and GDSII, and pro-

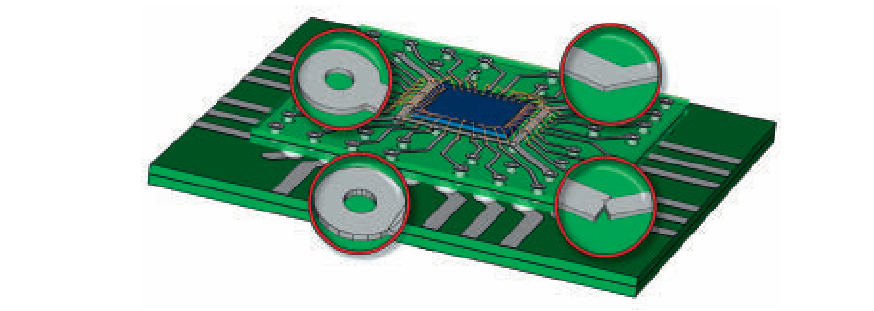


Fig. 8 *An imported model of a package, showing the automatic cleaning of faceted edges and healing of shape errors.*

prietary formats from leading design and layout tools from vendors including Dassault Systèmes, Siemens, Mentor Graphics and Zuken.

Automatic model cleaning and healing tools built into CST STUDIO SUITE make it easier to prepare CAD data for simulation purposes (see ***Figure 8***), and imported models can be modified and parameterized just like native data. Even within a single team, there may be different departments working on different parts of the same product simultaneously since the engineers designing the logic board of an electronic device will not be the same ones who design the casing. The 2014 version of CST STUDIO SUITE introduced CAD data version control to make it easier for engineers in large teams to keep track of the work being done across different departments. CST STUDIO SUITE monitors the imported data and, if a file changes the user is notified. The model can then be automatically updated, with the changes highlighted and the model settings retained. Selective updating is also available for EDA files, in order to preserve the component, net and stackup definitions from the simulation model.

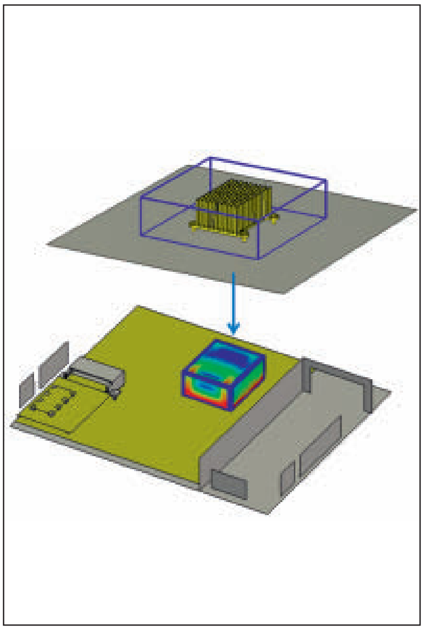
Once the model has been created, it needs to be simulated. CST STUDIO SUITE contains both full-wave 3D solvers and circuit simulation tools, along with specialized solvers for PCBs, cables and multiphysics applications. These solvers each have their own strengths, and can complement each other in many design workflows. CST's Complete Technology approach to simulation means that these solvers are developed to work together. Not only does this allow a simulation to be cross-verified with a different solver, interoperability also unlocks the ability to combine simulation techniques and take advantage of the benefits of each.

One common design project that benefits from this approach is emissions analysis (see ***Figure 9***). An accurate calculation of the radiated emissions from a component usually requires a dense mesh around the component to capture its geometric details, but only a coarse mesh across the rest of the volume. Modeling the aggressor as a field source means that the most efficient mesh and

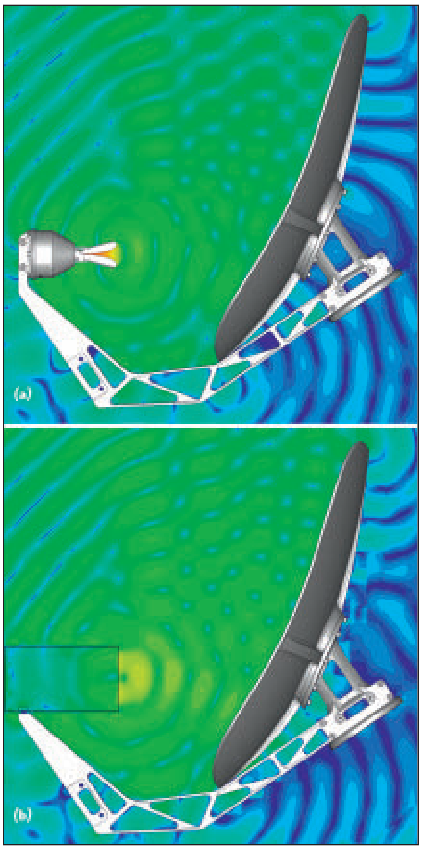
simulation method for each part can be used. The same approach is also useful for problems such as antenna placement.

For a complex system, this approach may result in numerous different simulation and optimization tasks, all dependent on one another. For these, CST developed System Assembly and Modeling (SAM). With SAM, tasks such as simulation runs, parameter sweeps and post-processing can all be linked together and run as a chain. Different components can be linked together in the schematic view, and the transfer of signals, S-parameters and fields from one to another is handled automatically. CST STUDIO SUITE 2014 automates the process further, with tools to automatically set-up the SAM workflows for field-coupling and multiphysics workflows.

Many projects, especially in the world of EMC and compliance, straddle the border between virtual and physical testing. The engineer may have access to a prototype of a component, but not to the system it will be



▲ *Fig. 9 A nearfield source representing a heatsink in an EMC simulation of a router.*



▲ *Fig. 10 Simulation of a reflector antenna with (a) a 3D model of the feed horn and (b) an equivalent nearfield source created with INSIGHT.*

installed in, or the device may be designed to operate in an environment where measurements are difficult – whether that's the depths of space or the human body. As well as offering advantages in virtual prototyping, interoperability with test equipment allows simulation to bridge the gap when measurement is impossible.

Measured data can be imported into CST STUDIO SUITE projects in a number of different ways. Both farfield and nearfield data can be used as the excitation for a full-wave simulation through the link to INSIGHT from Microwave Vision Group (see ***Figure 10***), and measured S-parameters and I/O buffer information for components can be imported in formats such as TOUCHSTONE and IBIS. True transient/circuit co-simulation allows these elements to be directly included in a full-wave 3D simulation, even if they are nonlinear, and SAM can make the integration of measurement and both circuit-level and full 3D simulation straightforward.

CST also invests in developing links to third-party analysis tools, to help engineers make the most of simulation and tailor their results to the task. Among the compatible tools are Antenna Magus, for antenna and array design; Optenni Lab, for matching circuit optimization; Delcross Savant, for antenna placement, and Delcross EMIT for co-site interference analysis.

Delcross

About a year and a half ago, CST and Delcross cooperated to provide a workflow to take a complete CST analysis scene that incorporated several antennas, and import them directly into the Delcross EMIT software for RF cosite EMI analysis and mitigation. The idea is to make it easy for a CST user to take the EM results that characterized the complete antenna-to-antenna coupling in a given scene, pull it into EMIT and add system models for the transceivers, receivers, transmitters, amplifiers and outboard components (filters, cables), and look at the complete spectrum to search out in-band interference margin issues, broadband noise margin violations, and other issues that might lead to receiver desensitization.

In a specific example, a smartphone handset including multi-band cellular antennas, Wi-Fi, Bluetooth, NFC and navigation systems such as GPS and GLONASS was created in CST STUDIO SUITE. The model includes the antennas for the three systems of interest, and farfield monitors at key operating frequencies of the different systems. A simulation was carried out using the time domain solver across the spectrum from 0 to 6 GHz. This simulation provides both the S-parameters, which illustrates the wideband coupling (isolation) between each antenna, and the farfield patterns, giving the pattern degradation caused by installing the antennas in the environment of the handset.

Once all of the results have been calculated, the S-parameters, the field

patterns and the CAD data can be transferred to EMIT in a single directory. After importing the files, the next stage is to define the RF systems themselves. EMIT includes a library of radios, power amplifiers, filters and other components, which can be assembled to produce a complete system. These models can include data such as channels, modulation and mixer products, as well as the programming of the radio.

With the RF systems defined, the potential for interference between the systems can be calculated. EMIT helps engineers investigating cosite interference consider the 1-on-1 scenario, where one system interferes directly with another, and the N-on-1 scenario, where multiple systems are transmitting simultaneously causing potential intermodulation problems.

Sonnet

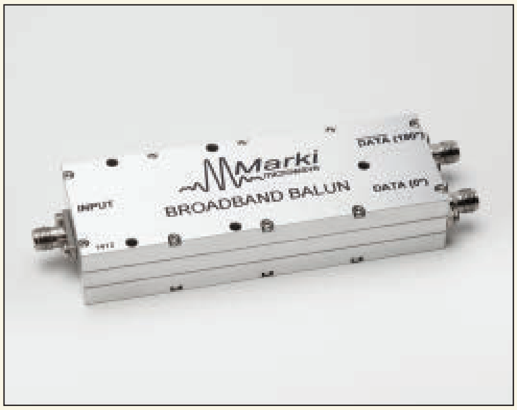
In late 2013 Sonnet Software introduced an easy-to-use EDA environment for the analysis of on chip passive devices such as spiral inductors and MIM capacitors called Blink™. This multi-solver passive device modeling suite operates entirely from within the Cadence Virtuoso environment and offers users two full- wave electromagnetic (EM) solvers: Sonnet's traditional shielded method-of-moments (MoM) solver, and a new fast solver that uses advanced algorithms to accelerate the device modeling process. Both solvers operate with PDK-specific stack ups, which can be customized for the user's implementation.

Blink allows high frequency silicon circuit designers to include their stack up and PDK information in EM analysis with just a few button clicks. With Blink, integrated circuit designers now have an automated way to access electromagnetic analysis of passive RFIC devices without limiting them to any specific PDK. The new product automates the process of setting up electromagnetic simulations of passive integrated circuit devices including center-tapped spiral inductors.

Integrated circuit designers can now easily model new and unique passive devices within your normal Cadence Virtuoso based IC design flow. Blink's new fast solver enables you to quickly characterize spiral inductors, baluns, transformers, MIM Caps, interdigitated capacitors, and transmission lines for radio frequency integrated circuit and mixed signal IC design. ■

Most Valuable Product

Isolated Baluns Eliminate Tradeoffs in Differential Measurements



Marki Microwave
Morgan Hill, CA

Christopher Marki,
director of operations at Marki Microwave.
Visit www.mwjournal.com to read this in-depth interview.

Executive Interview

Microwave and signal integrity engineers face difficult choices when deciding how to perform differential measurements. Many test solutions are inaccurate, expensive, limited in bandwidth, and inconvenient. The broadband nature and high isolation of the new BAL-0026 and BAL-0036 baluns from Marki Microwave eliminate these difficult decisions by providing an all-in-one test solution for all classes of differential system measurements. With frequency coverage from 300 kHz to 36 GHz (BAL-0036) or 26 GHz (BAL-0026), typical balance of 0.5 dB/5°, and 25 dB typical isolation, these new baluns provide the differential test capability necessary for any requirement. See ***Table 1*** for a comparison of technologies.

When designing a differential device or system, an engineer must decide how to properly characterize performance. For a device such as an amplifier, this includes linear frequency domain parameters (S-parameters and the like), nonlinear frequency parameters (spurious generation, P1dB), and potentially time domain characteristics (rise time, eye diagrams). While any of these can be evaluated by terminating one side of the differential inputs and/or outputs with a 50 ohm load, only linear S-parameters can be measured confidently using this method. If only linear S-parameters are desired for a device, they can be measured and post-calculated using a two-port VNA.

The proper method for measuring the nonlinear and time domain response of a system, however, is with differential excitation. This can be provided, at significant additional expense, using a dual-source four-port VNA. Unfortunately, this only extends the measurement capability of the VNA to single frequency excitations, which is suitable for testing 1 dB compression and single tone harmonic generation, but not for more general parameters such as multi-tone intermodulation or spurious generation. Furthermore, it does not provide measurement capability for any real-world time domain testing with

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"S" Series Solid State

Numerous models from 0.7 to 18 GHz, 1 to 1200 Watts. For Immunity, Wireless Testing and TWTA replacements. Our "S" Series amplifiers are Mismatch Tolerant providing 100% of rated power without foldback. These amplifiers will reproduce input signals and remain stable with any magnitude and phase load impedance, without damage.

1000S1G2z5 (1000 watts, from 1 to 2.5 GHz)

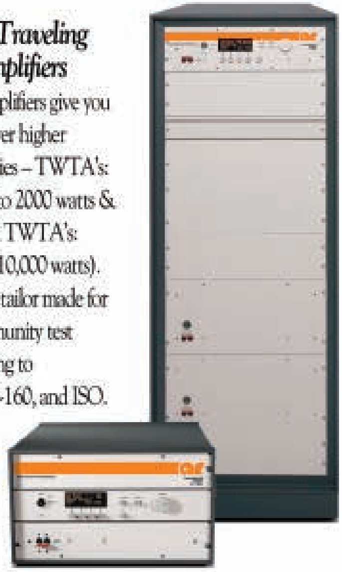

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TABLE I

COMPARISON OF SOLUTIONS FOR DIFFERENTIAL MEASUREMENTS

<table>
<tr><th colspan="2"></th><th>Two Port VNA with Post-Processing</th><th>Four Port Dual Source VNA</th><th>Standard Baluns (No Isolation)</th><th>New Marki BAL-0036 with Isolation</th></tr>
<tr><td rowspan="4">Time Domain</td><td>Eye Diagrams</td><td>✖</td><td>✖</td><td>< 20 Gb/s</td><td>< 40 Gb/s</td></tr>
<tr><td>Step/Impulse Response</td><td>✖</td><td>✖</td><td>> 50 ps</td><td>> 25 ps</td></tr>
<tr><td>Bit Error Ratio</td><td>✖</td><td>✖</td><td>< 20 Gb/s</td><td>< 40 Gb/s</td></tr>
<tr><td>Error Vector Magnitude</td><td>✖</td><td>✖</td><td>< 17 GHz</td><td>< 36 GHz</td></tr>
<tr><td rowspan="4">Nonlinear Frequency Domain</td><td>Multitone Spurious</td><td>✖</td><td>✖</td><td rowspan="8">200 KHz - 17 GHz</td><td rowspan="8">300 kHz - 36 GHz</td></tr>
<tr><td>Multitone Intermodulation</td><td>✖</td><td>✖</td></tr>
<tr><td>1 dB Compression</td><td>✖</td><td rowspan="6">10 MHz - 67 GHz</td></tr>
<tr><td>Harmonic Generation</td><td>✖</td></tr>
<tr><td rowspan="4">Linear Frequency Domain</td><td>Insertion Loss</td><td rowspan="4">10 MHz - 67 GHz</td></tr>
<tr><td>Return Loss</td></tr>
<tr><td>Amplitude Balance</td></tr>
<tr><td>Group Delay</td></tr>
</table>

actual data. This requires a differential to single-ended mode converters.

There are two major options for such a converter: the balun and the 180° hybrid coupler. The advantage that baluns have are that they can have frequency coverage to very low frequencies (in the kHz range), which makes them suitable for baseband data. They have been limited, however, usually to frequencies below 10 GHz on the high end. The advantage of 180° hybrid couplers is that they can operate at high frequency (65 GHz or higher), but they cannot operate below 2 GHz, making them unsuitable for baseband data.

Hybrid couplers also have isolation between output ports, while most balun designs do not. Lack of isolation between the positive and negative balanced ports can cause erroneous measurements in both the frequency and time domain. It can also cause significant errors for testing of devices that do not have a perfect 50 Ω match.

The new baluns from Marki Microwave merge the best features of each device into one all-purpose unit. The broadband 300 kHz to 26/36 GHz operation makes the BAL-0036 suitable for all classes of signals, including baseband data, narrowband data, and high frequency single tone testing. The combination of excellent balance, isolation, low return loss, and flat insertion loss means that the baluns are transparent to the user during measurements.

The typical balance of the new BAL-0036 is ±3° of phase balance and ±0.5 dB of amplitude balance for frequencies up to 36 GHz. This translates into 8.6 ps of typical differential group delay ripple, and 6 percent of typical differential voltage variation across the band. The differential insertion loss increases from ~3 dB at low frequency to 5 dB at 36 GHz with low group delay ripple, making it more than capable of transmitting 40 Gb/s data with open eyes.

Differential signaling is generally preferred to single ended signaling because it has inherent immunity from electromagnetic interference (EMI) noise. Signal integrity engineers are adopting differential signaling for more applications and in higher frequency designs, as more stringent dynamic range requirements require the elimination of EMI noise. Despite this clear advantage, adoption of differential signaling is hampered by the dearth of options for testing differential devices and systems at frequencies above 10 GHz. By providing convenient and accurate measurements of all differential parameters at a fraction of the cost of a dual source VNA, the broadband balun could serve as the cornerstone of any laboratory differential testing capability.

Marki Microwave,
Morgan Hill, CA
info@markimicrowave.com
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DefenseNews

Cliff Drubin, Associate Technical Editor

LM Selected to Provide USAF with Space Fence Radar to Safeguard Space Resources

VIEW VIDEO

The U.S. Air Force has awarded Lockheed Martin a $914 million contract to improve the way objects are tracked in space and increase our ability to prevent space-based collisions.

Lockheed Martin's Space Fence solution, an advanced ground-based radar system, will enhance the way the U.S. detects, catalogs and measures more than 200,000 orbiting objects. With better timeliness and improved surveillance coverage, the system will protect space assets against potential crashes that could intensify the debris problem in space.

"Space-based technologies enable daily conveniences such as weather forecasting, banking, global communications and GPS navigation, yet everyday these critical services are being threatened by hundreds of thousands of objects orbiting Earth," said Dale Bennett, executive vice president of Lockheed Martin's Mission Systems and Training business. "Space Fence will locate and track these objects with more precision than ever before to help the Air Force transform space situational awareness from being reactive to predictive."

> The system will protect space assets against potential crashes that can intensify the debris problem in space.

Lockheed Martin will deliver up to two advanced S-Band phased array radars for the Space Fence program. The Space Fence radar system will greatly improve space situational awareness of the existing Space Surveillance Network. Construction of the new Space Fence system on Kwajalein Atoll in the Marshall Islands is slated to begin in early 2015 to meet the program's 2018 initial operational capability goal. The total contract value is estimated at greater than $1.5 billion over an eight-year period of performance if all options are exercised.

GA-ASI and Rohde & Schwarz Team to Develop Voice Communications Certification for Predator B

General Atomics Aeronautical Systems, Inc. is a leading manufacturer of Remotely Piloted Aircraft (RPA) systems, radars, and electro-optic and related mission systems, and Rohde & Schwarz, the world's leading manufacturer of wireless communications, Electromagnetic Compatibility (EMC) Test and Measurement (T&M) equipment, and broadcasting equipment for digital terrestrial television, announced that they have signed a Teaming Agreement to integrate and flight demonstrate Rohde & Schwarz's air traffic control radios on the Predator® B/MQ-9 Reaper® RPA.

The agreement supports both companies' efforts to add additional German and European content into Predator-series aircraft. At the same time, the integration of the Rohde & Schwarz radios also supports GA-ASI's effort to deliver a "Certifiable" Predator B RPA. GA-ASI is forecasting to deliver aircraft that are fully compliant with the airworthiness certification requirements of NATO customers, including STANAG 4671.

"We are continuing to integrate German and European payloads and communications systems into our aircraft while ensuring compliance with airworthiness standards," said Linden P. Blue, CEO, GA-ASI. "Rohde and Schwarz's expertise in the design, development and production of radio communications systems that carry airworthiness certifications will bring us one step closer to achieving this goal."

"Our products provide users with a high degree of security and reliability in airborne radio communications," stated Scott Bausback, CEO, Rohde & Schwarz USA, Inc. "Together with General Atomics Aeronautical, we will develop both companies' capabilities regarding their technical state-of-the-art portfolios."

In the final design configuration, two radio systems will be placed in the aircraft, along with potentially another two radios in the Ground Control System (GCS). The R&S MR6000A—from the successful Rohde & Schwarz VHF/UHF R&S M3AR airborne transceiver family—is the first radio of its kind in the world that meets civil aviation certification requirements and ensures compatibility with military and civilian avionics specifications.

The first flight test of Predator B with a single R&S MR6000A radio system is scheduled for later this year at GA-ASI's Gray Butte Flight Operations Facility in Palmdale, Calif. The test will encompass verification of control and frequency management using the Beyond-Line-of-Sight (BLOS) communications path. In addition, GA-ASI foresees an adjunct demonstration of a radio relay and communication to dismounted soldiers should flight resources allow.

GA-ASI's Certifiable Predator B is envisioned to be a multi-nation, certifiable, exportable configuration built

Source: U.S. Air Force photo

For More Information Go to mwjournal.com for more defense news items upon the company's Block 5 Predator B aircraft capabilities and Advance Cockpit GCS layout. In April 2013, the company expanded its relationship with its German partner, RUAG Aerospace Services GmbH, to allow for increased collaboration in establishing compliance with NATO airworthiness standards. Similarly, the radio certification effort with Rohde & Schwarz will be leveraged to market the aircraft jointly to U.S. and European government entities.

Harris Successfully Demos Mid-Tier Tactical Radio Providing Vehicular-Based Connections to Data and Wideband Networking Services

VIEW VIDEO

Harris Corp. tactical radio systems successfully connected soldiers on the move with their command headquarters during the initial demonstration of the U.S. Army's new Mid-Tier Networking Vehicular Radio (MNVR) program.

The MNVR program is designed to seamlessly connect vehicular-based soldiers to the Army tactical network. The program can also extend Warfighter Information Network-Tactical (WIN-T) services into the terrestrial network, providing enhanced throughput and range for communication requirements at the tactical edge.

Soldiers used the Harris Falcon III® AN/VRC-118 MNVR solution, operating the JTRS Wideband Networking Waveform (WNW), to provide wireless enterprise services including email, tactical chat and rapid file downloads. The effort was conducted during the Army's Network Integration Evaluation (NIE) 14.2 at Fort Bliss, Texas, in advance of initial delivery of production units in June of this year.

The Army awarded the $140 million MNVR contract to Harris in September 2013 following a competitive procurement. The radios for this demonstration were delivered within six months of contract award.

