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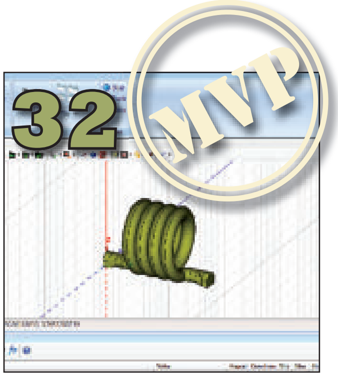

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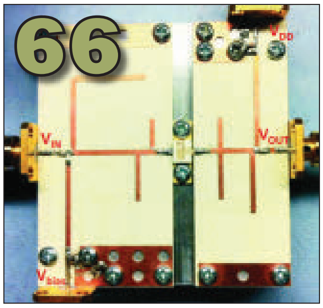

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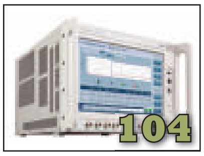

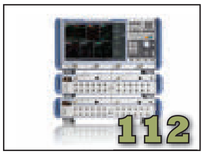

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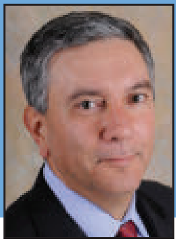

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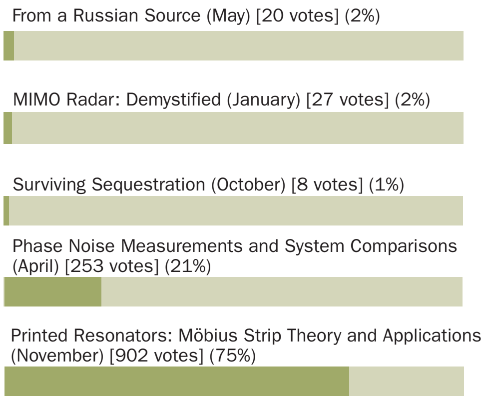

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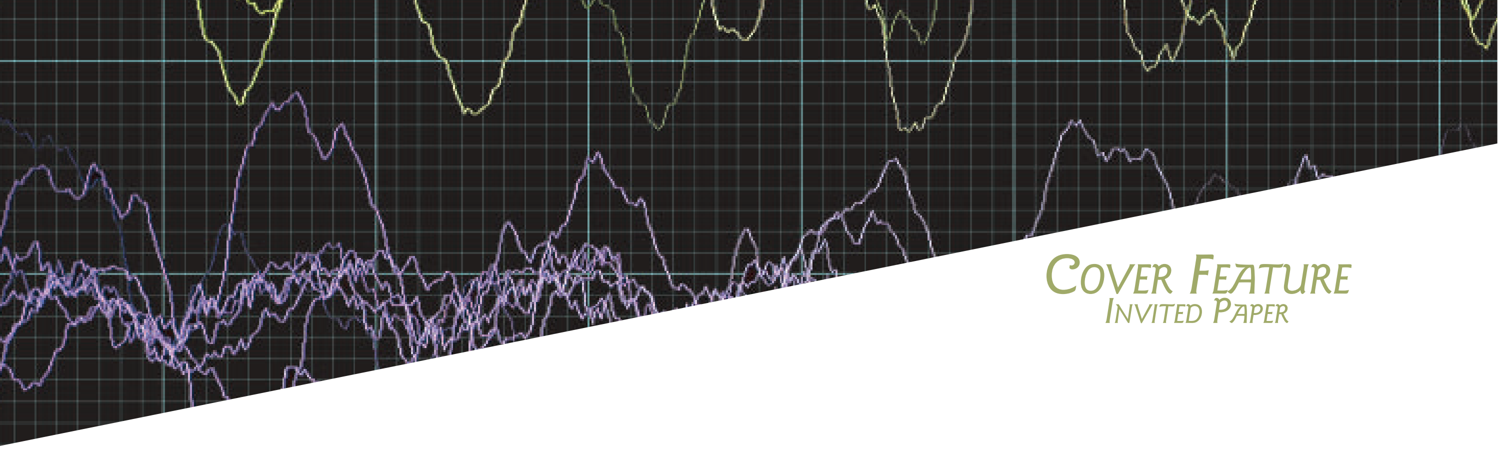

COVER FEATURE
INVITED PAPER

Tips for Transitioning Designs to Manufacturing

Bill Reid
National Instruments, Austin, TX

A culture of continuous innovation in the consumer electronics industry has conditioned us, as consumers, to expect technology improvements at rates that are faster than ever before. Not only are these products becoming more complicated, but increasing competition has dramatically reduced the typical design cycles. As a result, the ability of an engineering organization to move a product from schematic to final product through efficient design and test practices has become a competitive advantage.

Although improvements in development practices can often require organizational change, there are several practical tips that engineers can implement to ultimately reduce time-to-market. In this article, everything from simple design choices for better manufacturability to careful planning of test software and hardware will be discussed. Three of the most critical best practices include:

- Design for manufacturability and debugging
- Writing scalable and reusable test code
- Replicating the physical manufacturing environment in all stages of development

In order to understand best practices for taking a product from design to test, one must consider that manufacturing test goals are often quite different from the goals of design verification. Design verification testing is meant to verify that the product meets its specifications under all operating conditions. By contrast, manufacturing test is designed to ensure that the product was assembled correctly with all components functioning as expected. In spite of the differences between these goals, engineers can leverage verification testing development in manufacturing with careful planning. Note that although the best practices described here are specifically applied to RF product developent, the philosophies presented apply to any type of commercial product design.

DESIGN FOR MANUFACTURABILITY

In many organizations, development groups often do not consider manufacturing test until the very end of a design cycle. However, in order to properly leverage design efforts for manufacturing, designers must anticipate manufacturing test issues from the very first revision of the design. Many times, if consideration is given for manufacturing test early in the design process, important decisions on layout and access to test signals/circuitry can reduce the overall cost of validation and manufacturing test.

For example, many times it is difficult to include control circuitry such as highly integrated ASICs in initial revisions of a product. This results in the need for expensive test equipment that emulates the device's operating environment – leading to longer and more costly test times. As an example, the lack of non-signaling modes on cellular chipsets can substantially increase product validation times. Without non-signaling modes in the initial revision of a product, engineers are forced to test the radio with more expensive and substantially slower base station emulators. Thus, by including critical control circuitry in initial revisions of a product, engineers can frequently reduce validation time through the use of less expensive test equipment such as a signal generator