"This successful demonstration represents a very important step for the Army in fielding a critical mid-tier solution that will enhance the robustness of the tactical network," said George Helm, president, Department of Defense business, Harris RF Communications. "This is the first time soldiers have used the MNVR and government-owned WNW in the field for transmitting high-bandwidth tactical information. The performance of Harris' AN/VRC-118 MNVR solution with WNW sets the stage for a successful limited user test this fall and showcases industry's ability to quickly deliver breakthrough capabilities through full and open competition in tactical radios."

The Harris AN/VRC-118 system provides two channels of tactical voice and data capability. In addition to WNW, the radio also operates the government-owned, open-standard Soldier Radio Waveform.

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GORE® Microwave/RF Test Assemblies offer unmatched precision, repeatability and durability.

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METIS Task Group Defines World's First 5G Channel Models

An Anite-led task group within the Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society (METIS) project has published the world's first channel models for 5G. An essential step towards further development of candidate 5G technologies, the interim channel models were co-authored by eight METIS partners and approved by other key members for publication.

Co-funded by the European Commission, METIS is a consortium of 29 key wireless industry players and the first international and large-scale research activity on 5G. Its main objective is to lay the foundation for 5G and address the huge surge forecast in mobile data consumption and the advanced capabilities of wireless devices.

5G has extremely challenging technical requirements which means that testing the radio channel is even more important compared to previous cellular technologies. It will adapt to various radio channel conditions in a more efficient way, utilising all dimensions of the radio channel such as delay, frequency, time, location, elevation and polarization.

> "...the huge surge forecast in mobile data consumption..."

One of the METIS project's overall technical goals is to provide a system concept that supports higher mobile data volume per area. Accurate radio channel model development enables higher data transmission volumes, which is why the definition of the radio channel model is seen as a key element in the development of 5G. The interim 5G channel models are part of the METIS Deliverable D1.2 and generally available for 5G technology developers worldwide.

ETSI and EIT ICT Labs to Boost ICT Innovation in Europe

The European Telecommunications Standards Institute (ETSI) and the European Institute of Technology (EIT) ICT Labs, the Knowledge and Innovation Community of the EIT have signed a Letter of Intent that will help future entrepreneurs to foster innovation through standardization.

This initiative will focus on the standardization of results in various areas where both EIT ICT Labs and ETSI are developing activities, such as 5G, security and privacy, urban life and mobility and other areas of common interest. While the focus is on standardization the collaboration may include joint research and education activities too. ETSI brings in experts from all stakeholders of the Information and Communication Technology (ICT) world while the EIT ICT Labs co-location centres bridge the gap between academia and industry.

"Bringing together ETSI and EIT ICT Labs respective communities and experts is a way to leverage standardization in Information and Communication Technology in Europe. Standards help to develop an eco-system for industry, covering diverse and broader markets, which in turn leads to growing and successful businesses" said Luis Jorge Romero, ETSI's Director General.

> "Standards help to develop an eco-system for industry..."

"It is the mission of EIT ICT Labs to bring innovations to life. Standardization is an important tool in achieving this especially when it comes to platforms and infrastructure solutions that are going to be deployed at large and will affect the life of hundreds of millions of people. The collaboration with an established player like ETSI in this is a great value for EIT ICT Labs and Europe," said Willem Jonker, CEO EIT ICT Labs.

Experts Examine Harmonization for SRD and UWB Devices

An ITU Workshop to facilitate the harmonization process for the global use of short range devices (SRD) and Ultra Wide Band (UWB) technologies attracted key players from the radiocommunication industry, regulators, operators, manufacturers and research institutions.

Discussions centred on the need for regional and worldwide harmonization, in particular the identification of suitable frequency ranges for these devices and new technologies along with international and national regulations to govern the conditions for their use.

Presentations on the status and developments of SRD and UWB systems were made by a number of experts, including those from regulatory bodies, academia and industry. They included representatives from CEPT, the Asia-Pacific Telecommunity (APT), the European Telecommunications Standards Institute (ETSI), the Regional Commonwealth in the Field of Communications (RCC), Airbus Industries, i4C Innovations, and UWB Communication Systems and Solutions (URAXS).

> "...an urgent need for worldwide harmonization..."

"The explosive growth of short range devices and Ultra Wide Band technologies in recent years has indicated an urgent need for worldwide harmonization to facilitate global adoption of these technologies," said ITU Secretary-General Hamadoun I. Touré. "This is especially relevant where applications such as telemedicine or airborne SRD cross national borders."

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BAE Systems and Airbus Defense and Space Form GEOINT Alliance

BAE Systems and Airbus Defense and Space have formed a strategic alliance to produce, market, and sell innovative geospatial intelligence (GEOINT) products and solutions using state-of-the-art satellite data collected exclusively by Airbus Defense and Space's TerraSAR-X® and TanDEM-X radar satellites.

Under the terms of the partnership, BAE Systems and Airbus Defense and Space will jointly aim to develop a new line of global synthetic aperture radar (SAR) products that are unrivalled in terms of accuracy, resolution, and quality. The two companies will exclusively market these jointly developed products to U.S. government, commercial, and select international customers.

> "...a major leap forward in SAR-based products and services..."

"The Airbus Defense and Space radar satellite missions are collecting data of unprecedented quality and accuracy on a global scale," said DeEtte Gray, president of BAE Systems' Intelligence & Security sector. "The products we are teaming to develop represent a major leap forward in SAR-based products and services that enhance various sophisticated applications."

"BAE Systems' expertise will leverage the SAR data we're collecting into refined sets of geospatial intelligence products, that meet stringent U.S. government standards," said Bernhard Brenner, senior vice president for Geo-Intelligence at Airbus Defense and Space.

Source: Airbus Defense and Space

photo courtesy of the
U.S. Military & NASA

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	CMA-545+	0.05-6	15	20	37	1	3	4.95
NEW	CMA-5043+	0.05-4	18	20	33	0.8	5	4.95
NEW	CMA-545G1+	0.4-2.2	32	23	36	0.9	5	5.45
NEW	CMA-162LN+	0.7-1.6	23	19	30	0.5	4	4.95
NEW	CMA-252LN+	1.5-2.5	17	18	30	1	4	4.95

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Wireless Infrastructure Drives RF Power Semiconductor Markets to Well Over $1B

Spending on RF power semiconductors for the wireless infrastructure markets has taken another jump in 2013. Other markets are seeing some moderation in growth as the global economic picture and political factors come into play but some sub-markets are showing a nice upside. Also, according to a new study from ABI Research, Gallium Nitride – long seen as the likely promising new "material of choice" for RF power semiconductors – is continuing its march to capture share, especially in wireless infrastructure.

"Gallium Nitride (GaN) is delivering increasing market share in 2014 and is forecast to be a significant force by 2019," notes ABI Research Director Lance Wilson. "It bridges the gap between two older technologies, exhibiting the high frequency performance of Gallium Arsenide combined with the power handling capabilities of Silicon LDMOS. It is now a mainstream technology which has achieved meaningful market share and will capture a significant part of the market in the future."

The vertical markets showing the strongest performance outside of wireless infrastructure in the RF power semiconductor business are the defense oriented segments, which Wilson now describes as "a significant market" in total. Despite the poor press for defense oriented electronic hardware, the actual performance in 2013 was better than originally thought for some sub-segments.

> "Gallium Nitride (GaN) is delivering increasing market share in 2014 and is forecast to be a significant force by 2019..."

Nearly 9 Billion Wireless Connectivity Chipsets to Ship during 2019 Alone

Annual wireless connectivity chipset shipments across Bluetooth, Wi-Fi, NFC, GPS, and ZigBee show no sign of slowing down, reaching almost nine billion annual shipments in 2019, finds ABI Research. Had it not been for combo chipsets and integrated platforms, the number of chipsets shipped would have been even higher. Cumulative chipset shipments from 2010 through 2014 will have reached over 21 billion; during the next five years from 2015 to 2019, cumulative shipments will almost double to over 39 billion. "That is over 60 billion wireless connectivity chipsets that will have shipped over the ten year span from 2010 to 2019, driven by the emergence of new device types," said research director Philip Solis. "There is constant change in the wireless connectivity space across wireless connectivity technologies, versions of technologies, and levels of integration at the same time."

The vast majority of wireless connectivity chipsets – 60 percent – will be stand-alone during 2014, and this share will increase to two-thirds of the market in 2019. Integrated platforms will remain relatively steady in share over the next five years. In contrast, combo chipsets will remain steady in shipment volume, but fall in share. With regards to smartphones, Broadcom dominates combo chipset solutions and Qualcomm dominates integrated platforms with wireless connectivity. In the overall market, Broadcom, Intel, Marvell, MediaTek, and Qualcomm Atheros are all strong players in stand-alone Wi-Fi chipsets. In the overall market for stand-alone Bluetooth chipsets, Broadcom, MediaTek, and RDA are strong. Broadcom is well ahead in the overall market for combo chipsets.

> "Wireless connectivity chipsets go into a vast array of types of products, and the dynamics of connectivity technologies and integration levels varies..."

"Wireless connectivity chipsets go into a vast array of types of products, and the dynamics of connectivity technologies and integration levels varies among them resulting in the aggregate effects we see," added Solis. "The technologies and integration level are going to be different in smartphones versus home automation versus other product types in the Internet of Things."

GNSS IC Revenue Heading for $3B

The GNSS IC market continues to go from strength to strength with Cellular GNSS IC revenue alone forecast to break $2 billon by 2016, with a host of secondary markets starting to emerge, according to ABI Research. This may help to explain why both Intel and Samsung have recently acquired GNSS IC design capabilities, creating competition for incumbents like Broadcom, Qualcomm and Mediatek.

The arrival of wearables, in-store advertising, ambient intelligence, IoE/IoT and the connected home has created a lot of justified excitement around indoor locations. However, GNSS is still an essential technology in tying these disparate networks together and remains the cornerstone of ubiquitous locations.

Senior analyst, Patrick Connolly comments, "Indoor locations will be a significant enabler for GNSS, driving growth in both commercial and personal asset tracking, the connected home and fitness/health. We also see consumer GNSS IC OEMs adopting sub-meter precision technologies, such as u-Blox's PPP technology, which will open up markets around UAVs, machine control, timing

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and synchronization, ADAS and the driverless car, etc. As a result, total GNSS IC revenues are set to hit $2.75 billion in 2019."

VP and practice director Dominique Bonte adds, "From an automotive perspective, the connected car, infotainment, insurance, telematics/diagnostics and safety will all increase adoption of GNSS. We can expect to see cars fitted with multiple GNSS ICs in the future. Furthermore, there are strong signals that satellite constellations such as Galileo and GLONASS will become mandatory for regional automotive applications such as emergency calling."

Global Wi-Fi Hotspots Will Grow to 7.1 Million in 2015 as a Method to Offload Traffic

Worldwide Wi-Fi deployments reached a total of 4.2 million hotspots in 2013, and will continue to grow at a CAGR of 15 percent between 2013 and 2018, exceeding 10.5 million. Among the global Wi-Fi hotspots, 68.6 percent of Wi-Fi is in Asia-Pacific, followed by 12.3 percent in Latin America, 9 percent in Europe, 8.7 percent in North America, and 1.4 percent in the Middle East and Africa. The numbers include Wi-Fi hotspots deployed by mobile and fixed-line carriers as well as third party operators.

"The mobile data growth has boosted the build-out of Wi-Fi hotspots, as it is expected that the global mobile data traffic will grow to 190,000 petabytes in 2018, from 23,000 petabytes in 2013," comments Marina Lu, Research Analyst at ABI Research. "Wi-Fi helps to offload 3G/4G mobile Internet users to Wi-Fi networks, which is a more cost-effective method for both mobile carriers and mobile users."

In Asia-Pacific, China alone has deployed 620,000 Wi-Fi hotspots, of which 420,000 have been built by China Mobile, followed by China Telecom with 128,000 hotspots, and China Unicom with 72,000. In Latin America, Brazil's carrier Oi has completed its target of 500,000 Wi-Fi hotspots by the end of 2013, ahead of the 2014 FIFA World Cup.

By deploying Wi-Fi, fixed-line operators can maximize their assets in terms of coverage, capacity, and customer experience. "Wi-Fi also represents a good opportunity for fixed-line operators to join in the mobile broadband field. The UK fixed-line operator BT with 200,000 of Wi-Fi hotspots (excl. homespots) is also providing Wi-Fi roaming services to mobile operators and other Wi-Fi providers," adds Jake Saunders, VP and practice director of core forecasting. Apart from the mobile and fixed-line carriers, the third party operators are also broadening their Wi-Fi network coverage, such as FON, provided access to more than 12 million Wi-Fi hotspots worldwide at the end of 2013 - either through its own Wi-Fi hotspots, or by securing retail access to the Wi-Fi hotspots of its carrier partners.

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Analog Devices and **Hittite Microwave Corp.** announced that the two companies have entered into a definitive agreement whereby ADI will acquire Hittite for $78 per share in cash. The closing price of Hittite's common stock on June 6, 2014 was $60.56 per share. This agreement reflects a total enterprise value for Hittite of approximately $2 billion. ADI expects to fund the acquisition through a combination of cash on hand and short-term debt financing. The Boards of Directors of each company have approved the transaction, which is expected to close near the end of ADI's third fiscal quarter of 2014, subject to regulatory approvals and other customary closing conditions. The transaction is expected to be accretive to ADI's non-GAAP earnings per share.

Cobham plc announced that it has entered into a conditional agreement to acquire **Aeroflex Holding Corp.** ("Aeroflex") for $10.50 per Aeroflex share in cash following completion, giving the proposed transaction an enterprise value of approximately $1,460m (£869m). This comprises the total issued and outstanding shares of common stock of Aeroflex and the total outstanding restricted stock units and performance restricted stock units, which are valued at approximately $920m (£548m), together with Aeroflex's net debt of $540m (£321m) at 31 March 2014.

Avago Technologies and **LSI Corp.** announced that Avago has completed its acquisition of LSI Corp. for $11.15 per share in an all-cash transaction valued at approximately $6.6 billion. The acquisition creates a highly diversified semiconductor market leader with approximately $5 billion in projected annual revenues.

RFMW Ltd. announced the acquisition of **Axomic Pte Ltd**, a specialized RF and microwave component supplier for Southeast Asian customers. The agreement increases RFMW's global footprint and enhances their corporate standing as an RF focused, technically proficient distribution organization catering to both highly technical and focused customers and suppliers.

COLLABORATIONS

Auriga announced that **Agilent Technologies Inc.** has designated Auriga Microwave a Global Solutions Partner, Agilent's highest level status for their Solution Partner program.

Remcom announced a strategic partnership with **AR Europe**, a supplier of power amplifiers, antennas, and EMC testing equipment and support. The partnership will expose Remcom's electromagnetic simulation software and services to a broader audience and make its solutions more easily accessible to European customers.

T-Tech Inc. and **The Geek Group** announced a joint agreement to offer a state of the art solution and facility for rapid printed circuit board (PCB) design, verification and fabrication. The collaboration will combine T-Tech's QCJ5 series Quick Circuit System and IsoPro® Software for PCB prototyping with The Geek Group's expertise and 43,000 square foot Leonard Street Labs Facility in Grand Rapids, Michigan. This combination is expected to represent the first makerspace in the United States with a turnkey rapid PCB prototyping solution.

STMicroelectronics and **Samsung Electronics Co., Ltd.** have signed a comprehensive agreement on 28 nm Fully Depleted Silicon-on-Insulator (FD-SOI) technology for multi-source manufacturing collaboration. The licensing accord provides customers with advanced manufacturing solutions from Samsung's state-of-the-art 300 mm facilities and assures the industry of high-volume production for ST's FD-SOI technology. FD-SOI technology at 28 nm delivers faster, cooler, and simpler semiconductor devices to meet the continuing demand for higher-performance, lower-power systems-on-chips for next-generation electronic products, such as mobile and consumer applications.

Towerstream Corp. announced a small cell services teaming agreement with **Alcatel-Lucent**, enabling a one-stop solution for carriers to deploy small cell wireless infrastructure.

Arrow Electronics, Inc. announced the availability and full design support capabilities for the expanded line of MLS flatpack aluminum electrolytic capacitors from **Cornell Dubilier**. The new additions to the MLS Series includes a high-vibration package (HVMLS) and a high-reliability burn-in option (HRMLS). The new devices are ideally suited for military and commercial flight-based power systems that require high-energy density, rugged capacitors for bulk storage. Prior to these new Cornell Dubilier devices, relatively expensive wet tantalum capacitors were the only type suited for these environments.

ACHIEVEMENTS

API Technologies Corp. announced the receipt of a strategic development order for a multi-channel microwave front end system. This integrated microwave assembly (IMA) will be used in a next generation radar warning receiver targeted for use in major Department of Defense military aircraft platforms.

Superconductor Technologies Inc. was awarded U.S. Patent No. 8,716,187, entitled "RF-Properties-Optimized Compositions of (RE) Ba2Cu3O7-8 Thin Film Superconductors" from the U.S. Patent and Trademark Office (USPTO). This patent further enhances the company's intellectual property portfolio that supports the Conductus(R) superconducting wire program.

TriQuint Semiconductor, Inc. announced that its advanced filtering solutions and multi-band, multi-mode PA modules

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Around the **Circuit**

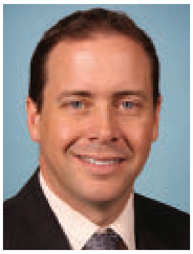
(MMPAs) for LTE smartphones have captured nearly 20 reference design wins with all six major chipset providers in greater China. In other news, TriQuint announced the appointment of Upstar Technology as its new distributor in China for TriQuint high-performance mobile products.

PEOPLE

Skyworks Solutions, Inc. announced that the board of directors has elected **David J. Aldrich** chairman of the board and CEO of Skyworks. David J. McLachlan, prior chairman, will remain a member of Skyworks' board of directors and has been designated as lead independent director.

▲ *Jay Alexander*

Agilent Technologies Inc. announced that **Jay Alexander** has been named Keysight Technologies' chief technology officer. Agilent announced in September 2013 that it would separate into two publicly traded companies in 2014. Agilent's Electronic Measurement Group is expected to begin operating as Keysight Technologies in August 2014. Alexander's appointment is effective immediately.



▲ *Paul Hart*

Paul Hart was recently promoted to senior vice president and general manager of **Freescale RF**. Hart joined Motorola Semiconductor as an RF engineer in 2001. He has been responsible for the development and new product introduction of the digital front end product family and has led the engineering efforts that have sharpened the company's focus on next generation PA architectures, radio algorithms and radio system integration, and RF PA customer reference designs. Hart's deep customer relationships and technical expertise cultivated during his tenure at the company position him well for this new role.

DelfMEMS announced the appointment of industry veteran, **David Doyle**, as vice president of sales and marketing. He joins the company from MEMS innovator, Baolab Microsystems where he was CEO, and his previous experience includes executive management positions at ARC International and Motorola Semiconductor amongst others.

▲ *Alex Cox*

Transline Technology announces the expansion of its West Coast operations. **Alex Cox**, the company's newest local sales engineer, will lead this effort from his San Francisco Bay Area office. Alex brings 19 years of technical sales experience in the electronics industry and has extensive working knowledge of defense aerospace, wireless, RF microwave, telecommunication, and semiconductor applications. Immediately prior to joining Transline Technology, Alex amassed a decade of hands-on experience with a major electronic equipment company. During that tenure, he provided R&D, electrical, and design

engineering teams with highly-responsive engineering and customer service support.

REP APPOINTMENTS

A1 Microwave Ltd announced a number of new appointments of representatives for their filters and waveguide assemblies business; **EMA** for Florida, Georgia, North and South Carolina, Maryland, Delaware, Virginia, Mississippi, Alabama, Tennessee, **MC Microwave** for Northern California and **S&S Technology** for Southern California. A1 Microwave continues to grow its business in the USA and is looking for representatives for Texas, New York, New Jersey, and New England territories.

Arrow Electronics, Inc. announced that its RF & Power business will distribute products in the Americas from **Telegesis Ltd.**, a U.K.-based company that specializes in ZigBee RF modules and firmware. Telegesis' product range features its core product family of ZigBee modules, as well as ZigBee USB sticks and a ZigBee-to-Ethernet gateway. Firmware for these products includes standard-compliant ZigBee Smart Energy and Home Automation profiles. Telegesis also offers support for custom ZigBee hardware and firmware, and management of ZigBee, EMC and safety certifications for customers' end products.

Custom MMIC is pleased to announce the appointment of **Spartech-South** as their technical sales representative in the southeastern states of the United States. Spartech-South's principals manufacture RF, microwave, and high frequency digital signal processing products and provide coverage in Florida, Georgia, Alabama, North Carolina, South Carolina, Tennessee and Mississippi.

Intercept Technology Inc. announced its newest authorized reseller, **Hankuk Valence Co.** With over 25 years of experience in the electronics industry, Hankuk Valence plans to increase its customer base by expanding sales with Intercept's EDA software solutions. Intercept's EDA software solution provides users with scalable design and engineering software that can be tailored for simpler designs to the most complex PCB, RF, Hybrid and mixed signal boards, panels, and panel arrays.

Peregrine Semiconductor Corp. announced the addition of six new sales channel partners in the EMEA and Asia Pacific regions. The channel partners have been appointed to drive design wins for UltraCMOS high performance analog (HPA) products in these important markets. To serve EMEA, Peregrine has appointed Interlligent, Link Microtek and Vostock. In the Asia Pacific region, Peregrine has appointed Asiacom, Tecnomic and Acromax.

RFMW Ltd. and **Delta Electronics Manufacturing Corp.** announced a worldwide distribution agreement effective immediately. Delta Electronics offers a full range of RF/Microwave and Millimeter wave interconnects. The agreement authorizes RFMW to stock, promote and sell Delta's complement of RF connectors and cable assemblies. The company's 7/16, BNC and N types, along with their high frequency components have expanded to include PIM sensitive offerings.

Interoperability Enables a Complete RFIC/Package/ Board Co-Design Flow

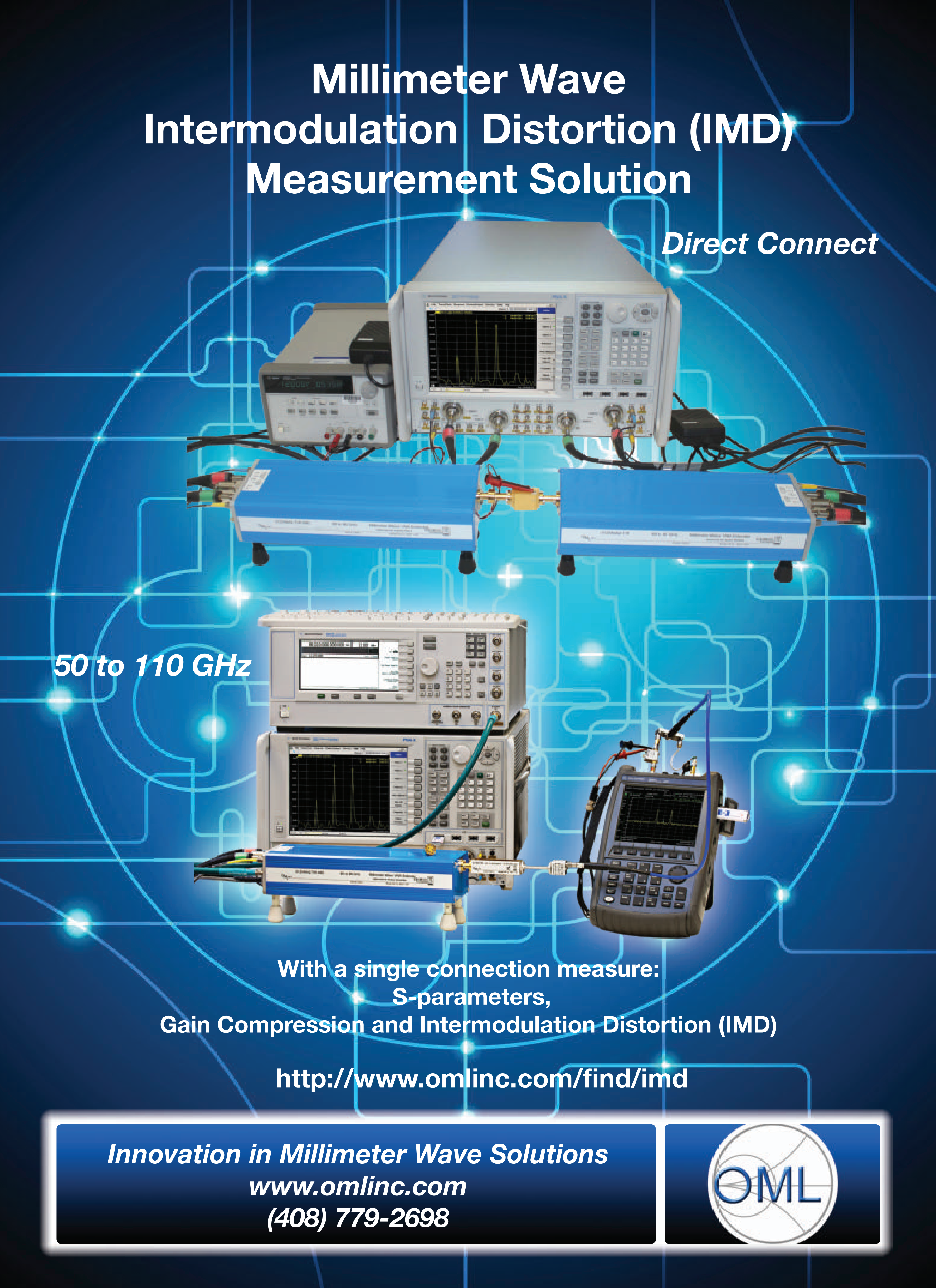
Juergen Hartung
Agilent Technologies, Santa Clara, CA

The demand for mobile communication devices has grown dramatically in recent years, further taxing an already difficult design process. Adding to the stress is the need for multi-standard support at higher and higher data rates and new applications at mm-wave frequencies. Product form factors are shrinking and designs must be lower cost, have a tighter power budget and higher electrical performance. Just as critical, those designs and subsequent products are being constrained by shrinking design cycles.

The main challenge is no longer the implementation of the RFIC itself, but its integration into the overall system—which could be a single package, some type of chip-level wafer-scale package, or a module/System-in-Package (SiP)—while still ensuring that the system meets tight performance requirements when measured on a reference board. Addressing these challenges requires a holistic approach with a complete, interoperable tool flow and design methodology; one that provides enough flexibility to accommodate the varying integration types, underlying process technologies and customer-specific design constraints that may change from one product generation to the next or across applications.

AN INTEROPERABLE CO-DESIGN FLOW

Traditionally, MMIC and silicon RFIC designers have worked independently. Their designs have been created, simulated, implemented, and verified separately using different tools, methods and flows. Cadence Virtuoso is a widely used platform for silicon-CMOS design, especially for larger analog/mixed-signal applications. Agilent ADS is a leading tool for gallium-arsenide (GaAs) and gallium-nitride (GaN) MMIC design.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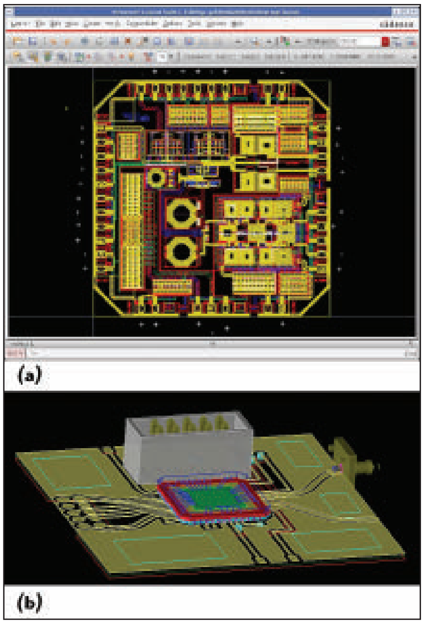


▲ *Fig. 1 EM simulation of parts of the RFIC together with the QFN package and the board.*

While there is already a need to interface between the two worlds, the move from III-V materials to silicon for components (e.g., antenna switches in CMOS-SOI) and the increase in mm-wave silicon applications for wireless HDMI and radar, further blurs the boundary between these tools and the specific jobs for which they should be used. Which tool to use and when was previously determined by a variety of factors, including: designer preference, process design kit (PDK) support, circuit type, or even just historical factors like what the designer may have used in the past and whether that experience was a good one, rather than how the designer might best accomplish a given task.

A one-size-fits-all tool is not realistic given the breadth of applications and processes. Going beyond the IC level, the need for solutions across design domains becomes even more obvious. Conventional IC layout tools are 2D and only allow a single (silicon) substrate carrier for drawing devices and interconnects, while a tool like ADS enables multi-technology design and the integration of parameterized 3D components.

In order to provide the best design support at any given time, a true interoperable co-design flow is required. What is co-design? Simply put, a co-design environment allows the designer to validate and optimize the overall system, including the interfaces between the connected components (e.g., IC-to-IC, IC-to-package or package-to-board).

In the past, a great deal of effort was spent integrating a certain capability (tool) into a widely used platform or providing import/export links between the two environments. Several years ago, however, OpenAccess was introduced as a new common database for custom IC design. Since then it has become the de-facto standard, with most EDA vendors now supporting it. Additional efforts like the introduction of iPDKs have followed with the goal of enabling interoperability between EDA tools.

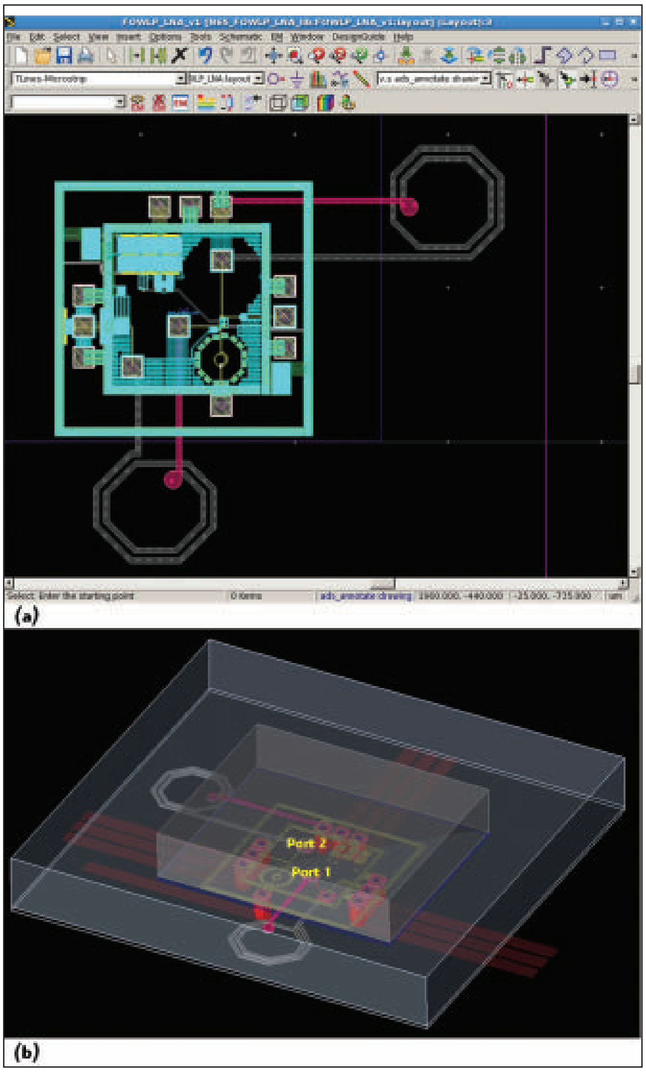
These efforts have provided tools like ADS and Virtuoso enhanced interoperability, and enabled them to present designers with a true interoperable co-design flow. Using this flow, designers working at the schematic level can now open a single OA schematic view in Virtuoso or ADS, modify it, simulate it, and then bring it up again in the other environment. At the layout level, designers can open a Virtuoso layout view in ADS, assuming the SKILL pcells are flattened.

Now the question is: How does this help designers address the challenges associated with designing today's wireless front-ends? To answer that question, we'll show three different examples of how RFICs are currently being integrated (an RFIC in a QFN package, a flip-chip wafer-level chip-scale package and an RF module) and how the proposed interoperable co-design flow can be used to address them. All three examples have the same design requirements.

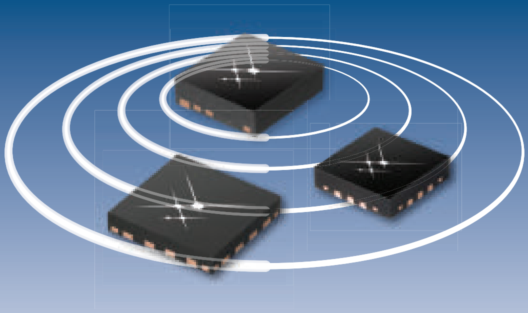
VALIDATING AN RFIC, INCLUDING QFN PACKAGE AND BOARD EFFECTS

RFICs are typically put in surface mount technology (SMT) packages with maximum operating frequencies of up to about 45 GHz. The most popular package style for radio and microwave frequency ICs is the quad flat no-leads (QFN) package.[1] At higher frequencies, the series inductance of the RF signal bond wires and the overall grounding inductance (IC, package and board) are two examples of the challenges designers need to consider.

Figure 1 shows the layout of a transceiver IC in Virtuoso. The pad ring, along with the top-level intercon-



▲ *Fig. 2 Fan-out wafer-level package test structure with integrated passives (a) and 3D view including solder balls and board traces (b).*



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- Typical input $P_{1\,dB}$: 30 dBm @ 3 V
- Low insertion loss: 0.3 dB @ 0.9 GHz
- Low DC power consumption
- Package: QFN 6L 2 x 1.25 x 0.9 mm

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- Integrated high performance 5 GHz PA with harmonic filter, LNA with bypass, and SPDT
- Transmit / receive gain: 30 / 11 dB
- Output power: 18 dBm @ 3% EVM, 64 QAM 54 Mbps
- Package: QFN 16L 2.5 x 2.5 x 0.45 mm

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- For tablet/notebook computer, monitor, and other portable device applications
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- Frequency range: 600 kHz to 2 MHz
- Up to 93% efficiency
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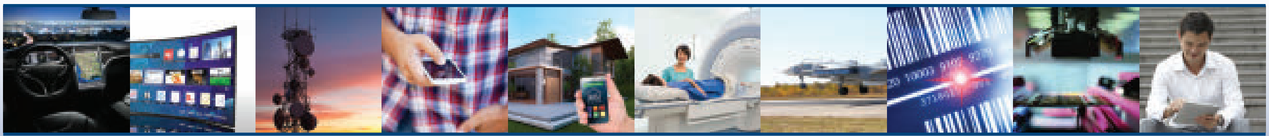

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nects from the low noise amplifier (LNA) to the power amplifier (PA), are saved as a layout cellview in Virtuoso and opened in ADS. This part of the IC is put into a QFN package, which is available in ADS as a "pcell." The designer does not need to draw any package layout other than adding the bondwires to the chip and placing it on a reference board that includes parameterized 3D models for connectors.

From the full configuration (shown as a 3D image from ADS), a 3D finite-element method (FEM) simulation is launched that captures the complete couplings in the resulting S-parameter file. An EM/circuit co-simulation could also be launched from the corresponding schematic test bench to minimize parasitic effects or optimize the grounding path, while considering additional coupling from the package, or how the matching at the RFIC outputs changes and would require circuit retuning.

ENABLING FAN-OUT WAFER-SCALE-PACKAGE CO-DESIGN

Wafer-level chip scale packages (WLCSP) are becoming more and more popular as a way to reduce RF parasitics and overall design size, while improving performance. In flip-chip wafer-level packages, solder balls are directly put on top of the silicon die and connected by metal traces in one or more re-distribution layers (RDLs.) This is then mounted directly onto the board with the surface of the die facing down. In so-called fan-in configurations, the resulting "package" is truly chip scale, while with fan-out, the die is embedded in a molding compound that allows a higher I/O count without being limited by the actual die size. Fan-out configurations also allow for multiple dies to be embedded within the molding compound and enable larger, more highly integrated systems.[2]

Figure 2 shows a layout of a fan-out wafer-level package CMOS IC along with two embedded inductors over the molding compound. Even without considering the 3D nature of the solder balls or taking the board into account, this configuration cannot be captured in a classical (2D) IC

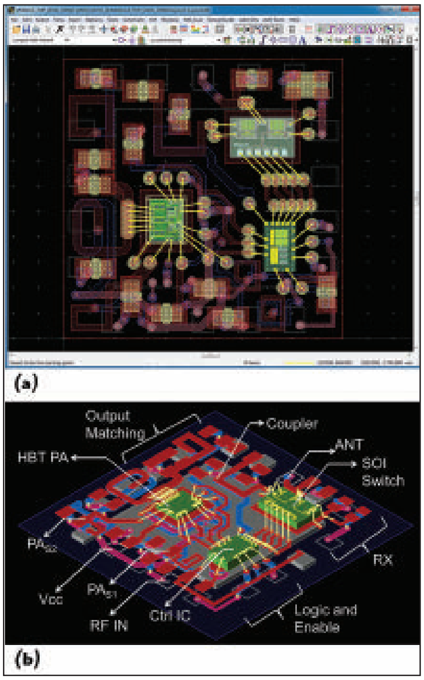

Fig. 3 PA module.

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- Frequency Range:
  0.5 to 2.0 GHz & 2.0 to 18.0 GHz
- Dynamic Range & Phase Shift:
  20dB & 360 deg. (0.5 to 2.0 GHz)
  16dB & 360 deg. (2.0 to 18.0 GHz)
- Attenuation vs. Frequency:
  +/1.5dB Typ. (0.5 to 2.0 GHz)
  +/3.5dB Typ. (2.0 to 18.0 GHz)
- Phase vs. Frequency:
  +/-10 deg. Typ. (0.5 to 2.0 GHz)
  +/-20 deg. Typ. (2.0 to 18.0 GHz)
- Switching Speed: 500 ns Max.
- Size: 5.0" X 5.0" X 1.0" (0.5 to 2.0 GHz)
  4.25" X 3.5" X 1.0" (2.0 to 18.0 GHz)

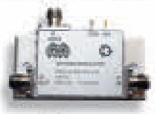
50MHz to 1.0 GHz & 0.5 to 2.5 GHz Single Sideband Modulators
Model No: PSM-50M1G-CD-1 & PSM-0R5G2R5G-CD-1


- Frequency Range:
  50MHz to 1.0 GHz & 0.5 to 2.5 GHz
- Quadrature Phase Accuracy:
  7.5deg. Typ. (50 MHz to 1.0 GHz)
  7.0deg. Typ. (0.5 to 2.5 GHz)
- Quadrature Amplitude Accuracy:
  +/-1.5dB Typ.
- Carrier Suppression:
  15dBc Min. (50 MHz to 1.0 GHz)
  20dBc Min. (0.5 to 2.5 GHz)
- IF Modulation Frequency Range:
  DC to 10MHz (50MHz to 1.0 GHz)
  DC to 500MHz (0.5 to 2.5 GHz)
- Size: 6.0" X 3.5" X 1.0" (50MHz to 1.0 GHz)
  2.5" X 2.0" X 0.5" (0.5 to 2.5 GHz)

85MHz to 18GHz I/Q Modulator
Model No: PIQ-85M18G-360/20-CD-2

- Frequency Range: 85 MHz to 18.0 GHz
- Phase Range: 360 deg.
- Attenuation Range: 20dB
- Attenuation Resolution: 0.1dB Max.
- Phase Resolution: 0.8 deg. Max.
- Size: 6.0" X 3.0" X 1.0"

1.0 to 2.0GHz Bi-Phase Modulator
Model No: BPM-1G2G-1-SFF



- Frequency Range: 1.0 to 2.0 GHz
- Amplitude Balance: 0.75 dB Max.
- Phase Balance: +/-5deg. Max.
- Carrier Suppression: -30dBc Typ.
- Switching Speed: 5 ns Typ.
- Size: 2.0" X 1.0" X 0.5"

2.0 to 6.0 GHz & 50MHz to 14.0GHz Phase Shifters
PMI Model No: PS-2G6G-8B-SFF & PS-50M14G-10B-SFF

- Frequency Range:
  2.0 to 6.0 GHz & 50 MHz to 14 GHz
- Phase Range: 360 deg.
- Control:
  8 Bit TTL (2.0 to 6.0GHz)
  10 Bit TTL (50 MHz to 14.0 GHz)
- Switching Speed: 500 ns Typ
- Phase Accuracy: 0.5 deg. Typ.
- Size: 3.25" X 3.25" X 0.84"

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layout tool. The 3D view of an excerpt of a test structure, including true 3D solder balls and the test board, is also shown in Figure 2. Simulation results of the complete configuration confirmed a noticeable shift compared to simulations where the test structure needed to be split into an on-die and a molding area and without considering the solder balls or test board interconnects.

IMPLEMENTATION OF AN RF MODULE

RF front-end modules are a final example used to describe the design challenges of multi-technology systems in more detail. ***Figure 3*** shows a typical PA module with 3 die—a GaAs HBT PA in a WIN process, Silicon-on-Insulator (SOI) transmit/receive switch in a CS18 process from TowerJazz and a control IC—on a 4-layer laminate with additional surface mount devices and embedded passives. The main design challenge here is to understand and address any potential problems coming from the interface between the IC technologies. Since design cycles are very short in the commercial wireless space, it is necessary to predict and solve these problems up front so that demanding product sampling schedules can be met.

Assume that the GaAs PA was implemented front-to-back in ADS and the digital control IC was implemented in Virtuoso. The RF section of the SOI switch was done in ADS in order to model the EM effects on the device, while the analog portion was done in Virtuoso. With the interoperability support described earlier, the RF module designer can now easily bring the design collateral together and co-design the system with full fidelity.

For example, the switch IC designer may design a circuit that meets a receiver isolation requirement, only to find out that at the module level, adjacent wire coupling degrades this isolation. The switch designer can now co-design the switch within the SOI and laminate technologies simultaneously; that is, the designer can investigate whether spacing of IC pads would help, if another series/shunt device should be added, or if a flip chip approach would yield better isolation.

An automated EM/circuit co-simulation flow, like that in ADS, makes it very efficient to mix and match different levels of the design hierarchy and manage what should be covered by the EM simulator or if existing schematic representations, models or even parasitic extracted views are being used. Also critical for such applications is an electro-thermal simulator, which provides "thermally aware" simulation results that account for thermal coupling between devices, as well as heat transfer through the die and packaging.

An important element of the flow is the efficient back-annotation of the extracted model or S-parameter data files to the top-level test bench for a parasitic re-simulation. As an example, ***Figure 4*** shows the PA module top-level test bench in ADS with look-

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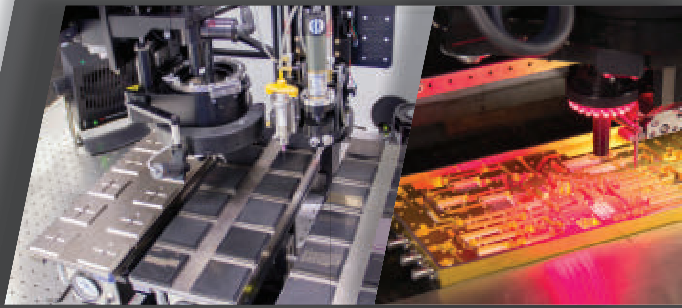

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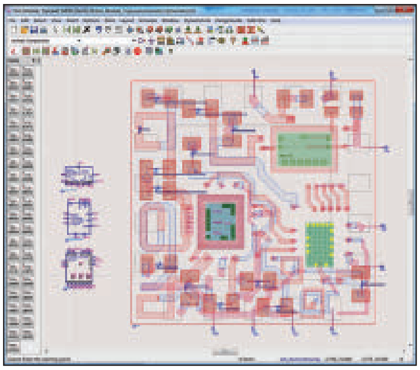
alike symbol for the laminate. Having all the design collateral in a single database not only allows quick setup and EM simulation, but also easy usage of the results across the design hierarchy, like capturing die to laminate interferences.

CONCLUSION

Based on the three different application examples presented, it is easy to understand why an interoperable co-design flow is so critical to confidently and efficiently designing RFICs and integrated packaging configurations. The design process manages the electrical and physical interfaces between design components across all of the associated design domains. In the future we will see continued trends toward increased integration, such as further PA module integration in SOI technologies, as well as tighter integration between front-end modules and transceivers. Despite this, the need for and importance of an interoperable, co-design flow does not go away. Instead, it becomes even more crucial. Use of this flow is the only way to reconcile aggressive time-to-market demands, complex cost structures and challenging tradeoffs in system architecture.■



▲ *Fig. 4 PA module top-level test bench in ADS with look-alike symbol for the laminate.*

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2. C.C. Liu et.al. "High-performance integrated fan-out wafer level packaging (InFO-WLP): Technology and system integration," *Electron Devices Meeting (IEDM)*, IEEE International Conference, San Francisco, CA, 2012, pp. 14.1.1-14.1.4.