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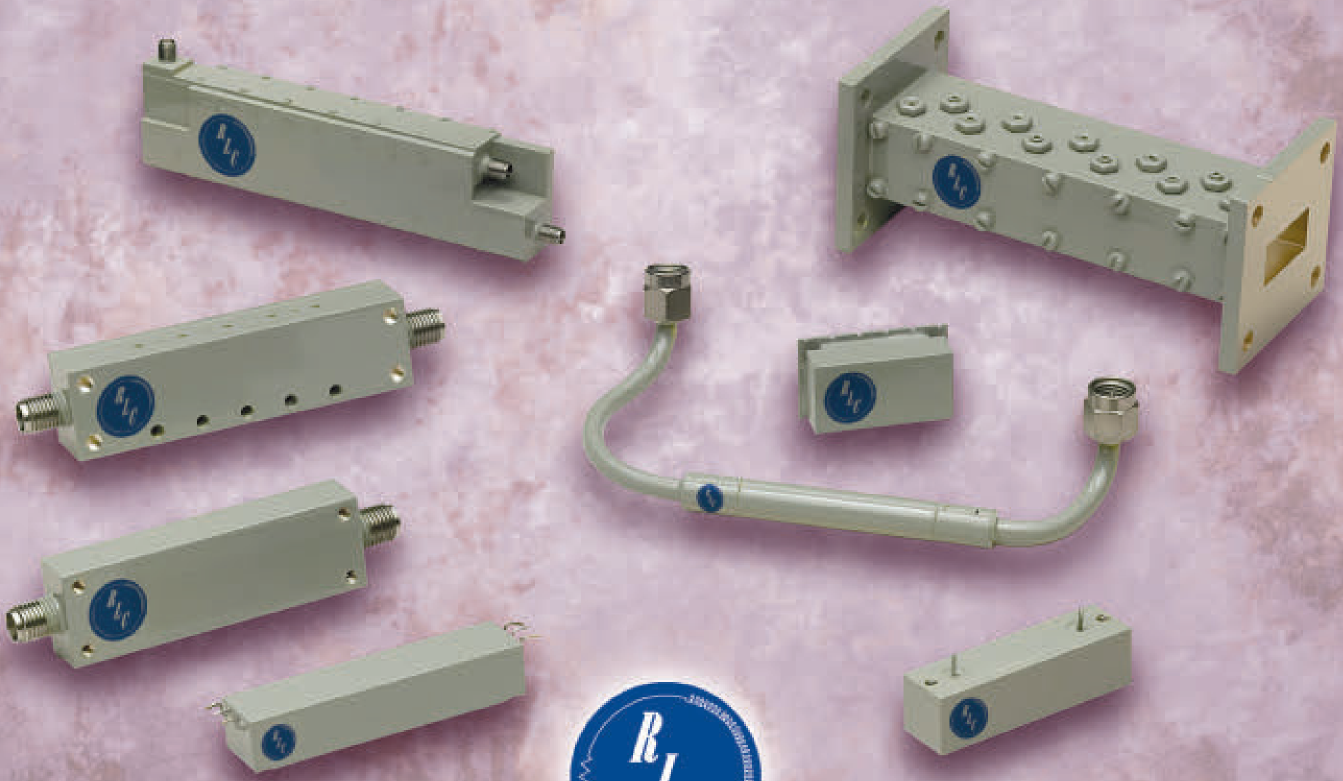

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One of the simplest ways to reduce potential issues in manufacturing is to strictly adhere to design rules such as: component spacing, "keepout zones," and proper pad shapes to prevent component "tombstoning." Both PCB and chip-level manufacturers frequently provide design rule checking software to ensure that the design can be practically manufactured. Following these design guidelines from the very first layout is extremely important. Although designers are often tempted to "fudge" design rules until later revisions, the delay often makes the changes even more difficult to implement. On the other hand, engineers considering design rules on the first revision will result in a much more robust design and easier transition to manufacturing.

PROBING AND DEBUGGING

One practical tip to identify manufacturing issues in complex designs is to use appropriate debugging and test interfaces. Engineers can generally improve their ability to test or debug or troubleshoot a circuit through two primary methods. First, it is important to design probe pads and various test interfaces into the product itself. Second, engineers should develop production-grade test fixturing in parallel with the initial design to ensure more repeatable validation measurements.

In development, engineers frequently use manual probes to troubleshoot problems with a circuit. However, manual probes are subject to measurement error and can lead to incorrect assumptions about circuit performance. In both design and manufacturing, it is often essential to provide detailed insight into the performance of a product. Thus, designers must consider adding the ability to probe a design in a way that is repeatable and has minimal impact on the impedance of the circuit. Considering probing needs early in a design cycle enables engineers to ensure the circuit layout and component placement allows for proper probing.

Engineers are often reluctant to use inter-board connectors due to the cost. Probes can be a viable solution provided one gives attention to the attenuation and uses the proper probe and landing pattern. For low frequencies (below 100 MHz), designers frequently use "pogo"-type probes to measure signals on specific PCB traces. These probes are named for their spring-loaded mechanical action (like a pogo stick) and are very effective when used with the appropriate probe pad. At RF frequencies, however, pogo-type probes and the associated landing pads are susceptible to a host of high frequency related parasitic behavior that can impact electrical performance such as impedance match and insertion loss.

There are several probing solutions at RF and microwave frequencies, and one that we have found to be particularly effective is the use of broadband coaxial probes. Coaxial probes, such as the Everett Charles K-50L (see ***Figure 1***), feature an SMA connector for easy connectivity to a spectrum analyzer or power meter. Although probes and probe landing pads

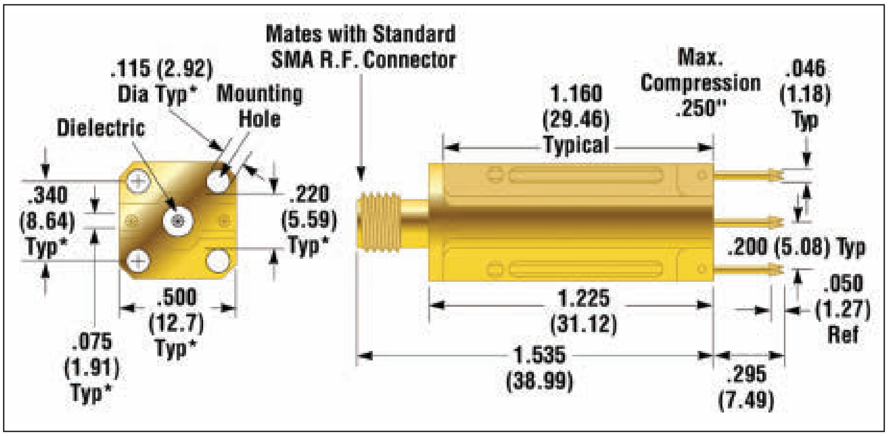

Fig. 1 Schematic of an Everett Charles Coaxial Probe.