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Overview of RF Switch Technology and Applications

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Peregrine Semiconductor, San Diego, CA
Drew Fischer and Ruan Lourens
National Instruments, Austin, TX

Modern RF instrumentation is heavily dependent on switch technology. As both power consumption and space requirements shrink, selecting the appropriate switch solution becomes increasingly important. This article provides an overview of RF switches and considerations for selection based on function within the RF instrument.

OVERVIEW OF TECHNOLOGIES

Solid State Switches

Solid state switches can be divided into two primary categories: diode and field-effect transistor (FET). PIN diode switches are generally realized using discrete implementations and are known for higher power handling and fast switching speed, but the fairly complex biasing schemes and high levels of DC power required are significant disadvantages, especially for battery-operated instrumentation. PIN diodes require a forward current through the device to establish a low series resistance. This direct injection of DC current into the RF channel limits low-frequency operation.

FET-based switches are more commonly found in integrated solutions because the switching behavior is voltage-dependent. The control voltage applied to the gate of the FET "switches" the channel from a low-resistance "on" state to a high-resistance, capacitive "off" state. Three-terminal FET devices feature minimal DC power consumption and separate gate control of the channel. The high impedance of the gate supports a broadband response, but the FET is still frequency limited by finite capacitance between the RF channel and the gate terminal, as well as channel capacitance when the device is in the "off" state.

There are two distinct FET types commonly used in industry today: MESFETs and MOSFETs. MESFETs are fabricated using gallium arsenide (GaAs) and gallium nitride (GaN) processes, while MOSFET devices are commonly silicon-based. A primary distinction between the two types is the asymmetric behavior of the MESFET gate to applied voltage.

Electromechanical and MEMS Switches

Electromechanical (EM) switches use a different mechanism than their solid state counterparts. In an EM switch, a metal contact is actuated to make or break the connection. This technology offers the advantages of low insertion loss, high isolation, and high linearity.[1] Emerging microelectromechanical systems (MEMS) switch technology attempts to deliver the advantages of traditional EM switches, but in a small form factor. MEMS switches employ micro-miniaturized mechanical contacts controlled by electrostatic forces to make RF connections.[1, 2]

PERFORMANCE CATEGORIES

No single switch solution can satisfy all of the various requirements for each application. Frequency range, power handling, linearity, switching speed, insertion loss, isolation, video feedthrough, power consumption, and reli-

ability are important considerations in determining which technology to use.

Frequency Coverage

Operating frequency is often one of the first considerations when selecting an RF switch for a given application. This category is multifaceted in that several other performance metrics, such as power handling and linearity, are dependent on frequency.

Low-frequency performance is another consideration that is equally important. The frequency response of FET and PIN diode switches is influenced by external components, such as RF bias chokes and DC-blocking capacitors. Even though a switch may be specified to operate at very low frequencies, the frequency response of DC-blocking capacitors may limit its ability to do so. Careful selection of these external components is necessary to preserve switch performance.

PIN diode switch performance degrades at low frequencies, where the diode no longer behaves like a variable resistance, but begins to function as a PN junction diode that rectifies the signal, thereby degrading switch linearity. The frequency at which this transition occurs is not clearly defined, but performance degradation can usually be avoided by operating the PIN diode above the transit time frequency of the device (f_c), which depends upon its physical size per the equation:[2,3,4,5]

$$f_c > \frac{1}{2\pi\tau} \tag{1}$$

where:
f = transit time frequency (Hz);
τ = transit time of device (s).

FET-based switches have the capability of operating down to very low frequencies;[2] however, power handling degrades due to the impact of the FET's reactance on the gate.[6] At the high end, GaAs FET switches have operating frequencies extending beyond 50 GHz. PIN-based switches are available with operating frequencies in excess of 70 GHz.

EM switches can operate all the way down to DC, as their inherent metal-to-metal switch contacts have no fundamental limitation to low-frequency operation or the passing of DC signals. As a miniaturized advancement of EM switch technology, MEMS switches can also operate down to DC; however, more attention must be paid to the maximum current carrying capabilities of the conductor to avoid fusing the switch.

Power Handling and Linearity

Power handling has come a long way from being just a simple maximum current or voltage rating for a switch element. Today's extremely low energy-per-bit modulation schemes, such as 16,384-QAM of DOCSIS 3.1, and increased potential of self-jamming, as in LTE-A Band 5 and 13, require the RF switch to perform exceptionally well at peak power levels to meet in-band error vector magnitude (EVM) requirements as well as adjacent and out-of-band metrics. Out-of-band harmonics, adjacent channel leakage ratio (ACLR), and spurious levels are critical in today's communication schemes.

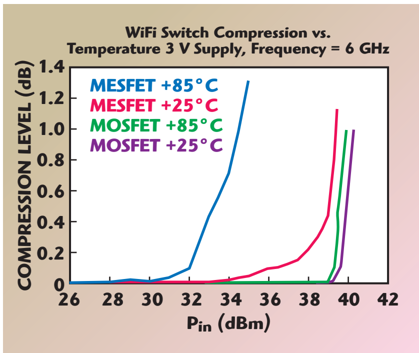
Power handling is determined by the voltage or current limitations of the fundamental device technology. Linearity assesses the ability of the switch to faithfully transfer a signal without distortion. Common metrics are third-order intermodulation products and generated harmonics.

An important consideration is the ability of the technology to scale to power requirements. In MOSFET switches, this is commonly achieved by stacking multiple devices to support the maximum voltage level. A 3 V device requires a stack of four to support a 30 dBm (1 W) 50 ohm referenced RF signal. Multiple devices in series increase the total channel resistance, which is compensated by increasing the gate periphery of each individual device.

Compression characteristics can also affect linearity metrics where AM-AM distortion maps into nonlinear behavior and increases EVM. The soft compression behavior of MESFET devices is a drawback versus MOSFET devices, which have a definitive breakdown characteristic. ***Figure 1*** compares a MESFET- and a MOSFET-based WiFi switch showing sharper compression of the MOSFET device.

Switching Speed

For certain systems, the switching speed of an RF switch is critical. "Switching time" is described as the RF signal rise time through the switching elements (typically the 10 to 90 percent transition). The complete turn-on time (t_{ON}) includes the delay of the internal bias circuitry and is typically defined as 50 percent of control signal to 90 percent of output signal. Conversely, the turn-off time (t_{OFF}) is defined as 50 percent of control to 10 percent of output. PIN diode and FET switches can switch on the order of microseconds or nanoseconds, whereas EM switches typically take much longer (on the order of milliseconds).



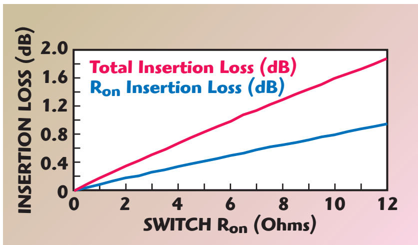
▲ *Fig. 1 Compression characteristic of a MESFET versus a MOSFET WiFi switch showing the sharper compression behavior of the MOSFET device.*

Another important switching time definition, especially in amplitude-sensitive applications, is the time period beyond the 10 to 90 percent switching and is commonly referred to as the "settling time." This period is defined for amplitude settling within, for instance, 0.1 or 0.05 dB of the final value. GaAs switches have relatively long gate lag periods due to charge trapped in the channel, but progress is being made to reduce this settling delay with improved device structures and biasing schemes.

Related to device switching is repeatability. The insertion loss of mechanical switches can vary from cycle to cycle due to contact surface effects. In comparison, solid state switches are generally more repeatable, but can suffer from variations in insertion loss over temperature, process, and bias levels.

Insertion Loss

Insertion loss defines the amount of signal attenuation that occurs for a given switch path. The insertion loss of a basic single-pole-double-throw



▲ *Fig. 2 Insertion loss versus switch R_{on}.*

(SPDT) switch can be divided among three major factors: (1) resistive loss caused by the finite resistance of the "on" channel; (2) reflective loss due to the resistance R_{ON} added to the load impedance; and (3) signal leakage through any "off" path device capacitance. ***Figure 2*** compares the total insertion loss of a switch to that due to its "on" resistance.

Any change to reduce either the "on" resistance or the "off" capacitance while holding all other parameters constant would be beneficial. The switch figure of merit ($R_{ON}{\cdot}C_{OFF}$) provides a means of comparison between different technologies, where a lower figure of merit will result in lower insertion loss. ***Table 1*** shows the figure of merit for common solid state switch technologies. EM and MEMS switches typically offer very low insertion loss and have lower figures of merit than their solid state counterparts. It is important to note that $R_{ON}{\cdot}C_{OFF}/V_{MAX}$ is sometimes used instead to capture differences in the maximum device voltage between processes. A drop in R_{ON} may be accompanied by a drop in V_{MAX}, and this may negate the R_{ON} improvement if power handling is a critical parameter.

To achieve broadband insertion loss performance at high frequencies, the challenge is in managing the "off" device capacitance. This is commonly done by reducing device size while accepting degradation in the minimum insertion loss at low frequencies. Sometimes asymmetric switch architectures are used to optimize for unique frequency bands or to optimize insertion loss and isolation for distinct paths, such as minimal loss and power handling on transmit paths and minimal loss and increased isolation on receive paths. Narrowband tuning techniques can be leveraged to minimize capacitive effects and recover much of the insertion loss degradation over a 10 to 20 percent bandwidth.

Isolation

Switch isolation is defined by the transmission of an RF signal to the disengaged throws of the switch. Ideally, the entire input signal flows from the input to the desired output; however, in reality, some of this signal leaks to the undesired outputs.[4] A PIN diode or FET impedes signal flow through the device when it is not in its conducting state; when reverse biased, the device presents a high resistance. An EM or MEMS-based switch achieves isolation by physically disconnecting the metal-to-metal contact of the conduction path.

The non-conducting states of these devices, however, are not perfect, with non-idealities, such as parasitic capacitances that degrade the ability to impede signal flow. For series PIN diodes, the presence of a parallel junction capacitance degrades isolation between its terminals at higher frequencies. In general, a smaller junction capacitance yields higher signal rejection.[3,4] For FETs, capacitance between the drain and source introduces similar frequency-dependent effects on isolation.[2,6] For EM and MEMS-based switches, isolation is determined by the separation distance between switching contacts; greater distance yields higher isolation.

For each switch technology, different topologies can be employed to improve isolation. One primary example is the combination of series and shunt switching elements: when a switch path is disengaged, the series element is biased in the isolation state and the shunt element is biased in the conduction state, which essentially shorts the input signal to ground.[2,4,6] Both PIN- and FET-based switches are available with low-frequency isolation as high

TABLE I

SWITCH FIGURE OF MERIT ($R_{ON}{\cdot}C_{OFF}$)

$R_{ON}C_{OFF}$ (fsec)	PIN	VPIN[11]	GaAs[2]	GaN[10]	UltraCMOS 8[12]	UltraCMOS 10[12]
	1.5×	1.1×	2×	4.1×	1.6×	1

as 80 to 90 dB and high-frequency isolation as high as 40 to 50 dB. EM switches are available with ratings as high as 100 to 120 dB.

Video Feedthrough

Video feedthrough is manifested in the form of voltage transients that appear at the outputs when an RF switch changes path. This unintended signal occurs even without an RF signal passing through the switch. It is generated by the switch's control signal and the discharge of biasing components.[7]

Video feedthrough is not commonly specified for RF switches, but can be an important consideration for certain applications. For example, high-gain amplifiers – especially those with automatic gain control – will momentarily compress or even sustain damage due to video feedthrough spikes. Similarly, these voltage spikes could cause damage to or interfere with the operation of instrumentation connected to the switch outputs. Receivers used for covert monitoring for signal intelligence (SIGINT) require very low levels of video leakage to remain invisible to outside observers.

Although this effect can be observed in both PIN diode and FET-based switches, it is generally more prominent in PIN diodes due to the presence of both the DC bias and the RF signal on the same path. The DC-blocking capacitors used to contain the bias within the PIN diode switch will charge and subsequently discharge when the control signal toggles from forward to reverse bias (and vice versa). In FET-based switches, the separation of the control signal from the RF path greatly reduces the amount of video leakage generated during switching.[7]

Switch Control and Power Consumption

The circuitry required to bias different solid state switch technologies has various degrees of complexity depending on the desired frequency, bandwidth, power levels, and switching speed. PIN diodes may have very fast switching speeds, but the drive circuitry can be complex. Limitations in the ability to tune out parasitic elements result in the need for expensive broadband chokes and more exotic assembly techniques. Bias voltages can also be relatively high and may consume high DC power while requiring large and complex filter networks to combat video feedthrough and other noise from coupling into signal paths.

Control circuits for voltage-controlled FET devices are generally simpler and require lower power, but often have a fixed RC delay that limits switching speed. There is design flexibility in setting the switching speed with possible tradeoffs in low-frequency power handling and insertion loss. Additional components, such as blocking capacitors, may need to be placed in the signal path due to the common-mode level requirements needed to ensure proper channel control.

Many solid state switch solutions are available with integrated bias and control. This reduces system cost and complexity, but can impact performance and limit flexibility. For example, some parts use integrated charge pumps to generate the internal bias levels needed for switching; however, charge pump spurs can be injected into the RF signal.

Reliability and Lifetime

Reliability and lifetime are critical when selecting switches for applications that require repeated switching or expose the device to harsh or uncontrolled environments. EM switches have limited lifetimes due to their mechanical switching mechanisms. Normal wear and tear over time will cause these structures to degrade. Solid-state switches provide the unique advantage of never wearing out by simply being switched under normal operating conditions, since no moving parts are used. For these switches, life expectancy is determined by overall time in operation, not the number of switching cycles. When used within specifications, solid state switches can exceed 500 million cycles, whereas EM switches typically endure 10 million or fewer operations.[8] Switch lifetime can degrade when operated under conditions that introduce additional stresses, such as elevated operating temperature, thermal fluctuations, or exposure to excessive signal power.

Another potential stress is hot-switching, which occurs when the device is switched while an RF signal is being applied. Although switches are specified for a maximum power

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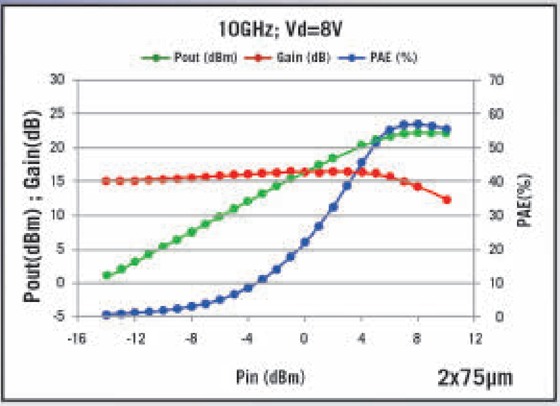
- 0.25μm PHEMT process on 100μm substrates
- Power performance at 8V and 10GHz: >1W/mm, PAE 56%, 14dB Gain

PP25-21 (Class-AB) Tuned for Pout



Gain (dB)	P1dB (dBm)	P1dB (mW/mm)	Psat (dBm)	Psat (mW/mm)	PAE Max(%)
15.0	22.1	1086	22.2	1114	56.8

2x75μm device @8V, 10GHz, 150 mA/mm

Summary of WIN mmWave pHEMT portfolio

	PP25-21	PP15-50/51	PL15-12	PP10-10/11
Gate length	0.25 μm	0.15 μm	0.15 μm	0.1 μm
Max Drain Bias	8 V	6 V	4 V	4 V
Idmax (Vg=0.5V)	490 mA/mm	620 mA/mm	525 mA/mm	760 mA/mm
Peak Gm	410 mS/mm	460 mS/mm	580 mS/mm	725 mS/mm
Vto	-1.15 V	-1.3 V	-0.7 V	-0.95 V
BVGD	20V(18V min)	16V(14V min)	9V(8V min)	10V(8V min)
f_T	65 GHz	90 GHz	100 GHz	130 GHz
f_{max}	190 GHz	185 GHz	150 GHz	180 GHz
Power Density (2x75μm)	1100 mW/mm @ 8V, 10GHz	870 mW/mm @ 6V, 29GHz	580 mW/mm @ 4V, 29GHz	860 mW/mm @ 4V, 29GHz (2x50μm)

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handling, this can degrade when hot-switched. PIN diode switches are typically more robust when switched at high powers, whereas switched FETs transition through a region during which high amounts of signal power may be dissipated.[9] The ability of the FET switch to withstand this increased dissipation depends on its specified power handling. For example, GaN devices exhibit excellent power handling and can thus handle hot-switching at higher power levels.[10] MEMS switches are typically more sensitive to hot-switching, as micro-welding between contacts can occur, resulting in reduced lifetime.[1]

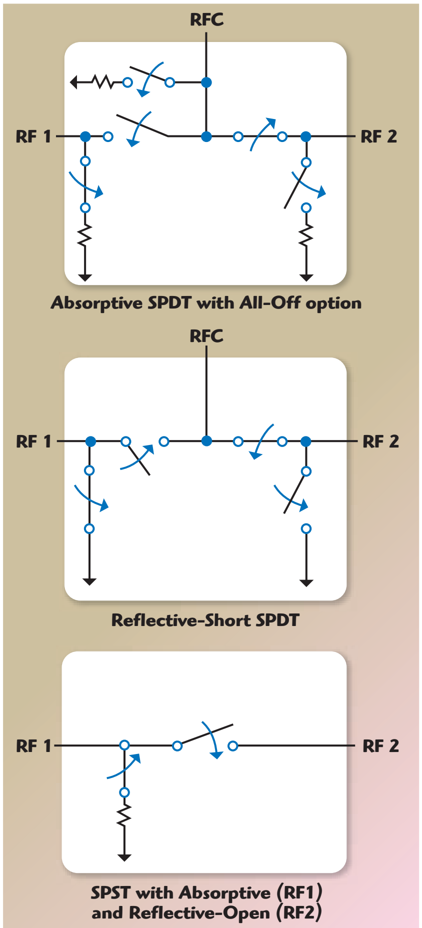
RF switches can also be susceptible to electrostatic discharge (ESD), which occurs when static charge is suddenly transferred between surfaces with differing voltage potentials. This can subsequently damage sensitive devices. GaAs switches are generally more sensitive to ESD, with typical ratings of 200 V. MEMS switches are similarly sensitive. PIN diode switches have a moderate sensitivity to ESD, and CMOS technology (including SOI) are relatively robust in this regard, with ratings as high as 4 kV.[2]

APPLICATIONS

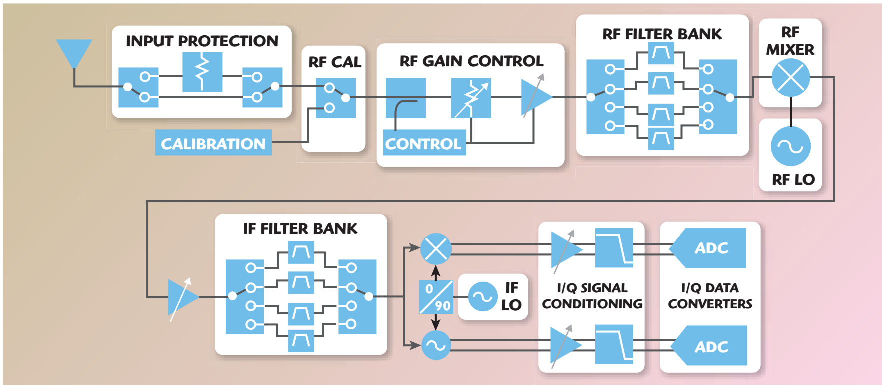
Architecture Considerations

Two basic switch architectures that describe the behavior of the unused switch port are classified as absorptive or reflective (***Figure 3***). Absorptive switches present a termination (most commonly 50 Ohms) to the unselected arm typically at the expense of increased insertion loss. Reflective switches leave the unused port unterminated.

Reflective switches can be further categorized as either reflective-open or reflective-short. This distinction is critical in understanding the corresponding impact on the circuitry tied to that path. Reflective-open architectures do not have a shunt path to ground in the "off" state; as a result, the loading on the unused port will be minimized. For example, LNA bypass switches are reflective-open in order not to disturb the LNA's functionality when the switch is in the "off" state. For reflective-short architectures, a shunt path to ground is established. This low impedance renders attached circuitry effectively useless.



▲ *Fig. 3 Basic switch architectures that describe the behavior of the unused switch port.*



▲ *Fig. 4 Example receiver block diagram highlighting typical switching requirements.*

Overview

Switching requirements for RF systems vary dramatically, and the performance metrics outlined in this article provide a means by which switch performance can be evaluated and compared. Test and measurement applications use broadband switches extensively, while communications systems are more likely to use narrowband switches to maximize performance. Narrowband designs often use inductance to resonant-tune the switch "off" capacitance in order to minimize insertion loss and maximize isolation over a more restricted bandwidth.

Transmit/receive-based radar applications require very fast switching speeds since this is crucial in setting the minimum close-in range that can be detected by the radar system. Switch too slow and the reflected transmit signal will already be past the receiver by the time the switch settles. Conversely, less time-sensitive applications, such as one-time, "set-and-forget" uses, can target better insertion loss or very low operational frequencies at the expense of a greatly reduced switching speed.

Application Example: RF Receiver Architecture

Covering all possible system considerations is beyond the scope of this article. As such, an example receiver block diagram (see ***Figure 4***) is used to highlight typical switching requirements. The front end of a receiver typically requires an input protection system, which can be based on RF limiters, alone, or combined with a variable attenuator to keep the input power within a predefined range to maintain linear operation. Switches used in a dynamic, power-limiting structure need to switch fast enough to protect the system and prevent damage further down the signal chain. These switches must cover the full frequency range of the receiver without introducing unnecessary distortion as well as handle a wide range of input power levels.

RF gain control, functionally shown in Figure 4 as a digital step attenuator and a variable-gain LNA, consists of banded gain blocks, that can be bypassed, and various DSAs. The relative input power is detected and the signal can then be amplified or attenuated to ensure optimal power level at the RF filter banks and subsequent mixers. These switches require fast settling times to allow the measurement to reach its final value when gain changes are required.