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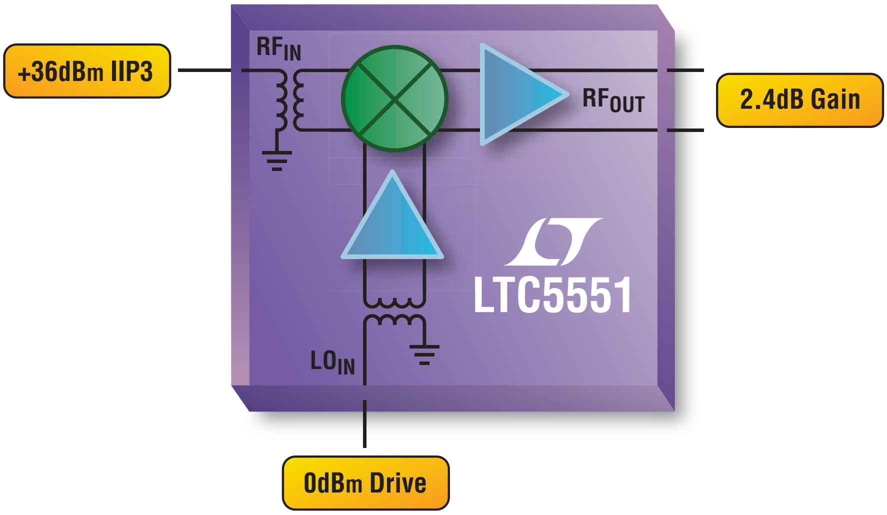

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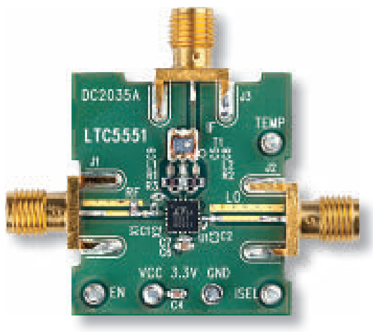

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are useful in many instances, RF engineers are often reluctant to use probe pads since they can lead to destructive capacitance and degrade circuit performance. One frequent workaround is to design the probe pads from the actual board traces. For example, if the designer knows he will be using an RF probe, the board geometry (such as trace width and ground plane spacing) can be designed to accommodate this probe without the need for specific landing pad geometries. In some instances, one can use surface mount component pads to double as a probe pad, allowing one to probe the circuit in a well-matched interface with the component removed.

Another effective solution for both validation and manufacturing test is to use a coaxial connector with an integrated switch. In this approach, the mechanical action of connecting a probe drives a single-pole double-throw switch. Thus, the switch will internally route to one terminal when the probe is not connected, and a second terminal when the probe is engaged. The integrated connector/switch probes were initially designed for the cellphone industry as a means to measure RF power through a connector by disconnecting the antenna. Today, RF engineers can choose from a range of devices with excellent performance at 12 GHz and beyond.

LAYOUT BEST PRACTICES

One important yet often overlooked consideration in design for manufacturability is isolation of key circuitry. For example, consider the block diagram of a typical receiver shown in ***Figure 2***. In order to adequately determine the performance of individual components, the designer needs to be able to isolate the mixer from the amplifier and isolate the local oscillator from the mixer. If the synthesizer is directly attached to the mixer without any interface to separate the two components, it would be more difficult to troubleshoot potential issues with the synthesizer. By separating these interfaces and testing each section individually, one can accurately troubleshoot issues with more complex components.

There are multiple ways to separate critical interfaces. One is to physically separate the layout of each subassembly and connect them through coaxial connectors such as an SMA. Unfortunately, SMA connectors often increase size and add cost to the design. Integrated switch/connector assemblies (such as the one described earlier) provide an excellent alternative as they are a well-matched pass-through part with essentially nonexistent insertion loss.

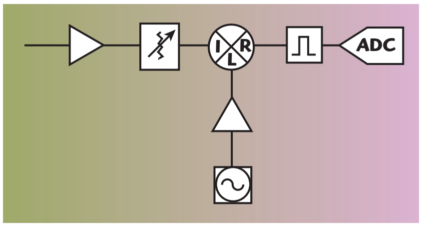


Fig. 2 Typical receiver architecture.

CORRELATING MEASUREMENTS THROUGH REUSABLE TEST CODE

Another issue that test engineers often face is the ability to correlate manufacturing data with measured results completed during validation testing. Difficulty in correlation can occur for several reasons, including the use of different test equipment, the effect of test fixtures, and changes in the physical environment. One of the easiest issues to mitigate is the errors associated with using different measurement algorithms in validation and manufacturing test.

In general, R&D groups typically require very high performance instruments to ensure that the specification limits of the instrument do not influence the validation test results. By contrast, the sheer amount of instrumentation required for a large-scale production operation typically requires manufacturing test equipment to be cost optimized. Unfortunately, the differing requirements of validation test and manufacturing test often lead organizations to use very different test equipment – causing problems with measurement correlation and introducing additional effort to write test software.

Because differences in measurement algorithms can lead to differences in measurement results, one of the simplest steps to improve correlation be-

tween validation and production testing is to ensure that all measurements use the same measurement algorithm. One can ensure algorithm standardization through practices such as:

- Use of software algorithms that run on a PC (or PXI system) rather than a test instrument
- Use of similar test equipment (same vendor) in both validation test and production test
- Use of industry-defined measurements such as those defined by IEEE standards.

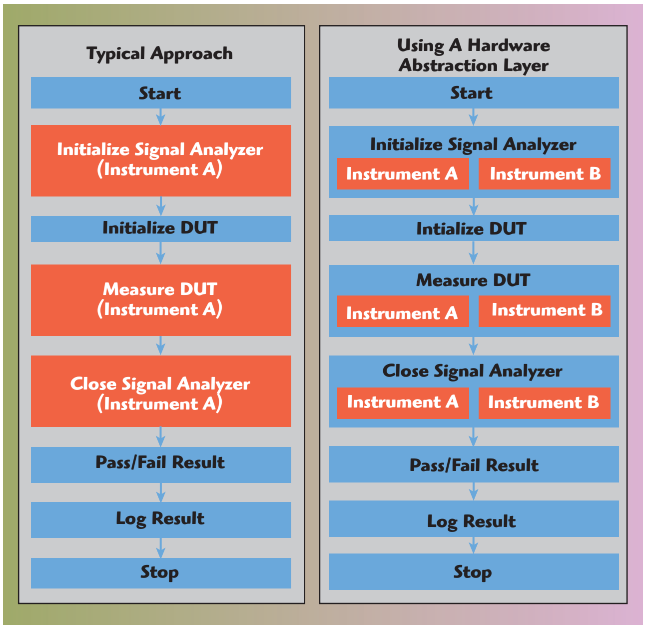
Of these, one of the simplest methods to ensuring measurement algorithm standardization is the use of instrumentation from the same vendor in all stages of product development. This approach also provides the added benefit of being able to more easily leverage test code written for validation test in the production test phase.

LEVERAGING TEST CODE BETWEEN VALIDATION AND MANUFACTURING TEST

Although leveraging validation test code in manufacturing might seem like an obvious best practice, it requires careful attention to software architecture. For example, using a modular and hierarchical software architecture is critical in order to leverage validation test code in manufacturing test. When writing software for validation testing, it is often tempting to generate code in the fastest way possible – without attention to architecture or long-term supportability. However, because much of the same measurements performed in validation are also performed in production test, it is useful to ensure that the validation test code is as flexible as possible.

A simple best practice for writing test software is to use a hardware abstraction layer. The idea of this practice is to encapsulate driver calls for a particular instrument within a higher-level function call. This approach makes it easier to modify the test code in the future to add additional instrumentation without a major rewrite. As observed in ***Figure 3***, the use of a hardware abstraction layer requires that the test code be architected such that a specific instrument's driver calls are within the framework of a function call to the instrument family. Although it requires better upfront planning, the implementation of a hardware abstraction layer improves test code reuse and can ultimately reduce test software development time. Note that the hierarchical nature of a hardware abstraction layer is relatively straightforward in natively hierarchical programming languages such as NI LabVIEW system design software or other similar languages.