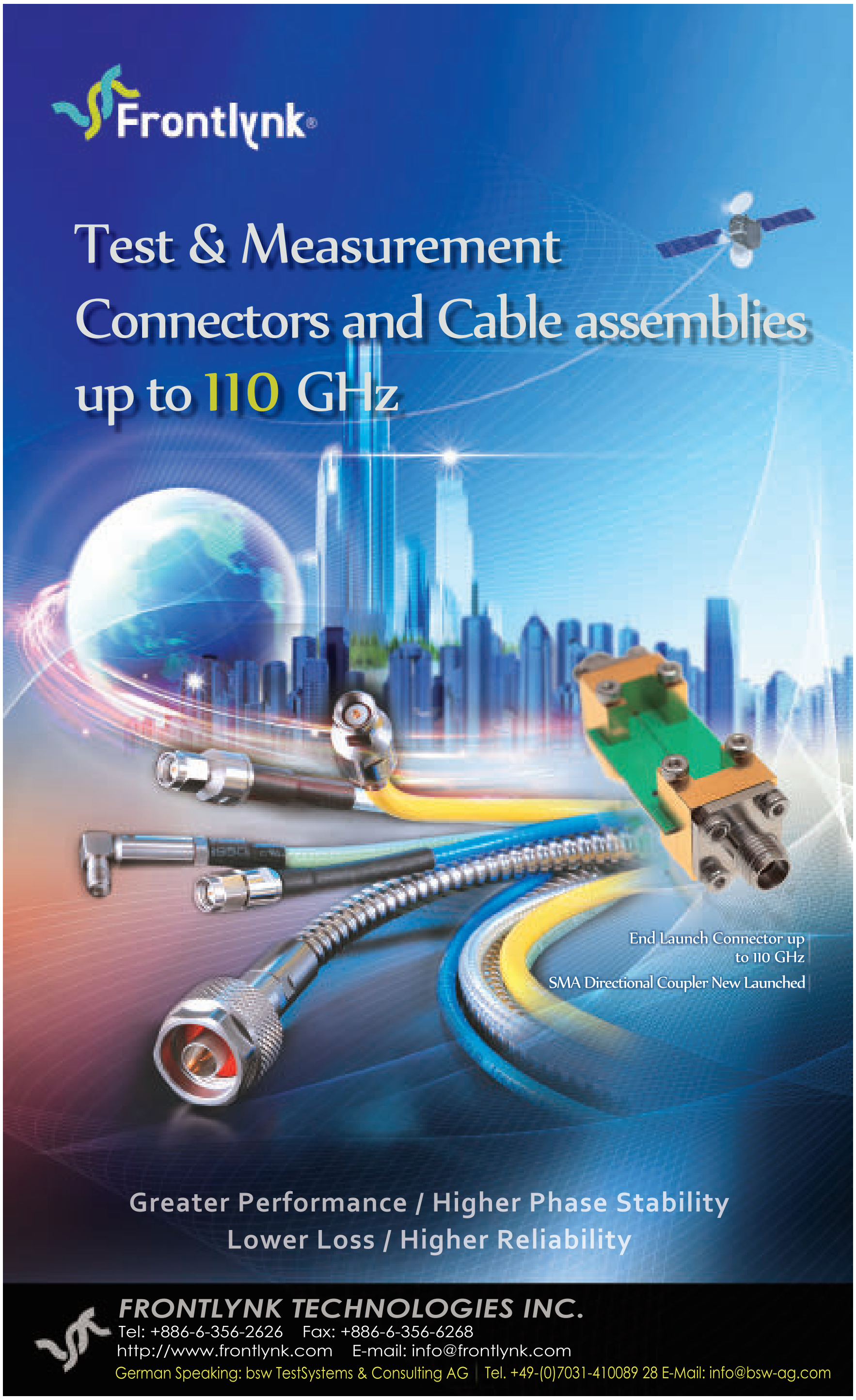
The next functional block consists of an RF filter bank needed for harmonic and interference suppression. Here, a four-way filter bank is shown, but systems can have more elements depending on filter sharpness and covered bandwidths. These switches require high isolation at the out-of-band frequencies and low insertion loss within the selected frequency bands. This function can be obtained by using a combination of series and parallel switches or by using high-throw-count integrated switches (e.g. SP6T, SP8T).

The first mixer has a tunable local oscillator (LO) with many of the same system elements as the primary signal path. For applications with fast tuning requirements, short settling time switches are required having good

isolation in the band of interest. The example shown in Figure 4 employs a direct conversion receiver at its final stage. This provides bandwidth efficiency, but in turn, requires I/Q signals that extend to DC; as such, the switches used in this section need to be DC-capable with low phase distortion at the maximum bandwidth.

CONCLUSION

Selecting the appropriate switch is extremely important for successful RF applications. As highlighted in this article, switch requirements can vary greatly even within a single system, such as an RF receiver. When equipped with the knowledge of available RF switch solutions, application requirements, and performance tradeoffs, engineers can effectively implement their designs and meet today's advanced systems demands. ■



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Simulating Antenna Measurements in an Anechoic Chamber

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Altair Engineering Inc., Hampton, Virginia

The measurement community has a substantial and increasing interest in utilizing computational electromagnetic (CEM) simulation tools to minimize the financial resources required to design custom anechoic chambers without sacrificing performance. Traditionally, engineers have analyzed anechoic chamber designs with a method similar to 'ray-tracing' due to practical limitations of the available resources. Recent technological advances have, however, helped computational resources and numerical solvers emerge as powerful tools capable of analyzing anechoic chambers. Systematic error sources are then easily identified by emulating antenna measurement techniques in a virtual environment. The resulting insight facilitates convergence between measurement and simulation data, which ultimately provides confidence in the final characterization.

This article presents a coherent characterization process for anechoic chambers[1] and antenna measurement techniques,[2] which unites several communities even though the engineers involved address drastically different challenges. Errors in an anechoic chamber design can be identified by emulating a measurement technique with a fully characterized antenna. Quiet zone disturbances can be accounted for when emulating subsequent antenna measurements.

In addition, measurement techniques that may adversely affect quiet zone behavior can be validated. Examples include (a) customers requesting measurements outside the normal mode of operation (e.g. structures larger than the quiet zone) and (b) operating with modifications to the chamber environment. Finally, the performance and cost associated with purchasing or refurbishing measurement equipment can be estimated with improved accuracy.

MEASUREMENT TECHNIQUE

The measurement community has several tools and respective techniques to characterize an antenna under test (AUT). Commonly used measurement tools include free space antenna ranges that are designed to suppress contributions from the surrounding environment during an antenna measurement. An anechoic chamber is a specific type of free space antenna range that provides protection from weather and vandalism as well as electromagnetic interference. In addition, rectangular anechoic chambers are designed to simulate free space conditions and maximize the quiet zone volume.

Although rectangular anechoic chambers facilitate various measurements, the capability to measure antenna gain is of critical importance. Uniform plane waves, which can be approximated by increasing the separation distance between the source and receive an-

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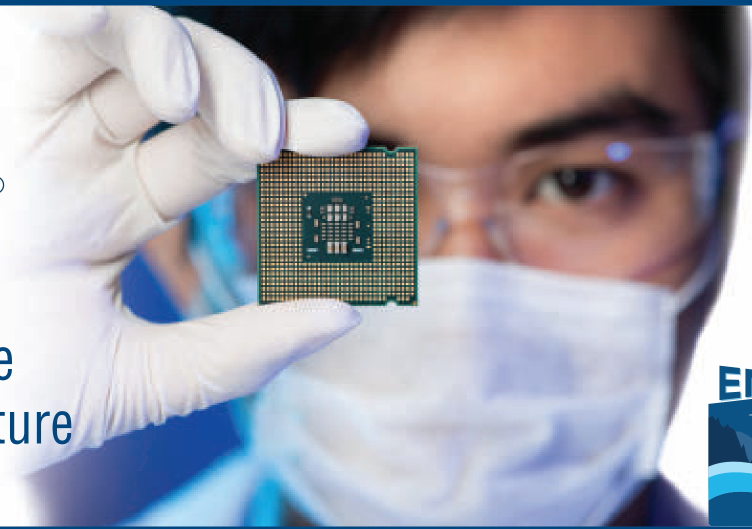

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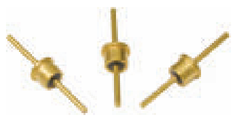
EMC Sample Kits

Microwave Applications

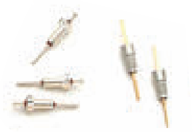
When board space and high performance are critical, CTS' miniature EMI filters suppress unwanted EMI and allow a fast, mechanical bonding by offering an excellent alternative from traditional soldering installation to significantly reduce assembly costs. Samples of these small packages and large range of electrical characteristics are available in CTS' new solder mount EMI/RFI Filters, 4300-900 and 4306-900, kits.



Solder Mount and Press-in EMI/RFI Filters

Military, Industrial Control, Telcom and T&M Transport Systems Applications

Miniature sized EMI filters with high performance in "C" and "Pi" configurations and a threaded mounting technique are highly desired in the US and Europe. CTS specifically assembled four kits, 4100-900, 4100-901, 4400-900 and 4400-901, which include a range of solder mount and US as well as metric thread bushing "C" and "Pi" filters that are unique to these markets.



Solder Mount and Thread Bushing "C" and "Pi" Filters

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CTS' 4700-900 sample kit consists of small surface mount filters which offer cost and space savings and improved insertion loss. In addition, the filters have excellent electrical and mechanical performance. The square body allows easy handling, positioning and soldering onto the PCB.

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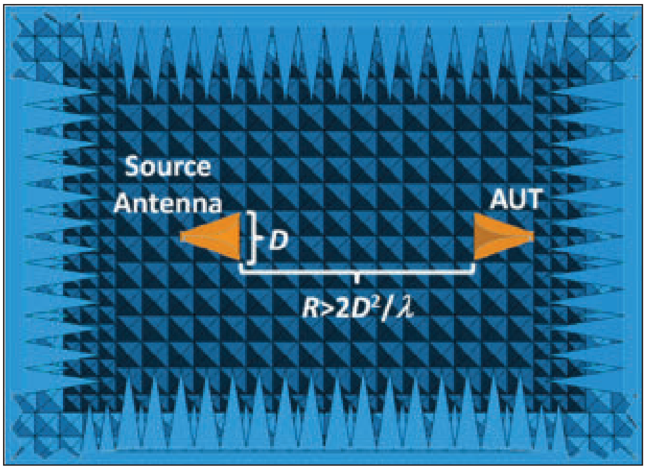
tennas, are the ideal illumination for antenna gain measurements. As the distance increases, the curvature of the spherical phase-front produced by the source antenna becomes negligibly small over an antenna aperture. A uniform phase-front approximation facilitates several antenna measurement techniques including the gain-transfer method.[3]

The gain-transfer method provides a simple yet accurate solution for measuring antenna gain. This method utilizes a gain standard with well-known performance characteristics to determine the gain of an AUT in conjunction with the following equation:

$$G_{AUT} = G_{cal} \frac{P_{AUT}}{P_{cal}} \frac{1}{1-\left|S_{11,AUT}\right|^2} \quad (1)$$

G_{AUT}, P_{AUT} and $S_{11,AUT}$ are the unknown gain, received power and reflection coefficient associated with the AUT, respectively. G_{cal} and P_{cal} are the known gain and received power associated with the gain standard, respectively. Pyramidal horn antennas are a universally accepted and widely used gain standard. The source and receive antennas are located inside the anechoic chamber as illustrated in ***Figure 1***.[3]

The receive antenna is placed in the far field of the source antenna where R denotes the respective separation distance, D denotes the maximum dimension of the antenna and λ denotes the operating wavelength as illustrated in Figure 1. The gain-transfer method is then calibrated by measuring the received power with the gain standard. After replacing the gain standard, the AUT is rotated in the principal plane and the received power is converted to an antenna gain estimate at each angle. Note the source antenna transmits constant power across all measurements.[3]

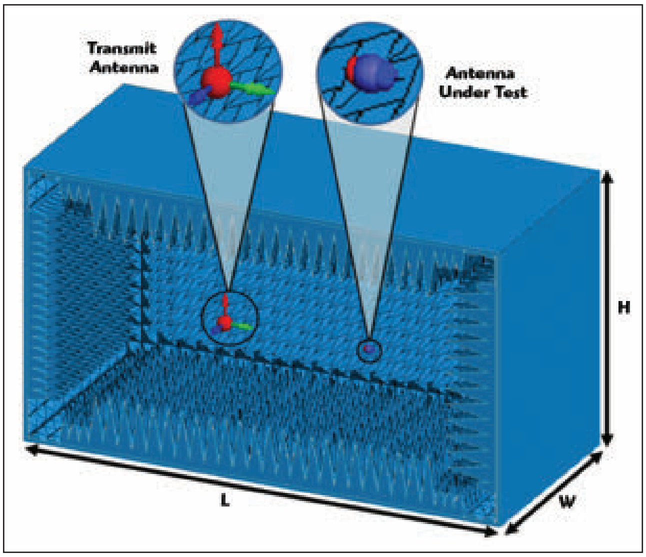


▲ *Fig. 1 Measurement configuration for the gain-transfer method inside an anechoic chamber.*

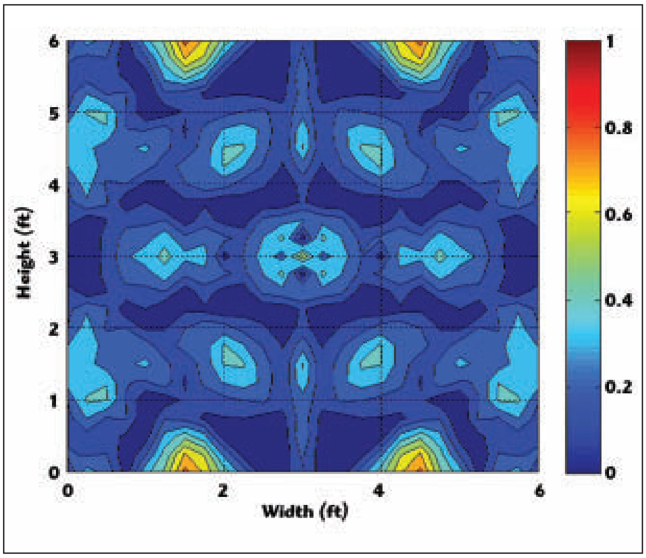
NUMERICAL METHODS

Modern full-wave and asymptotic CEM methods, available in commercial software packages such as FEKO, offer several options for either computing or approximating the relationships between electromagnetic fields and currents. Full-wave CEM methods accurately solve Maxwell's equations without approximations, while asymptotic CEM methods achieve a solution with limited resources by operating with underlying assumptions. Vigilance is then required from the user to model the problem well within those approximations. Fortunately, an increase in electrical size further validates the assumptions underlying asymptotic CEM methods and improves the accuracy of the final results. In response, software companies offer asymptotic methods such as physical optics (PO) and the full-wave finite element method (FEM) hybridized with method of moments (MoM) to assist with solving large and complex problems.

In addition, several features can facilitate efficient modeling practices. For example, thin wire approximation, an inherent MoM feature, solves wire structures with minimal resources by discretizing thin cylindrical shapes into linear segments rather than a surface mesh. Domain decomposition minimizes computational resources by solving the far field pattern of an arbitrary source antenna in an isolated environment, which becomes an imported source for subsequent simulations. Modelling an ideal receive antenna involves a similar process. Two hybridized CEM methods, namely MoM/



▲ *Fig. 2 Simulation configuration along with the dimensions for an anechoic chamber model.*



▲ *Fig. 3 Quiet zone error imposed by the anechoic chamber when operating at 500 MHz.*

FEM[4] and MoM/PO,[5-7] as well as efficient modeling practices facilitate the characterization of anechoic chambers and antenna measurement techniques.

CHAMBER MODEL

A custom anechoic chamber with a rectangular down-range cross-section (i.e. W × H) was modeled to fit within a physically limited volume. The chamber dimensions are 17' H × 24' W × 32.5' L as shown in ***Figure 2***, where blue represents absorbing material. The center of the quiet zone is 10' from the receiving wall and measures 6' H × 6' W × 6' L. The source antenna is modeled 20' from the receiving wall as shown left of center in Figure 2.

A central patch of two side walls, receiving wall, floor and ceiling were modeled with large pyramidal absorber surrounded by small pyramidal absorber as illustrated in Figure 1. The absorbing material was modeled with typical values for both the dielectric constant and loss tangent.[1]

CHAMBER CHARACTERIZATION

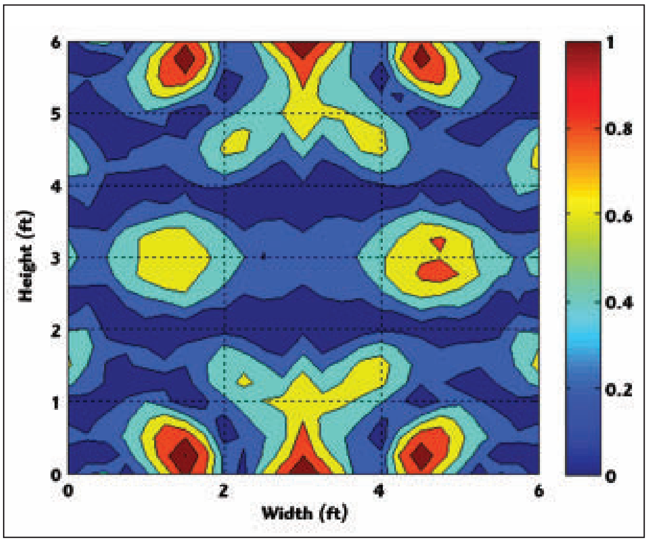
Disturbances inside the quiet zone of an anechoic chamber were characterized with full-wave and asymptotic CEM methods. The characterization employed a custom low-gain source antenna designed to increase reflections off the surrounding walls and therefore represent a worst-case scenario. Electric fields in the quiet zone were computed in the explicit presence and then absence of the anechoic chamber. The ratio of these two results produced a systematic error term that identified quiet zone disturbances imposed by the anechoic chamber.

A rigorous characterization was initially performed on the chamber with MoM/FEM. Negligible disturbances (i.e. less than 1 dB), illustrated in ***Figure 3***, were imposed by the low-gain source antenna when operating at 500 MHz, which validated both the chamber performance and the respective characterization process. A characterization was then performed on the chamber with MoM/PO when operating at 500 MHz. The difference between the full-wave and asymptotic CEM methods is illustrated in ***Figure 4***.[1]

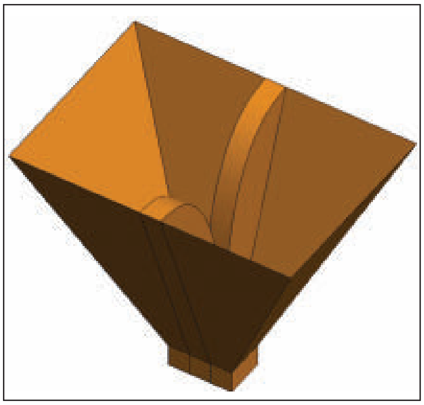
The approximations associated with the asymptotic method imposed negligible error (i.e. less than 1 dB), which validated MoM/PO as an effective characterization tool for anechoic chambers. Additionally, the underlying assumptions become more valid as the operating frequency increases. The approximations therefore become more accurate and the error term is further reduced. As a result, engineers can confidently replace rigorous full-wave methods with asymptotic methods and increase the frequency within the confines of the available resources.

MEASUREMENT EMULATION

Asymptotic CEM methods have provided an opportunity to emulate antenna measurement techniques in the explicit presence of the anechoic chamber. Specifically, the gain-transfer method was validated for both co-polarization (Co-Pol) and cross-polarization (X-Pol) antenna gain measurements using a Yagi-Uda antenna and a shunt-fed slanted V-dipole antenna, respectively.



▲ *Fig. 4 Quiet zone error imposed by MoM/PO when operating at 500 MHz.*



▲ *Fig. 5 Dual-ridge horn model represented both the source antenna and calibration gain standard.*

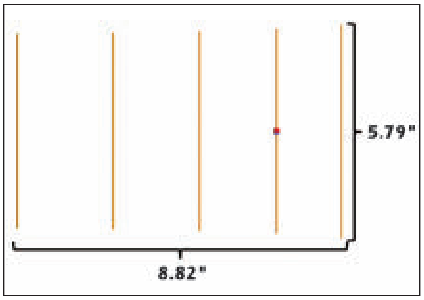
A dual-ridge pyramidal horn, illustrated in ***Figure 5***, represented both the arbitrary source antenna as well as the calibration gain standard with well-known characteristics (i.e. 6.618 dB broadside gain). The source antenna radiated 10 mW of power at an operating frequency of 1000 MHz across all simulations.

Recent advances in computational resources have helped modern workstations emerge as a cost effective simulation tool. The following simulations were performed on a workstation with 256 GB of shared memory and 2 Intel Xeon E5-2650 CPUs with 8 cores per physical CPU operating at 2 GHz. The simulation at each angle with the explicit presence of the anechoic chamber was solved on all 16 available cores, which required 45 minutes of computational time and 220 GB of memory.

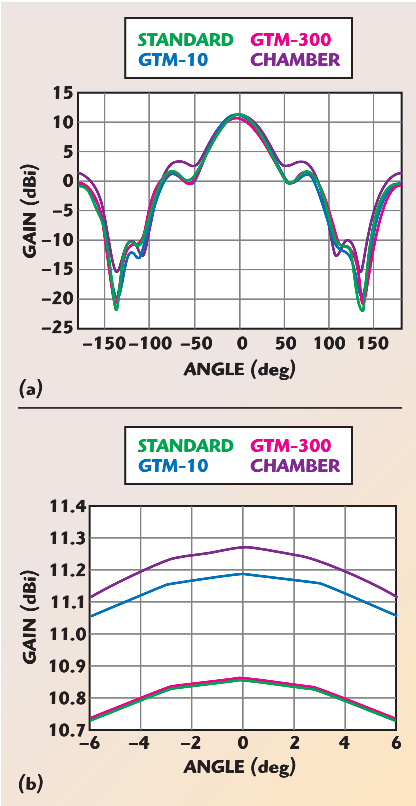
CO-POLARIZATION

The emulated gain-transfer method was initially validated with a Yagi-Uda antenna as illustrated in ***Figure 6***. The vertically polarized antenna facilitated a single plane of electric symmetry to minimize computational resources. These simulations considered angles that spanned from -180° to 180° in 3° increments.

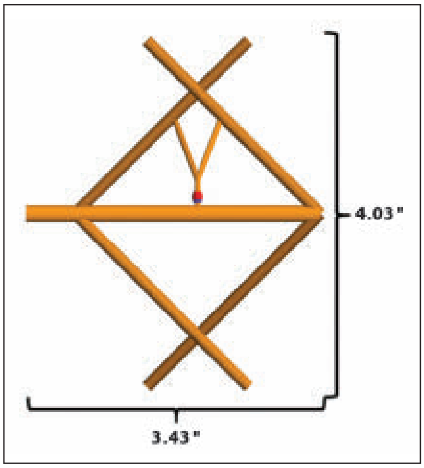
First, the H-plane gain of the AUT was computed with a standard MoM simulation. Next, the gain-transfer method was emulated with a 300 foot (i.e. electrically large) separation distance to compute the co-polarization (Co-Pol) antenna gain. The gain-transfer method was then emulated with a 10 foot separation distance. Finally, the gain-transfer method was emulated with the explicit presence of the anechoic chamber, while main-



▲ *Fig. 6 Yagi-Uda model used for co-polarization antenna measurments.*



▲ *Fig. 7 H-plane gain for a Yagi-Uda antenna, across all angles (a) and at broadside (b).*



▲ *Fig. 8 Shunt-fed slanted V-dipole model used for cross-polarization antenna measurements.*

taining a 10 foot separation distance. The results are illustrated in ***Figure 7*** where GTM refers to the gain-transfer method.

An electrically large distance between the source antenna and the AUT provided an excellent uniform plane wave approximation. Therefore, near perfect agreement between the standard MoM solution and 'GTM-300' was achieved, which validated the gain-transfer method as an antenna measurement technique. Although the AUT was still within the typically recognized far field region, emulating the gain-transfer method with a 10 foot separation distance imposed minimal yet distinct degradations in the uniform plane wave approximation and ultimately the antenna gain estimates.

The difference between 'GTM-300' and 'GTM-10' quantifies the error imposed by smaller separation distances. Finally, a quantifiable error term was introduced into the final antenna gain estimate when the gain-transfer method was emulated in the explicit

TABLE I ANTENNA GAIN FOR A SHUNT-FED SLANTED V-DIPOLE		
	MoM	GTM
Co-Pol	2.55 dBi	2.37 dBi
X-Pol	–22.94 dBi	-23.22 dBi

presence of the anechoic chamber.

CROSS-POLARIZATION

Estimating the cross-polarization (X-Pol) antenna gain in the explicit presence of the anechoic chamber provided the insight necessary to identify an additional systematic error term. A shunt-fed slanted V-dipole, illustrated in ***Figure 8***, was arranged into vertical and horizontal orientations when estimating the co-polarization and cross-polarization antenna gains, respectively. In contrast, the source and calibration antennas maintained a vertical orientation throughout the emulated measurement process. The estimated antenna gains were then compared with free-space MoM simulations as listed in ***Table 1.***

The shunt-fed slanted V-dipole, with smaller dimensions, experienced a more uniform illumination than the Yagi-Uda antenna. A smaller systematic error was therefore introduced by the limited separation distance. As a result, remarkable accuracy was achieved at the relatively low levels associated with cross-polarization measurements, which further validated the gain-transfer method.

CONCLUSION

Both full-wave and asymptotic methods were utilized to support several engineering communities. The results have shown that engineers can characterize the quiet zone behavior of anechoic chambers, which provides critical insight during the design process. Antenna engineers can determine the effect of quiet zone disturbances during an antenna characterization process. Measurement engineers can validate antenna measurement techniques and predict the respective performance when operating under non-ideal conditions. Managers can more accurately predict the performance levels and costs associated with purchasing or refurbishing measurement equipment. In conclusion, excellent agreement across various simulations allows several engineering roles to make more informed decisions based on quantifiable error terms. ■

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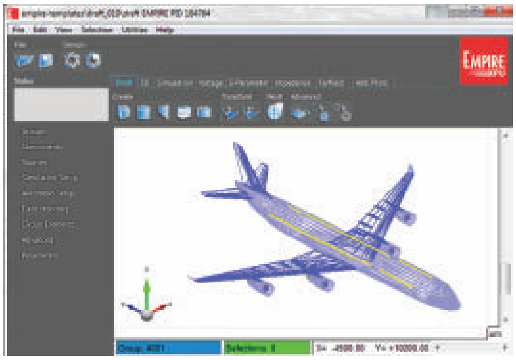


3D EM Solver

IMST GmbH
Kamp-Lintfort, Germany

EMPIRE XPU is a 3D EM solver, based on the Finite Difference Time Domain (FDTD) method and is a powerful tool for modeling antennas, microwave circuits, EM chip design and more. Due to its on-the-fly compilation it is highly efficient and extremely fast on plain conventional hardware using optimized algorithms.

With the release of EMPIRE XPU 7.00, the solver has been upgraded to meet the ever changing and challenging needs of the RF-engineers and antenna designers of tomorrow. The main new feature is a powerful and intuitive 3D Graphical User Interface (GUI) that makes the drawing, placement and import of arbitrary 3D shapes sweat free and efficient.

A new 3D modeling kernel enables fast import, modeling and meshing of large and complex objects like highly integrated RF modules and complete car models, for example. New pick-and-place library elements have been added for the parametrical creation of surfaces, sub-structures and conformal layout mappings.

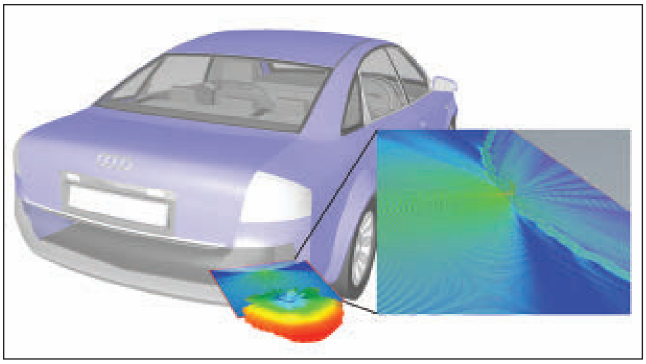
Near field data from measurements or 3D field simulations can be used as a source. This makes it possible to simulate high-detailed antennas and other sources in large environments without the need to model all details of the original sources. For low frequency applications such as wireless power transfer, the evaluation of averaged electric fields induced inside human bodies as required by the ICNIRP standard, has been implemented.

Also, a new circuit simulator has been added to allow, for instance, the import of touchstone data from transistor measurements for amplifier design or the tuning of matching circuits for antennas without the need to switch to external tools. Icons and menus have been adapted for a more intuitive workflow and hyperlinks referring to dedicated manual sections have been added for fast troubleshooting.

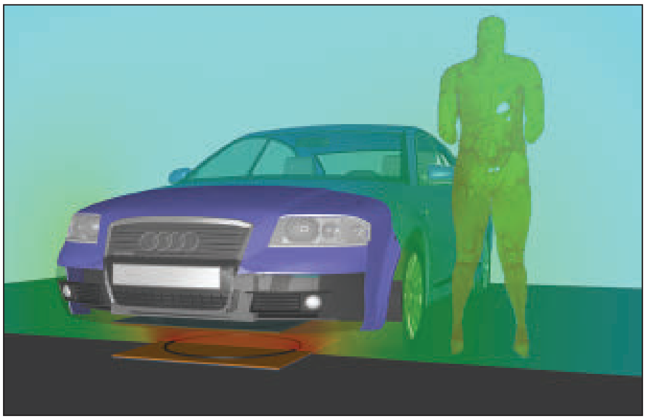
The following three examples illustrate the flexibility and adaptability of the EMPIRE XPU 7.00.

AUTOMOTIVE APPLICATIONS

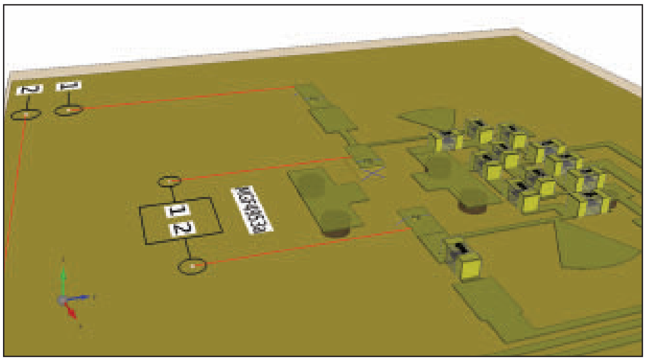
Car antennas for AM & FM radio and DAB are often integrated into the windscreen. The modeling of these antennas is usually difficult due to the conformal shape of the glass. A new layout mapping module in EMPIRE allows the automatic mapping of complete planar layouts on arbitrary surfaces. So windscreen antennas can be designed easily with full parametric control and direct layout export options for manufacturing.



▲ *Fig. 1 77 GHz radar antenna: electric near field, far field at 77 GHz.*



▲ *Fig. 2 Wireless charging system: E-field at 1 MHz, averaged induced in body electric field at 90 kHz.*



▲ *Fig. 3 Amplifier design at 24 GHz.*

Modern cars include more and more radar sensors to increase safety. They determine distance, speed and direction of moving or stationary objects, including people. Designing antennas for such systems is quite challenging. These radar systems are currently operated at 24 and 77 GHz. They are usually integrated behind the bumper of the car, which normally impacts strongly on the antenna performance. Accurate 3D EM simulations of the antennas including the car environment are a must for a short product development cycle. Due to the memory and speed efficient XPU algorithm of EMPIRE, even 77 GHz antenna systems can be simulated including the complete car environment (see ***Figure 1***).

These simulations can be performed even more efficiently in the latest release by using a new field source definition. This field source can replace the antenna by using accurate field data from measurements or previous antenna simulations. By using a local field interpolation, it is possible to model the source with a coarser mesh in the subsequent simulation run including the whole environment, thus reducing the overall required memory and increasing the simulation speed.

WIRELESS CHARGING

As electric vehicles are becoming more and more popular, the use of wireless battery charging systems will increase. This technology transmits electrical power by using magnetic resonances that result from changes in magnetic field intensity between a coil positioned on/in the ground below the car, and a receiving coil built into the chassis of the vehicle.

As the charging time should be minimal, high magnetic fields are used. This makes it mandatory to investigate the electromagnetic exposure on human bodies in the vicinity of wireless charging systems, which operate at around 90 kHz.

The recent ICNIRP standard requires the evaluation of the averaged electric field induced inside the body and its distribution in body tissues. EMPIRE can calculate these fields inside the human body either by modeling the complete wireless charging system and the environment (see ***Figure 2***) or by using a field source, based on measured data, which excites the same field. In addition to a reduced problem size, using a field source based on measured data has the advantage that complete wireless charging system details need not be known.

AMPLIFIER DESIGN

For amplifier designers the design of matching networks is a crucial part of daily work. The usual workflow requires the simulation of the passive structure in a 3D field solver, the utilization of measured data for active or nonlinear devices and merging the result into a circuit simulator for tuning the matching elements.

The new Empire software includes a circuit simulator. Inside the GUI, schematic circuit elements are available such as lumped resistors, capacitors, inductors, as well as couplers, lines and Touchstone files. These elements can be placed between the ports and connected with ideal wires. The simulator computes the complete scattering matrix and the circuit simulation is automatically carried out after the 3D EM simulation is finished.

This allows fast tuning of the complete amplifier design while profiting from the accuracy of the 3D full wave simulation. A combined EM and circuit model of a 24 GHz power amplifier design is shown in ***Figure 3***.

The new Empire XPU 7.00 includes a whole range of new powerful features that will accelerate and simplify the design workflow. Emphasis has been placed on user friendliness as well as enhanced functionality for today's and tomorrow's design challenges. EMPIRE guarantees fast and accurate 3D EM and thermal simulations of complex RF-systems and modules using off-the-shelf PC-equipment. With this tool the time-to-market can be reduced to a bare minimum. Because of the high accuracy of the simulation results, prototype cycles are considerably shortened and hence development costs are reduced as well.

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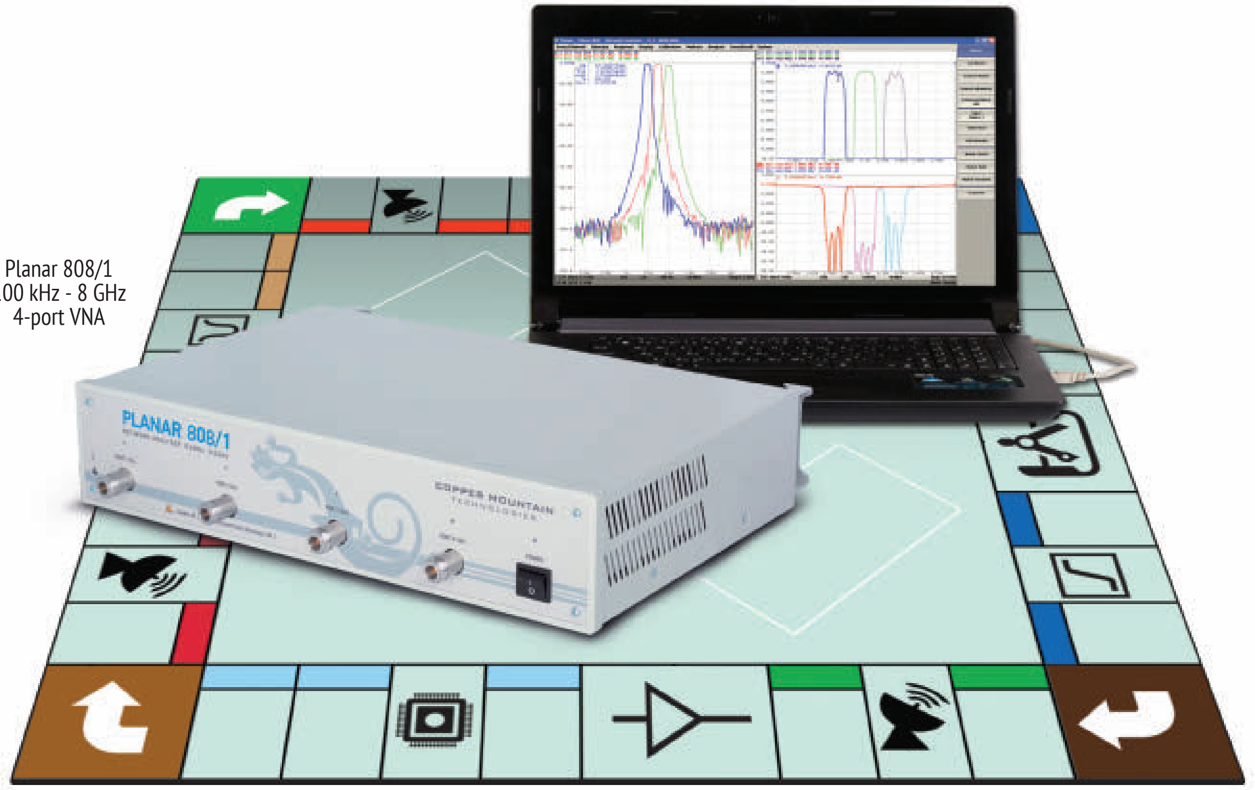

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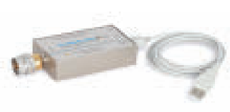

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Interference and Direction Analyzer

Narda Safety Test Solutions
Pfullingen, Germany

Detecting RFI, revealing the causes of interference and locating unauthorized transmitters are tasks performed by modern direction finding equipment. Spectrum analysis and time domain displays give much information about the type of signal but are limited to recording the amplitude versus frequency and/or versus time, and often lose information due to display compression. The full picture is only available when the measured values are recorded without compression and separated into their real and imaginary components, usually referred to as the in phase and quadrature components, or I/Q for short.

The IDA 2 Interference and Direction Analyzer provides the full picture as it does not simply record and save the I/Q data. It can also evaluate the data immediately on-site, as the results are needed for tracing impairments and interference straight away. Of course, results can also be checked when back in the office.

I/Q ANALYZER MODE

With the IDA 2, the I/Q analyzer mode can be selected, just like spectrum or time domain (scope) modes. As in time domain mode, the IDA 2 runs in zero span mode as an I/Q analyzer, being tuned to a fixed frequency, i.e. one channel that is selectively captured. The ability to set unusually high channel bandwidths (CBW) of up to 32 MHz is a special feature of the instrument.

When the measurement process is started, the IDA 2 records the results continuously in real time as I/Q data pairs with a memory depth of 250,000 data pairs. The instrument can even perform some evaluations online, e.g. displaying the pure I/Q data or the magnitude versus time, computing a High Resolution Spectrogram or building up a Persistence Spectrum.

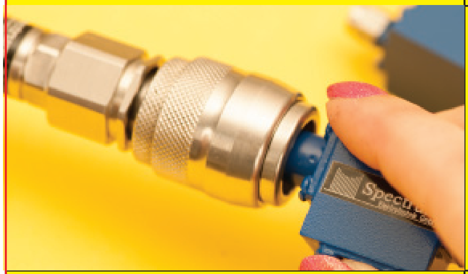
When the measurement is stopped, either manually or by automatic trigger, the last 250,000 I/Q data pairs are still stored, uncom-

Procedure for how to use the N, TNC and 7/16 Push-On male. Push-On Connectors mate with any standard female connector of the same connector style.

1. Convert your standard Assembly into a Push-On Assembly using the Nf to Nm Push-On Adapter.

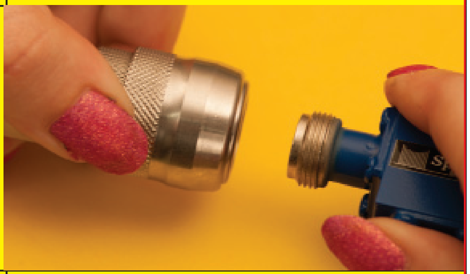
2. Put your fingers firmly onto the knurls of the "Lock Nut".

3. Push "Lock Nut" forward and engage the Push-On end of the Adapter with the mating female. Back nut must be released.



4. The Connection has been completed, easy and fast. The connector has been locked on safely.

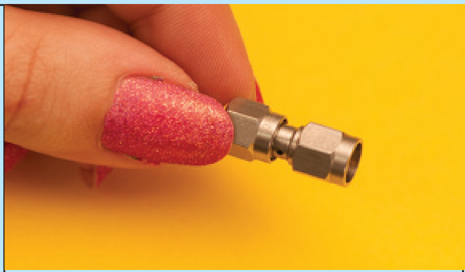
5 . To unlock (when "Back Nut" is in unlocked mode) push the "Lock Nut" forward and stop reverse movement by setting your fingers onto the "Back Nut".



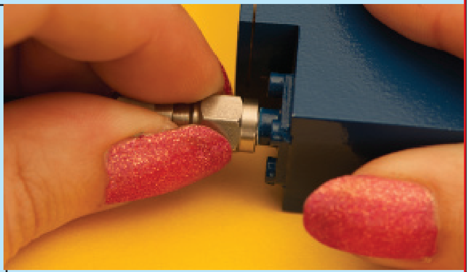
6. Keep fingers on "Back Nut" to ensure that "Lock Nut" cannot slide back and pull the connector off.

Procedure for how to use the SMA male and SMA female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.

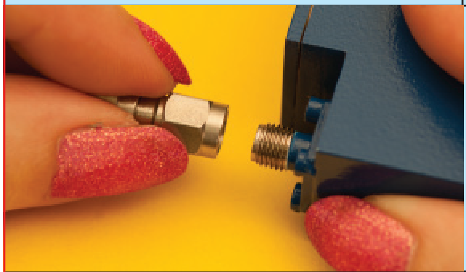
1. Convert your standard cable assembly into a Push-On Assembly by threadening the standard female side of the adapter onto the male connector of the assembly.



2. Your standard SMA male cable assembly is converted into an SMA male Push-On Assembly.



3. Just slide the Push-On SMA male Connector onto any standard SMA female. The connection is securely completed in seconds.



4. To disconnect, just pull the connector off.

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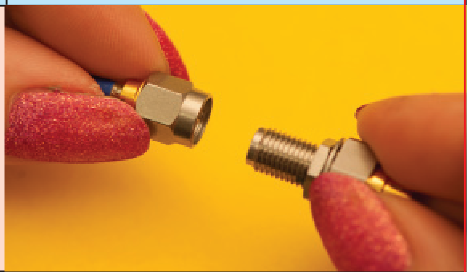
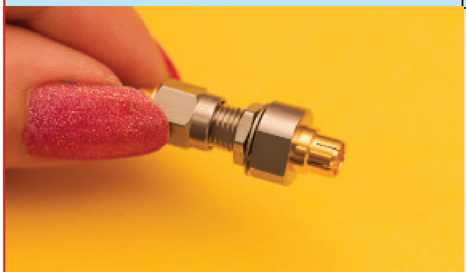
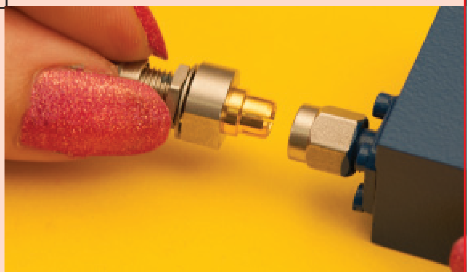


1. Convert your standard cable assembly into a Push-On Assembly by threadening the standard female side of the adapter onto the male connector of the assembly.



2. Your standard SMA male cable assembly is converted to a Push-On SMA female Cable Assembly.

3. Just slide the Push-On SMA female Connector onto any standard SMA male. The connection is securely done in seconds.



4. To disconnect, just pull the connector off.

pressed, in the background. In this way, any evaluation and display can be produced subsequently from one and the same data set.

Although it is necessary for the IDA 2 to compress the spectrums to correspond to the available number of display pixels in High Resolution Spectrogram Full display mode, everything is shown in High Resolution Spectrogram Zoom display mode: Every line of pixels corresponds to exactly one spectrum, with the color indicating the particular level. The IDA 2 also writes a specified number of spectrums over each other in a Persistence Spectrum where the color indicates how often a particular level value occurred.

EXAMPLES

An application where the I/Q analyzer can be utilized is in the GSM field to establish whether there is interference or an illegal transmitter hidden under the 'active' spectrum. This can be particularly difficult to determine if the GSM modulation method uses frequency hopping, where the communications channel switches frequency about every 4.6 ms. If the illegal transmitter also hops, it cannot be detected in the normal spectrogram. However, it is visible in the High Resolution Spectrogram, obtained from the I/Q data, revealed by the different duration and correlation.