Note from Figure 3 that an important architectural practice is to separate code to configure the DUT from code to configure the instrument. Although these tasks can often be executed in parallel, it is a better design practice to ensure that the two tasks are independent of one another. In some instances where measurement speed is of the utmost importance,



▲ *Fig. 3 Traditional approach versus use of a hardware abstraction layer.*

test executive software can automatically configure two independent function calls to execute in parallel.

COMMON PHYSICAL ENVIRONMENTS IN VALIDATION AND MANUFACTURING

The physical environment of an engineering lab is often very different than a manufacturing facility. Although it might seem counterintuitive, manufacturing environments often experience a much wider degree of variability than what is present in the lab. In addition, fluctuations in temperature, problems with power quality, and even spurious responses from other devices can affect test results. A final best practice is to ensure that the physical environment during validation testing is identical to the physical environment on the manufacturing floor.

Although a wide range of challenges in the manufacturing environment can influence a measurement result, temperature variation is one of the most problematic. On a manufacturing floor, the high density of electronic equipment can emit significant and widely varying heat radiation. In addition, simple attributes such as being located underneath an air conditioning vent or near a door can also affect the localized ambient temperature. Thus, while an ideal manufacturing facility might tightly control air temperature on a large scale, it is extremely difficult to control local temperature at the DUT. Not only do these fluctuations in temperature affect the accuracy of the instrumentation, but they also significantly affect the performance of the DUT.

In my years of manufacturing experience, I have personally observed factories where the ambient temperature was controlled to within one degree, but with up to 10 degree swings in temperature localized at a particular test station. As context to the effect of temperature on measurement quality, a typical high frequency amplifier typically experiences power variation of up to 0.03 dB per degree C. With instruments and complex devices having several amplifiers in a single signal chain – the power error associated with temperature variation can quickly stack up. Such large swings in temperature can cause substantial issues when trying to align the output power to within a tight range such as ±0.5 dB (or better) typically required for power amplifiers.

One of the best first-order attempts to reduce temperature variation due to electronic equipment is to ensure proper airflow and ventilation. In addition, it is often useful to accompany each RF measurement (either in validation or in manufacturing) with a temperature measurement. Especially in larger PCB designs, an on-board temperature sensor is a reliable method to monitor temperature. By monitoring the temperature, engineers can associate each RF measurement with the environmental conditions. As a result, the temperature data can often explain discrepancies between validation and production test results.

FIXTURING

Another way to replicate the production environment in validation is to use standardized fixturing practices. In many organizations, fixturing is often ignored until the product has been transitioned into the manufacturing phase of development. Although fixturing can either enhance or degrade measurement performance, it is important to use production-quality fixturing early in the development cycle. Fixturing should be designed and manufactured in parallel with one of the early or first design revisions.

In the characterization environment, it is common for engineers to test designs using poor cabling solutions such as flimsy cables and low-quality connectors that are difficult to de-embed. The use of high-quality fixturing, traditionally reserved for production test, has several benefits. First, using fixturing in validation testing improves this measurement quality by making them more repeatable and stable. Second, and perhaps more importantly, the use of better fixturing during validation often helps one to better correlate validation test results and manufacturing test results. An example of a board level fixture is shown in ***Figure 4***.

Production quality fixturing also enables engineers to test a DUT with little direct operator interaction. Typical production-grade fixtures provide repeatable interfaces for both RF/analog measurements, control I/O and DC power. In addition, fixtures can also protect from important environmental aspects such as electromagnet-

ic interference, and better heat dissipation. Fixtures also minimize touch from human hands – which can also affect the quality of the product.

ELECTROMAGNETIC EMISSIONS

A final method to ensure common physical environments between validation and manufacturing is to measure and, if necessary, compensate for the electrical environment. In general, validation labs are relatively electrically quiet. With fewer products being tested and less electronic equipment than in a manufacturing environment, the lab contains a relatively small number interference producers. In some instances, well-shielded enclosures in the validation lab protect a DUT from outside spurious emissions.

When performing validation testing, an important best practice is to duplicate the manufacturing environment in the lab. For example, one can use a spectrum analyzer to measure radiated electromagnetic spurs, and then use other DUTs to re-create the effect in the validation lab. Other conditions that are useful to replicate include power supply variations. Power supply analysis is especially useful when using manufacturing facilities in locations where power stability is more problematic. By emulating the manufacturing environment during validation testing, one can predict their test system robustness and also determine the impact to test limits. This type of investigation can prevent crisis management on test issues that could occur during early production runs.

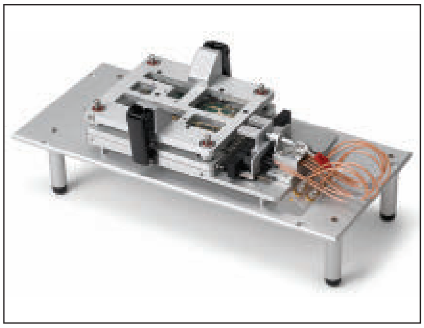


Fig. 4 Board-level validation and manufacturing test fixture.

CONCLUSION

As the electronics industry has evolved to become more competitive, it is increasingly important for organizations to adopt practices enable them to move products from design to production test more quickly. As this article discusses, engineers must become increasingly aware of design for manufacturability, test code development, and the conditions of the manufacturing environment. Taking these areas into account early on in a design will allow for a much-improved efficiency to transition the product to production. ■

Bill Reid *is a chief hardware architect at National Instruments with 29 years of experience in the RF/microwave industry. He has extensive expertise in micrpowave product design, developing manufacturing test systems, consulting with customers, and general management. During his 12 years at NI, he has served both a business and technical leader. Along with his system and board-level design experience, Reid also has extensive metrology experience, developing the calibration routines and accuracy models for NI's RF products. Prior to NI, Reid worked at General Dynamics, EG&G, Texas Instruments and Nokia Mobile Phones. Reid has a bachelor's degree of electrical engineering from the University of Illinois at Chicago and graduate studies at California State University, Fullerton.*