Another example is LTE, where interference due to intermodulation from (and with) GSM signals is not uncommon because the antennas are usually located together on the same roof. The rectification effect of a couple of rusty rivets on the mast is enough to generate intermodulation that is superimposed on the RF field. A first for a handheld device: the High Resolution Spectrogram of the IDA 2 makes the whole frame structure visible (see ***Figure 1***).

In the case when an interference signal is hidden beneath a DAB channel, this can best be detected in the transmission 'gaps': DAB transmits a null character for synchronization at fixed intervals, during which only the carrier frequencies remain. Any interference cannot avoid detection in the High Resolution Spectrogram as well as in the Persistence Spectrum of the IDA 2.

In the case of an illegal transmitter, deliberate jamming, an unknown defective device, or intermodulation from authorized communications signals, the signal versus time characteristics often tell much about the type of signal. The magnitude setting of the IDA 2 displays the magnitude of the I/Q data versus time, so that the timeslot structure of a GSM intermodulation can be clearly seen, as shown in ***Figure 2***.

TRIGGER

The IDA 2 shifts the I/Q data continuously through its memory on a first in, first out basis during the measurement. Just as with an oscilloscope, the triggers can be set to capture the measurement results when specific events occur, e.g. when a specific level is first exceeded or whenever this level is exceeded. The Trigger Delay setting is important because it facilitates the capture of the measurement values before and after the event, illustrating

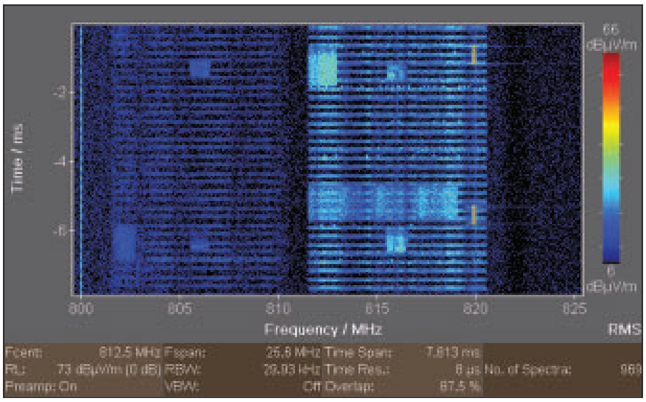


Fig. 1 High Resolution Spectrogram Full of two LTE channels (resolution 8 µs) showing the frame structure with its resource grid and synchronization signals.

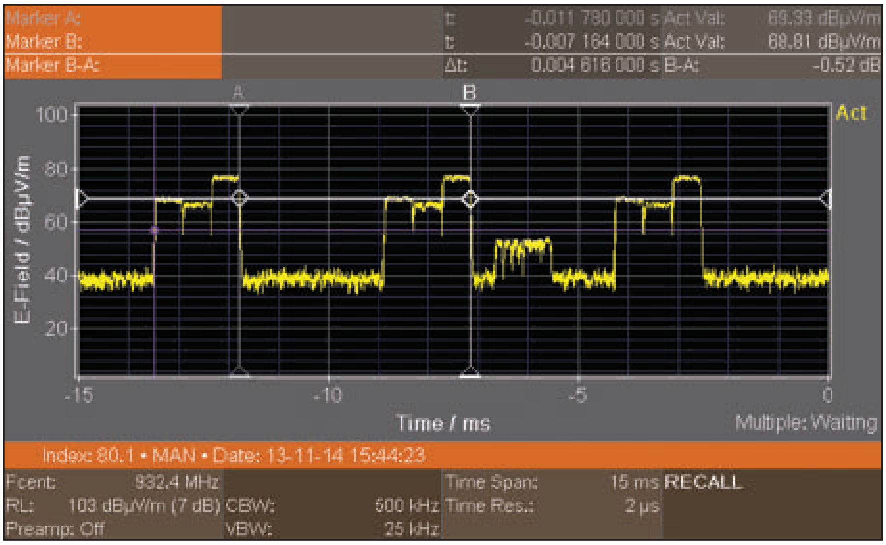
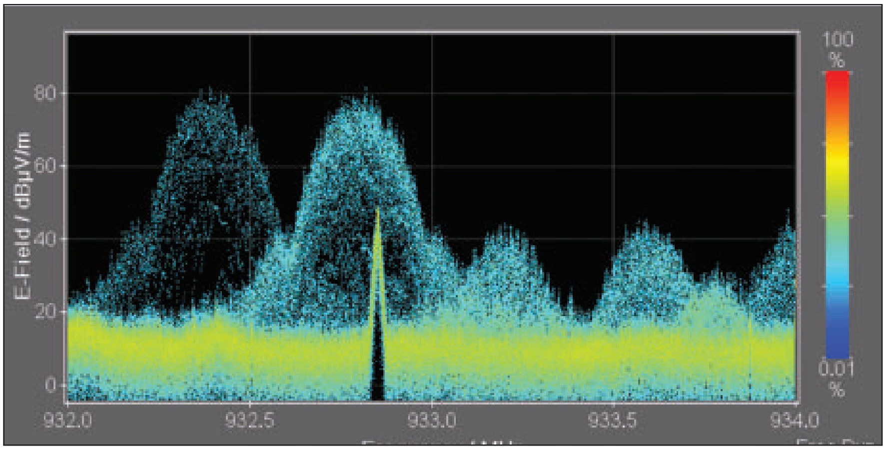


Fig. 2 A GSM downlink signal triggered on the rising edge (time resolution 2 µs) showing the 546 µs timeslots (frame duration is measured using markers A and B: Δt = 4.616 ms).



▲ *Fig. 3 Persistence Spectrum of a GSM downlink signal showing underlying interference at around 932.8 MHz.*

both the cause and the effect. Also, the SAVE function stores the I/Q data permanently in the IDA 2 memory for later evaluation.

EVALUATION OF I/Q DATA

There is a causal relationship between the channel bandwidth, resolution bandwidth, window overlap, time resolution, and possible recording time in any digital analyzer like the IDA 2. At the maximum CBW of 32 MHz, the IDA 2 captures an I/Q data set every 31.25 ns, corresponding to the inverse of the CBW. This gives a recording time of 250,000 × 31.25 ns = approx. 7.8 ms with a memory capacity of 250,000 data pairs. This is enough to completely capture cyclical sequences in modulated communications signals. The recording duration increases correspondingly for a narrower CBW, so that at the other extreme, a CBW of 100 Hz would give a recording time of 2,500 seconds.

The High Resolution Spectrogram and Persistence Spectrum are possible evaluations of the I/Q data that can be made online or subsequently, but also immediately on-site. ***Figure 3*** shows the Persistence Spectrum of a GSM downlink signal. The IDA 2 uses FFT analysis for this feature. The signals that have already been captured selectively by means of the selected CBW are further separated into their spectral components. Regardless of the setting used for capturing the measured values, users can determine or change the FFT parameters: the number of FFT samples and hence the resolution bandwidth (RBW) within the channel bandwidth, as well as the window overlap, i.e. the overlap of the time segments from the data set that are to be used for a FFT.

The rule is: The fewer the FFT samples and the greater the overlap, the finer the time resolution, i.e. the succession of spectrums. For example, the FFT yields a usable bandwidth of 25.6 MHz for a CBW of 32 MHz. With 256 FFT samples, the IDA 2 computes a spectrum with a RBW of about 240 kHz. If a window overlap (FFT Overlap) of 87.5 percent is selected, spectrums with a time resolution of 1 µs (corresponding to one million spectrums per second) will be obtained. For this reason, other analyzers compress the data for resolutions below 20 ms, whereas the IDA 2 retains the data without compression.

Based on the I/Q data, the battery operated, handheld IDA 2, which weighs 3 kg, offers a depth of analysis that was previously only available using costly and heavy laboratory instruments. Weak or sporadic interference, which may be hidden beneath strong and possibly variable frequency useful signals can now be revealed on site. In doing so, IDA 2 makes a significant contribution to the security of modern communications.

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9 kHz to 18 GHz Low Noise Amplifiers

Pasternack has added a new family of low noise amplifiers (LNA) capable of high gain and broadband performance between 9 kHz and 18 GHz that can be used across a wide spectrum of military and commercial applications. A total of 14 new LNAs are offered that provide customers with a choice of noise figures, gain levels, frequency ranges and power outputs depending on the intended use.

The new LNA category exhibits excellent broadband performance from 9 kHz to 18 GHz, noise figures between 0.8 and 3 dB, gain levels from 25 to 50 dB, gain flatness from ±0.75 to ±1.25 dB and power output levels (P1dB or Psat) between 10 and 18 dBm. The high performance of these LNAs is achieved using a hybrid microwave integrated circuit design and advanced GaAs PHEMT technology. The LNAs are connectorized SMA modules that are unconditionally stable and include built-in voltage regulation, bias sequencing and reverse bias protection for added reliability. All of the LNAs use a DC voltage supply of 12 V and range in current supply from 75 to 300 mA with an operating temperature of -40° to +75° or +85°C, depending on the device.

Depending on the intended application, both hermetically sealed and non-hermetically sealed versions are available. The LNAs are fully matched internally for input and output impedances of 50 ohms, which eliminates the customers need for any sensitive external RF tuning components. The LNAs are all EAR99 (no export license required) and are in-stock and ready to ship same-day.

VENDORVIEW

Pasternack Enterprises, Irvine, CA (866) 727-8376, www.pasternack.com.

DC to 12 GHz, 1 W SMA Fixed Attenuators

Mini-Circuits' new FW-series of 1 W SMA fixed attenuators provide accurate attenuation over DC to 12 GHz. The low cost FW-series attenuators offer a variety of attenuation levels from 1 to 20 dB with performance as flat as ±0.26 dB over the full frequency range. They feature SMA-M to SMA-F connector types and rugged unibody construction for high reliability and a long lifetime of use. They make ideal solutions for impedance matching, signal level adjustment, and other applications requiring accurate attenuation over wide frequency bands. FW-series attenuators are always available from stock for immediate shipment.

Mini-Circuits offers a wide variety of fixed, programmable and voltage variable attenuators. Their surface mount attenuators come in packages as small as 2 × 2 mm with a full line of hi-rel, hermetically sealed ceramic models for the harshest operating conditions.

Coaxial connector attenuator models in the company's lineup offer outstanding accuracy, repeatability and rugged construction for power levels from 0.5 to 100 W. Their programmable and voltage variable attenuators provide accurate attenuation control for applications from DC to 7 GHz. All models are available off the shelf for immediate delivery.

VENDORVIEW

Mini-Circuits, Brooklyn, NY, www.minicircuits.com.

8 Channel, 12-bit, 1 GHz Bandwidth Oscilloscope

Teledyne LeCroy has introduced the HDO8000 oscilloscope product line with eight analog input channels, 12-bits of vertical resolution utilizing their HD4096 technology, and up to 1 GHz of bandwidth. A 16 channel digital logic (MSO) option is also available. Eight channel high-definition oscilloscopes are highly useful in debugging deeply embedded systems in applications such as automotive electronic control units (ECU), consumer appliances (e.g. washing machines, refrigerators) and industrial systems (e.g. robotics) that contain a complex mix of power electronic, power, clock, digital logic, serial data, and analog sensor signals. More channels and more resolution provide faster insight into embedded system behavior. A wide variety of mixed-signal, serial data, long memory, probe options and accessories are also available with the HDO8000 oscilloscopes.

Teledyne LeCroy's new Q-Scape multi-tabbed display provides four times the display area and better organization of large numbers of channel, zoom and math waveforms (up to 40 total) on the oscilloscope's 12.1" WXGA high-resolution display. Four "tabbed" displays are provided. Waveforms can be simply dragged and dropped to the desired location to conveniently organize the many different acquired and calculated waveforms for more intuitive analysis. For those desiring a larger display area and even higher display resolution, the HDO8000 supports extended-desktop operation with a WQXGA (3840 × 2160 pixels) DisplayPort 1.2 video output.

The HDO8000 is standard with 50 Mpts/ch of acquisition memory with options for 100 Mpt or 250 Mpt/ch. These long acquisition memory options are ideal for power electronics and embedded/mechatronic systems where high-speed microprocessor signals may be captured coincidentally with lower speed pulse-width modulated (PWM), serial data, or analog sensor signals. The Teledyne LeCroy deep toolbox is provided for statistical, frequency and time-domain analysis using Tracks, Trends, Histograms and a variety of other math and measurement capabilities. Tracks are particularly useful for PWM analysis. A variety of other application-based software options are available.

Teledyne LeCroy,
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ADVANCE REGISTRATION CONFERENCE FEES (UP TO AND INCLUDING 5TH SEPT.)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 440	€ 120	€ 580	€ 160
EuMIC	€ 340	€ 110	€ 450	€ 150
EuRAD	€ 300	€ 100	€ 390	€ 130
2 Conferences				
EuMC + EuMIC	€ 630	€ 230	€ 830	€ 310
EuMC + EuRAD	€ 600	€ 220	€ 780	€ 290
EuMIC + EuRAD	€ 520	€ 210	€ 680	€ 280
3 Conferences				
EuMC + EuMIC + EuRAD	€ 760	€ 330	€ 1000	€ 440

STANDARD REGISTRATION CONFERENCE FEES (FROM 6TH SEPT. AND ONSITE)

CONFERENCE FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 580	€ 160	€ 760	€ 210
EuMIC	€ 450	€ 150	€ 590	€ 200
EuRAD	€ 390	€ 130	€ 510	€ 170
2 Conferences				
EuMC + EuMIC	€ 830	€ 310	€ 1080	€ 410
EuMC + EuRAD	€ 780	€ 290	€ 1020	€ 380
EuMIC + EuRAD	€ 680	€ 280	€ 880	€ 370
3 Conferences				
EuMC + EuMIC + EuRAD	€ 1000	€ 440	€ 1310	€ 580

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
	Standard	Student/Sr.	Standard	Student/Sr.
1/2 day WITH Conference registration	€ 90	€ 70	€ 120	€ 90
1/2 day WITHOUT Conference registration	€ 120	€ 90	€ 160	€ 120
Full day WITH Conference registration	€ 130	€ 100	€ 170	€ 120
Full day WITHOUT Conference registration	€ 170	€ 130	€ 220	€ 160

Proceedings on USB Stick

All papers published for presentation at each conference will be on a USB stick, given out FREE with the delegate bags to those attending conferences. For additional USB sticks the cost is € 50.

International Journal of Microwave and Wireless Technologies

Int'l Journal printed issues (6/year) € 42

DVD Archive EuMC

DVD Archive EuMC 1969-2003	FREE
DVD Archive EuMC 2004-2008	€ 10

Concert and Gala Dinner Wednesday 8th October 2014

The Gala Dinner and Concert will take place in the historical palace Palazzo Brancaccio and costs € 35 per person. Please note places are limited and assigned on a first-come-first-served basis.

SPECIAL FORUMS & SESSIONS						
Date	Time	Title	Location	No. of Days	Cost	
Wednesday 8th October	09:00h - 18:20h	Defence, Security & Space Forum	Flavia	1	€ 10 for delegates (those registered for EuMC, EuMIC or EuRAD)	€ 50 for all others (those not registered for a conference)

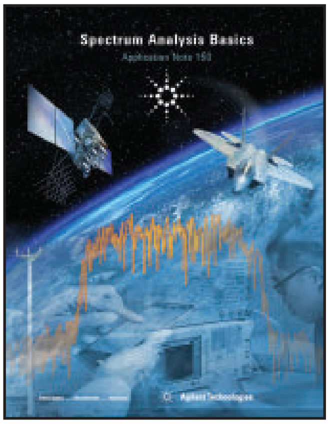
CatalogUpdate

Spectrum Analysis Basics – A Resource Toolkit

VENDOR**VIEW**

Insight into the workings of a spectrum analyzer can help you get the most out of it as a measurement tool. Learn about the fundamentals with Agilent's most popular and recently updated application note, "Spectrum Analysis Basics", which is paired with a toolkit of demo videos, web apps, articles and related material.

Agilent Technologies,
www.agilent.com.



Product Catalog

Anapico has released the new product catalog 2014/15 showing its latest releases of RF and microwave signal generators, synthesizers and phase noise analyzers. You will find key features and performance of Anapico's products ranging up to 26 GHz. The brochure is available directly from Anapico or from one of its authorized representatives.

Anapico,
www.anapico.com.

New Mobile Device App

VENDOR**VIEW**

AR RF/Microwave's new mobile app is available as a free download from Apple iTunes and Google Play. This application is a quick and easy tool to access various content for AR's products. Home screen icons give you easy access to basic and full product descriptions, app notes, AR's literature library, YouTube videos, contact information and social media icons. For more detail and to download the app, visit www.arww-rfmicro.com/html/ar-moblie-app.asp.

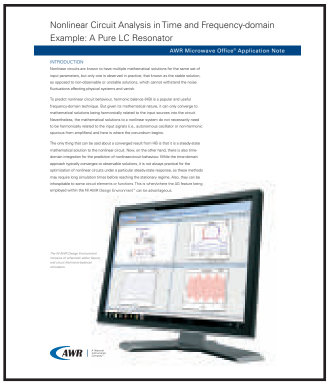
AR RF/Microwave,
www.arww-rfmicro.com.

Application Note

VENDOR**VIEW**

AWR Corp., in collaboration with its customer Jose Luis Flores, has added two new application notes to its technical papers library. These application notes introduce a technique known as auxiliary generator (AG) for nonlinear circuit analysis. AG is useful for broadening the set of solutions that can be reproduced from a harmonic-balance analysis and can help study their stability properties in order to optimize a nonlinear circuit for a desired response.

AWR Corp.,
www.awrcorp.com.



GPU Computing in CST STUDIO SUITE

VENDOR**VIEW**

The 3D electromagnetic simulation tool, CST STUDIO SUITE®, supports GPU computing in several solvers. The high memory bandwidth and parallel processing abilities of GPU cards mean that GPU computing can provide significant simulation speed advantages over conventional CPU computing. This brochure explains the benefits of GPU computing for the transient solver, integral equation solver and particle-in-cell solver. Find out more at https://www.cst.com/gpu.

CST,
www.cst.com/gpu.

"At a Glance" Brochures

VENDOR**VIEW**

Empower RF Systems continues to add to its selection of continuously updated and downloadable "At a Glance" brochures which detail (in separate editions) an overview of the company, recommended products for key markets and new product introductions as they occur. Twelve different documents, organized and consistent in presentation of key information, can be accessed via the website. The "At a Glance" materials are especially useful for engineers, buyers and sales reps.

Empower RF Systems Inc.,
www.empowerrf.com.

The 2014 Defence, Security and Space Forum

At European Microwave Week

EuMA

Microwave Journal
Frequency Matters.

Wednesday 8 October • Room Flavia, Fiera di Roma Conference & Exhibition Centre, Rome

A one day Forum addressing the application of RF integrated systems to defence & security infrastructure

Programme

09:00 - 10:40 Microwave Journal Industry Panel Session
The session offers an industry perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2014, the Panel will address: *Defence and security infrastructure*.

11:20 - 13:00 EuRAD Opening Session

13:10 - 14:10 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 the market.

14:20 - 16:00 Integrated RF solutions and its enabling and disruptive technologies on critical infrastructures and civil protection
Speakers from industry and academia present RF solutions and systems that contribute to civil protection, the protection of our critical infrastructures and disaster relief. The topics will be:

- The domino effects in critical infrastructures
- Civil protection, protection of critical infrastructures, disaster relief: vertical applications over a common architecture with heterogeneous communications
- Threats and countermeasures in the homeland security scenario
- Security at European institutional level

The three most highly rated unsolicited papers will complete the analysis of the main session topic.

16:40 - 18:20 EuMW Defence, Security & Space Executive Forum
Two executives from space industry and governmental institutions present their view on defence and space systems for our security. The titles of these two VIP talks will be announced closer to the event on the EUMW2014 website.
These two presentations will be complemented by three pitch presentations:

- Joint Applications of Airborne and Spaceborne Radars
- Instrumented fuzes for areo-balistics diagnostics of large-caliber projectiles
- New Technologies and Innovative Payload for Space Q/V-Band Telecommunications

The session will conclude with an open forum discussion with all speakers.

18:20 - 19:00 Cocktail Reception
The opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

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

Register online at www.eumweek.com

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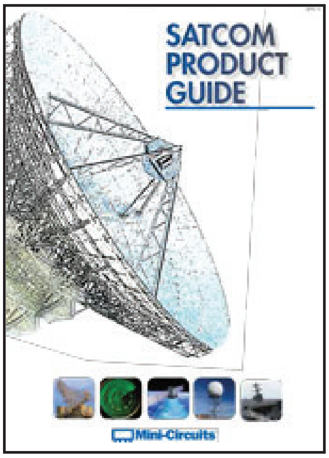
CatalogUpdate

SATCOM Product Guide

VENDORVIEW

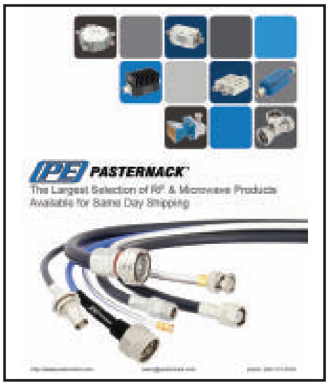


Mini-Circuits has released its new SATCOM product guide in print and for download from its website. This 32-page guide features a full survey of components and assemblies for satellite and earth station systems. With selected products from over 20 different product types to 40 GHz, the guide provides key performance parameters for each product and serves as a handy reference for engineers evaluating parts for their design needs.

Mini-Circuits,
www.minicircuits.com.

RF and Microwave Products

VENDORVIEW



Pasternack's latest 264 page catalog contains the largest selection of RF and microwave products available for same-day shipping worldwide. Improved features to the catalog include an updated adapter and cable assembly matrix that allows the user to easily identify all available in-series and between-series configurations. Product locators in the connector, adapter and cable assembly sections have also been modified for ease of use. The Pasternack catalog also includes useful reference charts, indexes and a glossary of commonly used RF terms.

Pasternack,
www.pasternack.com.

RF Switch Matrix Products

VENDORVIEW

SenarioTek's new catalog features the recently expanded FlexMatrix RF switch matrix family, which delivers off-the-shelf performance from DC up to 40 GHz. FlexMatrix offers test engineers a high performance RF switching capability over the broadest range of standard input and output configurations for applications such as radar, military communications, consumer wireless and signal integrity. To reduce cost of ownership, FlexMatrix products are designed for reliability with a guarantee of up to 10 million switch cycles and a standard three year warranty.