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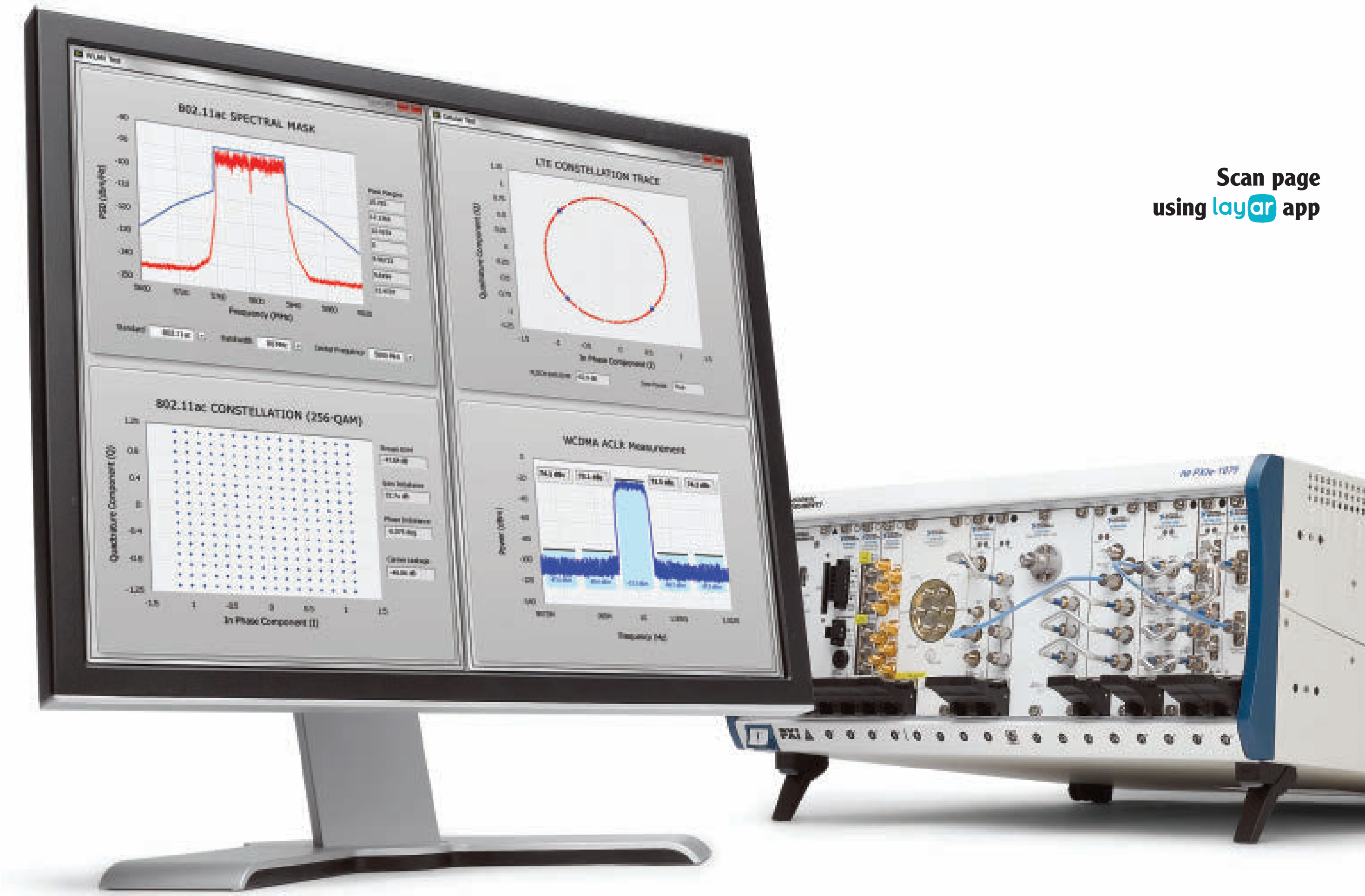

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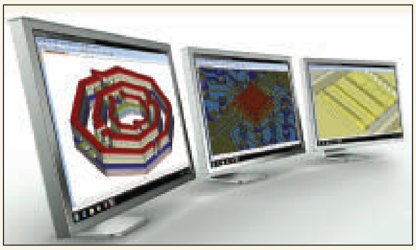


Analyst V11 Offers User-Customizable Library

AWR, A National Instruments Company
El Segundo, CA

Analyst™, AWR's full 3D electromagnetic (EM) finite element method (FEM) simulator, offers a user-customizable library of parts as well as new antenna capabilities in its second major release that's encompassed within the V11 release of the AWR Design Environment™. In particular, 3D PCells (parameterized cells) are the backbone for bringing user-customizable library parts to the engineering desktop. PCells have been added, making it easy for designers to develop and use fully customizable parts, which, once created, can be deployed multiple times across multiple users thereby ensuring maximum flexibility, engineering productivity and reuse.

As well as configurable PCells, the V11 release of Analyst has a number of new additions that aid in antenna analysis, including field patterns and standard measurements of interest to the antenna engineer. Other improvements include a connectivity viewer, additional example design projects, and more than a dozen pre-configured 3D PCells for structures ranging from gull-wing packages to capacitors, coaxial cables and air coils. (Note: The key features introduced in the first version of Analyst (AWR Design Environment V10.x) are detailed in a December 2013 *Microwave Journal* article.

V11 COMPLETES ANALYST INTEGRATION INTO MICROWAVE OFFICE

The idea for Analyst sprang from the design community's need for 3D EM simulation to be completely integrated within a circuit simulation environment. This alleviates the nuances associated with the manual interaction and cumbersome duplication of efforts associated with disparate EM point tools being manipulated to fit within a circuit design flow/framework. In the V10 release, Analyst was introduced into Microwave Office®, AWR's circuit design software. The designer could create designs using the already-available 2D-extrusion editor and include pre-defined PCells for the most common of 3D interconnect like bond wires, BGA balls, tapered vias and grounding straps. In addition, finite extent dielectrics and holes and voids in dielectric layers could be created. The focus was on making Analyst as transparent as possible for microwave engineers to use in the design of circuits ranging from MMICs to MICs RF PCBs and microwave modules. In fact, any designer already familiar with AWR's AXIEM® 3D planar EM solver could immediately access and use Analyst and readily grow more proficient after grasping the addition of expanded boundary condition options and port settings.

While the first release of Analyst addressed the user community's most common request for a seamless EM-circuit design flow that accounted for common arbitrary 3D structures, the request for additional shapes and flexibility for users to readily customize their own parts library brought forth V11 Analyst. V11 addresses the need for the occasional inclusion of 3D shapes that are not in the available set of preconfigured PCells and cannot be constructed through the existing 2D-extrusion drawing environment.

For example, an SMA connector was not available in V10 whereas in V11, the new user-defined library of parts (3D PCell feature) solves this problem. A designer can now open a 3D layout editor and draw the SMA connector as desired. Since the 3D editor is coupled to the Microwave Office environment, all units and electromagnetic environment and material properties remain consistent. A key feature of the editor is the ability to use parameters to develop the drawing. These parameters can be exported to Microwave Office. Since the user of the PCell can change the parameters, the resultant cell can be reused in a wide variety of cases. For example, with about 15 parameters, the SMA connector can be modified to represent a wide variety of available connector types. Examples follow.

HOW 3D USER-DEFINED PCELLS WORK

The new 3D PCells are created in Analyst's new 3D drawing editor, which augments the already existing 2D layout environment in the AWR Design Environment's Microwave Office circuit design software. Parameters can be used to control the drawing of the part. Once created, designers can simply use the part in Microwave Office, changing the shape by varying the parameters as necessary. A "create once, use often" library of cells is thereby created and configured for the designer's specific needs.