SenarioTek,
www.senariotek.com.

Product Selection Guide

This short form catalog includes a wide variety of surface mount voltage-controlled oscillator (VCO) and phase-locked loop synthesizer (PLL) modules ranging from 40 MHz to 15 GHz. A complete listing of all available parts and specifications can be found on the company's website. Users can also download an electronic version of the product guide online at www.zcomm.com or contact the company at sales@zcomm.com for a hard copy version.

Z-Communications,
www.zcomm.com.

Components

High Current Air Core Inductors

Coilcraft's new VS Series air core inductors combine current ratings of up to 57.0 Amps and excellent Q factors, making them ideal for high current IF/RF applications. Other applications include high power filtering, high frequency VRMs where magnetic material must be avoided (e.g., in MRI machines), and as high current IF chokes. The VS Series is offered in three sizes/configurations. The 1010VS measures 10 × 10 mm, with a maximum height of 6.10 mm.
Coilcraft,
www.coilcraft.com

Millimeter Wave Guide Balanced Mixers

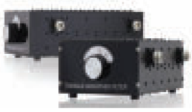
Ducommun LaBarge Technologies offers 6 waveguide bands balanced mixers to cover the frequency spectrum from 26.5 to 110 GHz. These mixers employ high power performance GaAs Schottky beam lead diodes and balanced configuration to produce superior performance and a moderate LO pumping level. The mixers are designed for full RF waveguide band operation with extremely wide IF bandwidth. Typical conversion loss for these mixers is 5 to 10 dB. Ducommun mixers can be used for test equipment, communication systems and radar receivers where frequency down conversion is required.
Ducommun Inc.,
www.ducommun.com.

Low-Loss Wideband Hybrid Couplers

VENDORVIEW

EMC Technology has released a new series of low-loss wideband hybrid couplers. The innovative HybriX® signal distribution product family, WH0530TF and WH1727F are the flagships of the new wideband hybrid coupler series power combining efficiency is maximized with low insertion loss and excellent amplitude and phase balance. HybriX products have been the preferred choice by RF and microwave designers in commercial wireless and space/military industries. Samples and evaluation boards are available now for these new low-loss wideband hybrid couplers.
EMC Technology,
www.emc-rflabs.com.

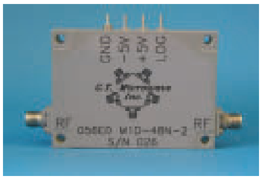
Tunable RF Filters



Fairview Microwave's tunable RF filters are commonly used in lab environments for testing many frequency bands including PCS, UHF, PMR, Tetra, LTE and WiFi. The tunable bandpass filters and band reject filters, also known as bandstop filters or band-rejection filters, are effective in band selection or frequency discrimination with high attenuation greater than 50 dB, allowing for excellent noise, harmonic and adjacent-band reduction. Fairview's tunable filters are designed with ruggedized aluminum casings with critical surfaces being silver plated, making them highly durable in a demanding environment.
Fairview Microwave,
www.fairviewmicrowave.com.

Digitally Controlled BPSK Modulator

Model M1D-48N-2 is a digitally controlled PIN diode BPSK modulator that operates from 2 to 6 GHz with a phase shift of 180°. The amplitude balance is ±0.5 dB with a phase vs. frequency of ±5.0°. This unit features an insertion loss of less than 2.5 dB with a 1.75:1 VSWR in 50 ohms. The supply voltage accommodates up to ±5 VDC @ ±50 mA with a handling power of +27 dBm CW, 1 W max. It offers TTL compatible logic and the switching speed is less than 100 nsec. max. The package size is 2.25" × 1.38" × 0.50".



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

Broadband Microlithic® IQ Mixers

Nearly all small form factor IQ mixers available on the market today are single octave units with frequency ranges (2:1, i.e. 15 to 23 GHz, 6 to 10 GHz, etc). Marki Microwave is proud to break the mold with the introduction of new Microlithic® IQ mixers, covering bands of 2 to 18 GHz and 4 to 16 GHz. Each of these mixers features excellent phase and superior amplitude balance, leading to typical untuned sideband suppressions of 30 dB.
Marki Microwave,
www.markimicrowave.com.

High Power Reflective Solid State Switch

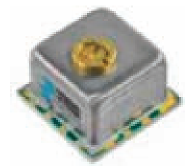
VENDORVIEW

PMI Model No. P2T-1G1R1G-25-R-SFF-100W is a single pole, two throw, hermetically sealed reflective switch designed to operate over the 1 to 1.1 GHz frequency range. This model is designed to handle 100 W average input power and 5 W peak having a 17 usec pulse width and 2 percent duty cycle.

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

Ultra Low Phase Noise DRO

Model SDRO1000-8 is an ultra-low phase noise voltage controlled dielectric resonator oscillator ideal for applications in high quality phase locked sources for single frequency applications. It is a vital signal source for RADAR, test instruments and high speed clocking circuits. This VCO operates at a fundamental output of 10 GHz, with low power consumption from an +8 V supply with less than 25 mA of current. The phase noise is -107 dBc/Hz at 10 kHz offset; operating temperature from -15° to +75°C.



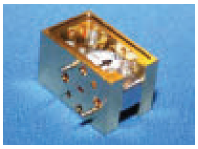
Synergy Microwave Corp.,
www.synergymwave.com.

Absorptive VHF Lowpass Filter

VENDORVIEW

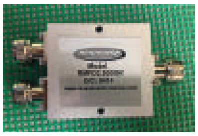
The Model AF9349 is a VHF, lowpass absorptive filter, covering the 10 to 150 MHz bandwidth. This high power design is conservatively rated at 500 W CW (passband), and 100 W CW (stopband). The rejection is guaranteed at -50 dB from 300 to 1500 MHz. The rejection is guaranteed at -50 dB from 300 to 1500 MHz. This compact design measures just 4.5" × 1.75" × 1.13", and is ideal for military and commercial applications.
Werlatone Inc.,
www.werlatone.com.

Isolators and Circulators



The HMI and HMC series broadband ferrite junction isolators and circulators are available from 18 to 120 GHz. They utilize a low loss H-plane structure in a modified Y-junction format to provide minimum loss with maximum isolation and bandwidth. 2 GHz bandwidth with 20 dB of isolation are standard. Wider bandwidth, high power handling and magnetic shielding are available in select units.
HXI Millimeter Wave Products,
www.hxi.com.

DAS Band Power Divider

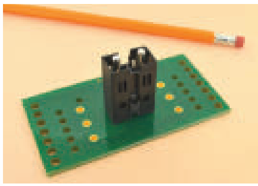


Response Microwave Inc. announced the availability of its new DAS band power dividers for use with distributed antenna applications. The new RMPD2.3000Nf covers the 600 to 3000 MHz band offering typical electrical performance of 0.25 dB insertion loss, VSWR of 13.5:1 and isolation of 20 dB minimum. Power handling is 25 W and the unit is operational over the -35° to +85°C range. Mechanical package is 2" × 2" × 0.75", plus N female connectors. Unit configurations are available in 2-way, 3-way, 4-way, 8-way and 16-way splits.
Response Microwave Inc.,
www.responsemicrowave.com.

NewProducts

Cables and Connectors

Board-to-Board Power Pin Connector



Hirose has strengthened its board-to-board power connector product offering with the development of the flexible and customizable IT-P Series. Featuring a 3-piece structure consisting of the mating receptacle, the interposer, and the mounting receptacle, the IT-P Series provides a wide range of variable height interposers to achieve board-to-board stack heights ranging from 13.5 to 44 mm. The low-profile receptacles are designed to ensure an easy reflow assembly process to the PCB.
Hirose Electric,
www.hirose.com/us.

Quick-Lock Connectors

The QLS® Advanced Quick-Lock solution offers a comprehensive range of advanced product features for reliable, quick lock interconnection. It is fully backward compatible with the quick lock standard offered by the company. Typical features include easy and fast assembly, high packaging density, simple installation without tools and high contact pressure. The range boasts excellent Quick-Lock Antenna Interconnection, color coding of the locking ferrule, which is plastic and thus exhibits very good PIM behavior and high temperature resistance.
IMS Connector Systems,
www.imscs.com.

Expanded-Beam Optical Cable Assemblies

Molex Inc. announced its expanded-beam ruggedized optical cable assemblies, delivering interconnects for use in harsh environments including aerospace and defense tactical communications, security communications, outside broadcast, petrochemical plant, mining and offshore systems. These connectors require minimal cleaning and deliver repeatable, error-free optical transmissions. They can also withstand thousands of mating cycles and feature a field-installable and repairable design to minimize maintenance downtime. The connectors work by utilizing lenses that expand and collimate the light emitting from optical fibers across a sealed connector interface.
Molex Inc.,
www.molex.com.

SMPS Connector Series

Finally, smaller is better! Check out SV Microwave's new SMPS connector series, the next generation in miniature blindmate connectors. The line is directly compatible with the G3PO interface. It is 45 percent smaller than the SMP and 30 percent smaller than the SMPM. The SMPS utilizes SV's threadless design of push-on and blindmate connectors and is capable of frequencies exceeding 100 GHz. Visit the company's website or email marketing@svmicro.com for more information.
SV Microwave,
www.svmicrowave.com.

Nano Circular Connector

TE Connectivity announced its new CeeLok FAS-T nano circular connector. The contact configuration minimizes crosstalk, making it ideal for a variety of markets and applications, including missiles, unmanned aerial vehicles (UAV), soldier systems and C4ISR. The CeeLok FAS-T nano circular connector's ergonomic, nano-miniature design requires less weight and bulk. Available in board-mount and cable-applied versions with quick disconnect or threaded coupling options, the connector is suitable for weapons, ground support systems, soldier-worn applications, avionics, instrumentation and down-hole telemetry tools.
TE Connectivity,
www.te.com.

Amplifiers

Detector Log Video Amplifier

VENDORVIEW

American Microwave Corp. has introduced a form, function and fit replacement for the Detector Log Video Amplifier (Litton part number 27338) utilized in the Litton ALR-85 Radar Warning Receiver and other related platforms. This announcement should be of particular interest to Air Forces looking for parts to maintain their Radar Warning Receiver systems in the F4 and F5 fighter aircraft.
American Microwave Corp.,
www.americanmic.com.

Hybrid Power Amplifier

VENDORVIEW

Model 50HM1G6AB-47 is a compact, wideband, Class AB solid state hybrid power amplifier module that instantaneously covers 1 to 6 GHz. It operates from a single DC voltage and provides 48 dB of

NewProducts

typical gain with excellent gain flatness, low noise figure and low intermodulation distortion for military and wireless applications. The unit offers over voltage and RF input overdrive protection and a fault monitor for over/under current. Additional output power levels in Class A and Class AB configurations are available.
AR RF/Microwave Instrumentation,
www.arworld.us.

Ultra-Wideband Linear Amplifier

Model AMF-5F-04001200-12-10P is a recent addition to MITEQ's family of low noise, wideband, and ultra-small coaxial LNAs in the 4 to 12 GHz band. This LNA has over 39 dB of gain in a housing that is only 0.89" long and 0.64" wide without the field replaceable SMA connectors. Gain flatness is a maximum of ±1.5 dB. The AMF-5F-04001200-12-10P has a maximum noise figure of 1.2 dB in the full band, though the typical value is 1 dB.

MITEQ Inc.,
www.miteq.com.

Medium Power Broadband Amplifiers

VENDORVIEW

Pasternack's new medium power broadband amplifiers are offered in 1 and 2 W models and range in frequency from 2 to 18 GHz depending on the RF amplifier configuration. The excellent performance of these broadband RF amplifiers is achieved using a hybrid microwave integrated circuit design and advanced GaAs PHEMT technology. The connectorized SMA amplifier modules are unconditionally stable and include built-in voltage regulation, bias sequencing, and reverse bias protection for added reliability. These wideband power amplifiers have over-voltage protection that is installed externally for easy repair.

Pasternack Enterprises Inc.,
www.pasternack.com.

4 W Power Amplifier

Model AHP1950-21-4036 is a power amplifier offering 40 dB of linear gain and 36 dBm typical output power at 1 dB gain compression point over the frequency range from 17.5 to 21.5 GHz with excellent gain flatness and VSWR. The amplifier has built-in DC voltage regulator and requires a single DC power supply of +9 to 12 V. The package size of the amplifier is 2.6" × 2.0" × 0.50".

Wenteq Microwave,
www.wenteq.com.

Packaging

Air Cavity Array Packaging

IKE Micro announced the completion of its in-house air cavity array packaging capability. The line includes automatic 01005/0201 SMT placement, die attach from wafer and waffle pack, wedge wire/ribbon and ball bonding, coil attachment, lid marking, lid attachment and dicing of array assemblies.
IKE Micro,
www.ikemicro.com.

MicroAmp MH-1 Housing Kit

Twin Industries MicroAmp MH-1 housing kits facilitate rapid prototyping of 2-port circuits. The aluminum enclosure kits include SMA connectors, ground terminal, bias feed-through, cover plate, and mounting hardware. The housing will accommodate a single Twin Industries MB-series circuit board to create a completely shielded 2-port circuit. Enclosure dimensions = 0.920" × 0.750" × 0.375".
Twin Industries,
www.twinind.com.

Semiconductors/ Integrated Circuits

10 Amp Backup Power Controller IC

VENDORVIEW

Linear Technology Corp. introduces the LTC3350, a supercapacitor charger and backup controller IC that includes all of the features necessary to provide a complete, standalone capacitor-based backup power solution. Many applications require reliable short-term uninterrupted power in the event of a main power failure. The LTC3350 provides all PowerPath™ control, capacitor stack charging and balancing, and capacitor "health" monitoring to ensure that the backup system is capable of reliable operation.
Linear Technology,
www.linear.com.

Limiter Diodes

VENDORVIEW

SemiGen Inc. offers limiter diodes that feature fast turn-on time, low loss, low capacitance and resistance, and easy bonding. SemiGen's RF Supply Center provides high-quality limiter diodes that can be supplied in chip form or in a choice of packages. The SemiGen SLP7100 series of limiter diodes is processed with a high-resistivity epi that has thin, intrinsic layers. These devices are typically in the 2 to 20 micron range of epi thickness and can be gold-doped to achieve specific performance goals.
SemiGen Inc.,
www.semigen.net.

Sources

Voltage Controlled Oscillator

Crystek's CVCO55CC-3274-3280 VCO operates from 3274 to 3280 MHz with a control voltage range of 0.3 to 4.7 V. This VCO features a typical phase noise of -115 dBc/Hz @ 10 kHz offset and has excellent linearity. Output power is typically +5 dBm. The model CVCO55CC-3274-3280 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 8 V, with a max. current consumption of 30 mA. Pulling and pushing are minimized to 3 MHz and 0.1 MHz/V, respectively. Second harmonic suppression is -12 dBc typical.

Crystek Corp.,
www.crystek.com.

E-Band Active × 4 Multiplier
VENDORVIEW

Model SFA-713863410-12KF-S1 is a 71 to 86 GHz × 4 active multiplier which is designed for E-Band communications and automotive radar applications. The active multiplier converts 17.75 to 21.5 GHz/+5 dBm input signal to deliver 71 to 86 GHz frequency band with a typical +10 dBm output power. The spurious and harmonic suppressions of the multiplier are 60 dBc, 20 dBc or better, respectively. The multiplier draws 250 mA current from a +8 VDC DC power supplier.

SAGE Millimeter Inc.,
www.sagemillimeter.com.

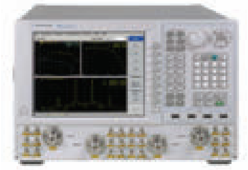
Direct Digital Synthesizer

Ultraview Corp. announced a dual DDS PCIe board with rapid profile switching for demanding uses in communications, radar, medical imaging, spectroscopy, RF/microwave testing and other critical applications. The Synth1000x2 can be set to produce two independent sine wave outputs, the frequency, amplitude, optional sweep rate and phase of which can either be changed manually using either a LabVIEW™ or QT GUI, or alternatively can be dynamically switched in real time (in under 50 ns), allowing the creation of complex modulated carriers, or rapid waveform sequences.

Ultraview Corp.,
www.ultraviewcorp.com.

Test Equipment

PNA-X Network Analyzer
VENDORVIEW



Agilent Technologies Inc. expanded the PNA-X family of network analyzers with an 8.5 GHz model that supports lower-frequency devices used in wireless communication applications. The PNA-X nonlinear vector network analyzer (NVNA) has also been expanded to include an 8.5 GHz model. The new solutions provide engineers developing and manufacturing active devices the flexibility to select just the right frequency required for their specific application. The 8.5 GHz PNA-X offers the unmatched performance and capabilities needed to deliver on all fronts.

Agilent Technologies Inc.,
www.agilent.com.

DAS Tray DCC500 Series

Microlab is releasing the active DAS tray DCC500 Series as part of the low PIM DAS tray product line. The DAS Control Rack (DCR) is the monitoring and controlling unit for Microlab's DCC Series® product offering. The stand-alone 19" rack mount 1RU system allows for real time monitoring of 8 independent wideband channels, 698 to 2700 MHz. These channels are comprised of 4 uplink and 4 downlink sections that can be monitored and controlled locally or remotely.

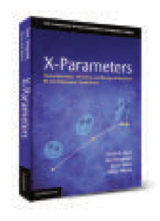
Microlab,
www.microlab.fxr.com.

RF Signal Generators
VENDORVIEW

Mini-Circuits SSG-series portable synthesized signal generators are high-performance and cost-effective signal sources ideal for production, lab and field test environments. All models come standard with pulse modulation, frequency and power level scheduling for applications requiring automation capability, frequency hopping, USB control and GUI software. Special features include, high power output, low harmonics, expanded frequency range, AM, PM and FM capability, frequency resolution in step sizes as small as 0.01 Hz, power level resolution in step sizes as small as 0.001 dB, fast tuning (< 300 µs), and TCP/IP Ethernet control.

Mini-Circuits,
www.minicircuits.com.

MICRO-ADS



X-Parameters

David E. Root,
Jan Verspecht,
Jason Horn and
Mihai Marcu

With modern communications systems pushing active devices for more efficiency, more devices are being used in the nonlinear region. Dealing with nonlinearity means that new measurement and modeling methods are required beyond S-parameters. *X-Parameters* provide a solution to this dilemma.

This book is a comprehensive introduction and guide to X-parameters, written by the original inventors and developers of this new paradigm for nonlinear RF and microwave components and systems. It covers how to use X-parameters to overcome intricate problems in nonlinear RF and microwave engineering. The general theory behind *X-Parameters* is intuitively introduced, and then simplified down to specific, practical cases, providing useful approximations that will reduce the complexity of measuring, modeling and designing for nonlinear regimes of operation. The chapters include a review of S-parameters, introduction to X-parameters, spectral linearization approximation, X-parameter measurement, multi-tone and multi-port cases and memory.

This book targets professional microwave engineers, device modeling engineers and scientists, RF and microwave circuit designers, electronic and communications engineers, CAE professionals developing simulator algorithms, and microwave and RF professionals developing new high-speed instrumentation for a wide range of nonlinear characterization applications. Due to the inherent interdisciplinary nature of *X-Parameters*, the goal of this book is to appeal to a broad audience. *X-Parameters* contains real-world case studies, definitions of standard symbols and notation, detailed derivations within the appendices, and exercises with solutions, as a useful reference for researchers, engineers, scientists and students looking to remain on the cutting-edge of RF and microwave engineering.

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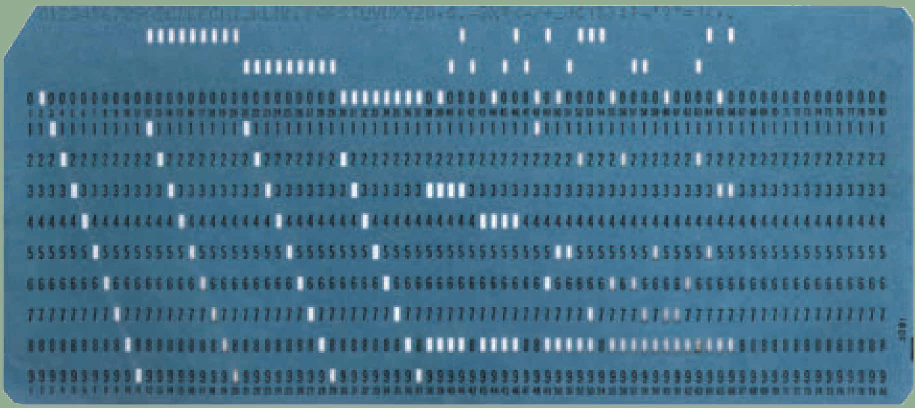
Simulation uses mathematical models and various numerical techniques to replicate the behavior of an actual electronic device, electrical structure, system or circuit. Simulation software allows for modeling of circuit operation and is an invaluable analysis tool. Simulating a circuit's behavior before actually building it can greatly improve design efficiency by identifying faulty designs early and providing insight into the behavior of electronics' circuits and physical designs. Almost all IC design relies heavily on simulation.



1969 UC of Berkeley grad student, Laurence Nagel begins development of a public domain general purpose circuit simulator called SPICE.

1971 Texas Instruments' file patent on use of automated data processing machine to generate a continuous analytical objective function on a coded circuit representation. A program known as CAIN.

1973 Les Besser commercializes a program he authored called Computerized Optimization of Microwave Passive CircuiTs (COMPACT) and establishes the first microwave CAD company, Compact Software.

1983 Chuck Abronson and Bill Childs start EEsof, releasing Touchstone, the first design software to operate on the rapidly growing personal computer platform.

1987 HP releases the first version of its in-house developed linear circuit simulator with integrated schematic capture and graphical layout, HP Microwave Design System (MDS) the pre-cursor to ADS.

Compact Software introduces Microwave Harmonica, the first commercialized nonlinear RF circuit simulator using harmonic balance techniques developed by Rizzoli.

1989 Jim Rautio releases the first version of Sonnet software, a planar electromagnetic simulator for solving and analyzing 2 and 2.5 dimensional structures.

1990 Microwave Journal's cover feature introduces HP's high frequency structure simulator (HFSS) co-developed with Ansoft Corp., introducing 3D finite element methods to RF/mW design.

1998 AWR first demonstrates Microwave Office, an object-oriented EDA Environment that includes EM, Circuit simulation and schematic capture at the IMS in Baltimore.

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