Analyst comes with a variety of common RF/microwave parts already created, including connectors, coils and transmission lines. These parts are sufficient to fulfill most designer needs, however, if a new user-customized cell is needed, cre-

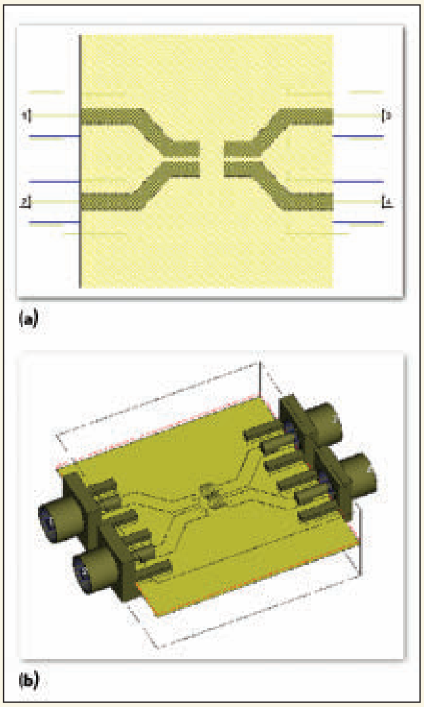
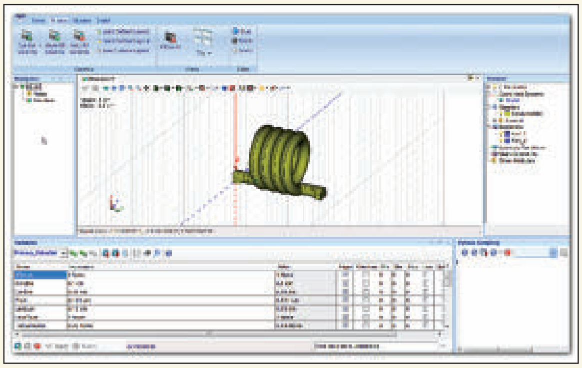


Fig. 1 Layout with SMA and coil PCells (a) and 3D view showing ports on SMA connectors (b).



◀ *Fig. 2 3D editor screenshot example.*

ating the part in the Analyst 3D editor is straightforward. The editor is closely tied to the standard Microwave Office layout environment, with the units and various electromagnetic material library properties and the technology stack up being shared as needed. In addition, 3D layouts can also be imported into Analyst by using the industry-standard ACIS (.sat) layout file format, which is supported by virtually all 3D CAD programs and/or other translators to additional 3D CAD files like IGES.

Figure 1 shows two examples of 3D PCells in action. An SMA cell is used four times to draw the SMA connectors at the edge of the board. A coil 3D PCell is used twice to show two air coils in the middle of the board. These cells were created in the V11 3D layout editor, placed into a user-defined library, and then called by the designer as needed. Figure 1a shows the 2D layout in Microwave Office. Note that there is a 2D outline of the cells, so that the designer can easily place them as needed. The lines and ground floods have been drawn in the standard manner. The 3D image in Figure 1b shows the completed board, four connectors and two air coils.

The 3D editor is shown in ***Figure 2*** for the example of the air coil used in Figure 1. The editor is opened from within Microwave Office, ensuring that material parameters and units are shared between the 3D editor and the 2D drawing environment. Figure 2 shows that the 3D editor contains the standard features expected in an industry-standard 3D CAD drawing tool. The coil is shown in the drawing area. Shapes are created through the usual choice of starting with generic 3D shapes, and then modifying them by changing their parameters. Standard Boolean operations and transformations are supported.

The right side of Figure 2 shows the material properties menu, where the various electromagnetic properties of the shapes making up the coil are set. The lower left window shows various parameters used in making the coil. Normally, parameters are used as a way of making the cell customizable. A designer using the cell in Microwave Office can change the parameter values without having to go into the 3D editor. The advantage of exposing parameters to Microwave Office is that most designers never need to use the 3D editor. For example, a designer using the coil cell shown in Figure 2 can quickly change the number of turns by changing one parameter value in Microwave Office. A well-created, user-customizable part (PCell) can therefore lead to tremendous reuse.

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Dynamic Range (BW=10Hz,dB,typ)	120	120	120	120	120	120	115	100	100	60
Dynamic Range (BW=10Hz,dB,min)	100	100	100	100	100	100	100	80	80	40
Magnitude Stability (±dB)	0.15	0.15	0.15	0.15	0.25	0.25	0.3	0.5	0.8	1
Phase Stability (±deg)	2	2	2	2	4	4	6	8	10	15
Test Port Power (dBm)	6/13	6/10	6/10	0	0	-6	-9	-17	-25	-35

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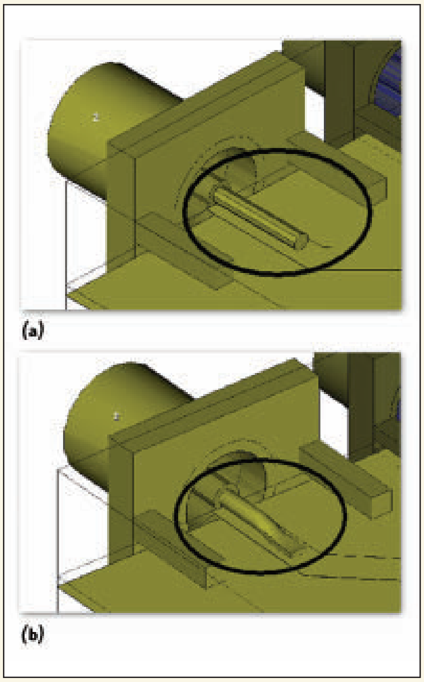
Another example of the versatility of parameters and 3D PCells is shown in ***Figure 3***. The designer can change the shape of the center pin of an SMA connector by setting one parameter. This was accomplished by equations in the 3D editor, which use the values of the parameters as input. If desired, the creator of the cell can even automate the creation operations using a built-in Python scripting capability.

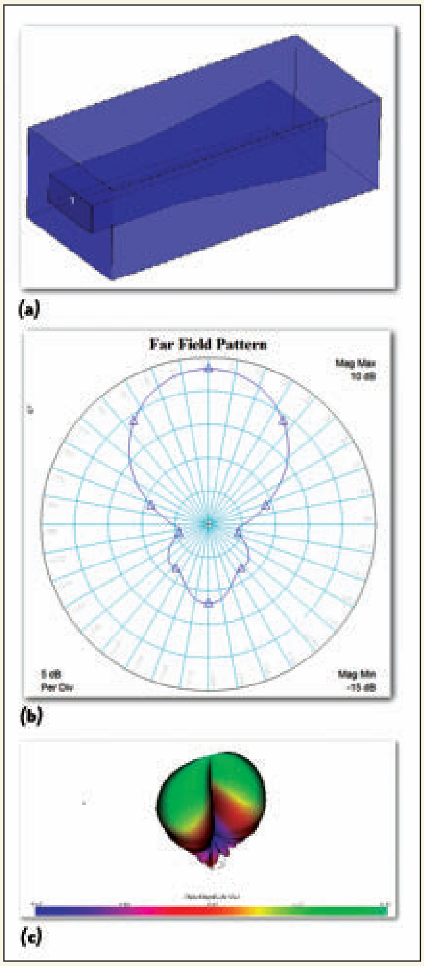
Finally, it is possible to import 3D layout files into the 3D editor using the standard ACIS layout language format. It is therefore also possible to reuse layouts created in other 3D EM simulation or mechanical drawing tools.

3D ANTENNA ANALYSIS AND VISUALIZATION

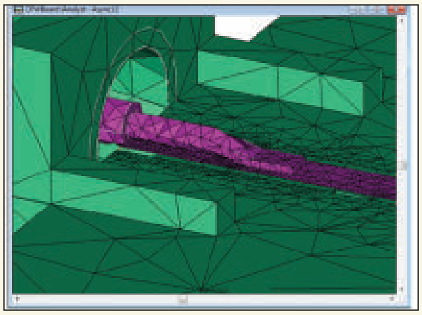
In addition to the user-customizable library of parts, V11 has a number of new features to help the antenna engi-



▲ *Fig. 3 3D view showing a round center pin (a) and a tabbed transition on center tab (b).*



▲ *Fig. 4 3D view of a pyramidal horn (a), total power radiation pattern (b) and 3D antenna pattern (c).*



▲ *Fig. 5 Example of DC connectivity checker.*

neer. ***Figure 4*** shows a simple pyramidal, microwave horn, designed to operate at 10 GHz.

Figure 4a shows the horn in the 3D editor. Special absorbing boundary conditions are used at the simulation boundaries to approximate infinite space. Figure 4b shows a typical radiation pattern that can be shown in Microwave Office. This one is the total radiated power at a phi of 0 degrees, sweeping over theta, the vertical angle. Figure 4c is a 3D representation of the E theta radiation pattern. Other typical measurements are available, including directivity and gain.

As another aid to visualization, Analyst now has a built-in DC connectivity checker to ensure that the circuit is connected properly. An example is shown in ***Figure 5***. The inner conductor of the coaxial line is a different color than the outer conductor. The designer can clearly see that the two are not electrically connected, which is what is intended. By using the connectivity view checker, designers can avoid costly layout mistakes, resulting in simulation errors and lost time.

With AWR's new Analyst V11 release, designers can simulate arbitrary 3D structures from within the Microwave Office environment. Using a combination of user-defined PCells and preconfigured shapes, the microwave designer has the power of 3D EM simulation without the distraction of having to work in an external tool disconnected from the main circuit simulation environment. Drawing time is reduced and possible set-up errors are eliminated. Powerful simulation concepts like parameter sweeping and model optimization are now easily accessed in AWR's fully integrated environment.

VENDOR**VIEW**

AWR, A National Instruments Company,
El Segundo, CA,
www.awrcorp.com.

Analyst Features at a Glance

- ☑ Schematic-driven EM
- ☑ Layout/drawing editor
- ☑ NEW: Any arbitrary 3D parts can be created and parameterized, or imported in SAT or IGES formats. Some of the new ready-to-use 3D EM models include SMA connectors, coaxial lines and air coil inductors.
- ☑ Automatic and adaptive meshing
- ☑ Discrete and fast-frequency sweeps
- ☑ 2D & 3D visualization (near-field animations)
- ☑ Results post-processing
- ☑ NEW: Antenna analysis is now fully supported in Analyst including radiation patterns. New antenna examples include pyramid horn antenna and patch antenna.

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DefenseNews

Cliff Drubin, Associate Technical Editor

U.S. Army and LM Complete Advanced Autonomous Convoy Demo

The U.S. Army Tank-Automotive Research, Development and Engineering Center (TARDEC) and Lockheed Martin have demonstrated the ability of fully autonomous convoys to operate in urban environments with multiple vehicles of different models.

The January demonstration at Fort Hood, TX was part of the Army and Marine Corps' Autonomous Mobility Appliqué System (AMAS) program, and marked the completion of the program's Capabilities Advancement Demonstration (CAD). The test involved driverless tactical vehicles navigating hazards and obstacles such as road intersections, oncoming traffic, stalled and passing vehicles, pedestrians and traffic circles in both urban and rural test areas.

"The AMAS CAD hardware and software performed exactly as designed, and dealt successfully with all of the real-world obstacles that a real-world convoy would encounter," said David Simon, AMAS program manager for Lockheed Martin Missiles and Fire Control.

"We are very pleased with the results of the demonstration, because it adds substantial weight to the Army's determination to get robotic systems into the hands of the warfighter."

The AMAS hardware and software are designed to automate the driving task on current tactical vehicles. The Unmanned Mission Module part of AMAS, which includes a high performance LIDAR sensor, a second GPS receiver and additional algorithms, is installed as a kit and can be used on virtually any military vehicle. In the CAD demonstration, the kit was integrated onto the Army's M915 trucks and the Palletized Loading System (PLS) vehicle.

"It was very important that we had representation from the technology, acquisition and user bases, along with our industry partners, here at the CAD," said TARDEC technical manager Bernard Theisen. "We are very pleased with the results of the demonstration, because it adds substantial weight to the Army's determination to get robotic systems into the hands of the warfighter."

Lockheed Martin MUOS Satellite Tests Show Extensive Reach in Polar Communications Capability

Lockheed Martin recently demonstrated that the U.S. Navy's Mobile User Objective System (MUOS) satellites may help solve communication challenges in the arctic. Now people spread over thousands of square miles could have access to more secure, reliable communications. During company-funded tests, MUOS voice and data signals reached much farther north than previously thought, just 30 miles and 0.5 degrees of latitude shy of the North Pole.

A team demonstrated Wideband Code Division Multiple Access (WCDMA) capability using three different radios as far north as 89.5 degrees, under peak orbit conditions. This inherent voice and data access is well beyond the 65-degree system requirement.

"As the arctic becomes more accessible, the U.S. and its allies need reliable communications..."

The additional coverage comes at a time when demand is surging for dependable polar communications. "As the arctic becomes more accessible, the U.S. and its allies need reliable communications to maintain a safe and secure presence," said Paul Scearce, director of Military Space Advanced Programs at Lockheed Martin. "Demand for consistent voice and data services will only increase. The area is experiencing more shipping, tourism and natural resource exploration, which will also likely increase demands for search and rescue."

The demonstrations show MUOS has an advantage over legacy satellite communications. "This joint testing gave us important system operation data at extreme conditions," said Dr. Amy Sun, Narrowband Advanced Programs lead at Lockheed Martin. "We did these evaluations to explore growing arctic communication demand, yet it also highlighted the dramatic capability improvements the WCDMA architecture will provide. Using MUOS, we were able communicate from the aircraft at high latitudes, which wasn't the case for the legacy Ultra High Frequency signal."

Harris Receives $18M for Falcon III Wideband Tactical Radios from U.S. Special Operations Command

USSOCOM is acquiring more Falcon III AN/PRC-117G and AN/PRC-152A radios as it expands deployment of a SOCOM-accredited wideband tactical communications network. The network enables operators to send and receive tactical voice, video and data, resulting in enhanced situational awareness and intelligence, surveillance and reconnaissance (ISR). In addition to advanced wideband data networking, the AN/PRC-117G and AN/PRC-152A provide users with interoperability through legacy narrowband waveforms.

"Harris Falcon III wideband radio systems are delivering the tactical Internet to the battlefield," said George Helm, president, Department of Defense business unit,

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> "Harris Falcon III wideband radio systems are delivering the tactical Internet to the battlefield..."

Harris RF Communications. "This new network opening up a world of new combat applications, such as collaborative chat, biometric enrollments, video conferencing and video ISR. These are next-generation capabilities, delivered today, using a proven commercial business model that thrives on competition and innovation."

Harris produces the world's most widely fielded wideband networking technology, with more than 45,000 manpack and handheld radio systems deployed to U.S. forces as well as Canada, France, the United Kingdom, Germany, Italy, Australia, Poland and other allies. These radios offer NSA Type-1 certified High Assurance Internet Protocol Equipment encryption, the highest level of information assurance available to tactical units.

Raytheon Secures 1st International Customer for its F-16 RACR AESA Radar

Raytheon Co. has signed a contract with BAE Systems in support of upgrading the Republic of Korea's fleet of more than 130 KF-16C/D Block 52 aircraft. As a key subcontractor to BAE Systems, the company will provide an integrated solution that includes the Raytheon Advanced Combat Radar (RACR), ALR-69A all-digital radar warning receiver, advanced mission computing technology and weapon systems integration.

> "The addition of our EW and mission computing expertise and our weapon systems integration will provide the Republic of Korea with an operationally superior solution that will keep their KF-16s relevant for years to come."

"South Korea's competitive selection of our RACR last year gave us an important foothold in the international F-16 upgrade market," said Jim Hvizd, vice president of International Strategy and Business Development for Raytheon Space and Airborne Systems. "The addition of our EW and mission computing expertise and our weapon systems integration will provide the Republic of Korea with an operationally superior solution that will keep their KF-16s relevant for years to come."

This contract, booked in the fourth quarter 2013, adds the F-16 Fighting Falcon to the roster of fighters retrofitted with Raytheon AESA radars (F-15C, F-15E, F/A-18E/F and the EA-18G Growler).


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Galileo Works and Works Well

The in-orbit validation of Galileo has been achieved: Europe now has the operational nucleus of its own satellite navigation constellation in place – the world's first civil-owned and operated satnav system.

In 2011 and 2012 the first four satellites were launched into orbit. In the following year, these satellites were combined with a growing global ground infrastructure to allow the project to undergo its crucial In-Orbit Validation (IOV) phase.

On 12 March 2013, Galileo's space and ground infrastructure came together for the very first time to perform the historic first determination of a ground location, taking place at ESA's Navigation Laboratory in the ESTEC technical centre, in Noordwijk, the Netherlands. From this point, generation of navigation messages enabled full testing of the entire Galileo system. A wide variety of tests followed, carried out all across Europe. As a result, the entire self-sufficient system has been shown to be capable of performing positioning fixes across the planet.

Following this success, the build-up of the Galileo system can proceed to place the remaining satellites into orbit and deploying further ground stations. The next two Galileo 'Full Operational Capability' satellites are currently at ESTEC, completing their testing to be cleared for flight. Over the course of 2014, six more satellites are planned to join the existing four in three separate Soyuz launches, with Galileo's initial services scheduled to start by the end of 2014.

> [Galileo is] the world's first civil-owned and operated satnav system.

"Europe has proven with IOV that in terms of performance we are at a par with the best international systems of navigation in the world," commented Didier Faivre, ESA director of Galileo and navigation-related activities.

QinetiQ Awarded UK MoD CSIIS Research Contract

QinetiQ has been awarded an initial three year contract to provide research in Command Control, Communications, Computing, Intelligence, Surveillance and Reconnaissance (C4ISR) Secure Information Infrastructure and Services (CSIIS) to the UK's Defence Science and Technology Laboratory (Dstl), a trading fund of the MoD which maximises the impact of science and technology for UK defence and security.

CSIIS research forms a major component of C4ISR research. Dr. Jeremy Ward, the MD of QinetiQ C4ISR said, "We are delighted to be working in partnership with Dstl on this important programme to realize the potential benefits from novel technology to our front line forces. We will build upon our established track record to provide a research capability drawn from across a wide supply base that is tuned to the varied and evolving needs of the MoD C4ISR customer."

The programme will primarily focus on research into Network Services, Communications, Information Assurance; and Information Management and Information Exploitation in relation to their impact upon Networks. QinetiQ will also identify and subsequently manage suppliers, contractors, information providers and subject matter experts who will provide a valuable contribution to deliver the research.

> Dstl ... maximises the impact of science and technology for UK defence and security.

The QinetiQ-led team comprises over 50 suppliers with representation from academia, small to medium enterprises (SMEs), technology providers and system primes. The team is supported by a steering group which has members from BAE Systems Advanced Technology Centre, Chemring Technology Solutions, Airbus Defence & Space, Exelis Defence, General Dynamics (UK), HP Enterprise Services and IBM as well as Dstl.

EDA and ESA Achieve DeSIREd Cooperation

The European Defence Agency (EDA) and European Space Agency (ESA) have agreed to pursue their cooperation in the domain of Remotely Piloted Aircraft Systems (RPAS) with the signature of the DeSIRE II Project Arrangement.

This cooperation is the result of the successful DeSIRE I project carried out in 2012 and 2013, through which EDA and ESA demonstrated the use of satellites enabling the insertion of RPAS in Europe. This project effectively demonstrated that RPAS complemented by satellites can be safely inserted in non-segregated airspace and thus fulfil user needs in maritime surveillance services.

> "...fulfil user needs in maritime surveillance services."

Source: European Defence Agency (EDA)

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DeSIRE II will demonstrate that services, such as environment and maritime surveillance applications, can be rendered with RPAS flying beyond radio line of sight through the use of safe and secure satellite-based command and control data links.

This demonstration project will also seek to illustrate the benefits of the integration of space assets, such as communication satellites, navigation satellites and Earth observation satellites, with terrestrial infrastructure for enabling new services. It will further tackle the implementation of an initial set of elements for air traffic management and related safety issues in order to support the evolution of air traffic insertion regulations and standards.

ERA-CAN+ Promotes Cooperation between European and Canadian Research

A fundamental aspect of European research policy is the establishment of cross-border cooperation, not just within the European Union but across the globe. This is why an ambitious project to connect European researchers with their counterparts in Canada has been launched. In particular, the ERA-CAN+ project aims to identify possible collaborative opportunities within Horizon 2020, the EU's Eighth Framework Programme for Research and Innovation.

The number of Canadians participating in European Framework Programme projects has been steadily increasing over the years. FP7 (2007-2013) involved a total of 228 Canadian researchers and research institutions, who participated in 187 projects. This is more than double the 97 Canadians who participated in FP6 (2002-2006).

> "Canada is a valued partner for the European Union..."

"Canada is a valued partner for the European Union in a wide range of cooperation areas and our partnership in research and innovation is particularly strong," said EU Ambassador Marie-Anne Coninsx. "ERA-CAN+ will further contribute to deepen the already existing strong ties."

The project will promote science, technology and innovation collaboration between Canada and the EU through policy dialogues, research exchanges and information sharing about funding opportunities. The consortium brings together seven leading associations and organisations for research, innovation and public policy discussions from across Canada and Europe.

ERA-CAN+ will also play a vital role in raising awareness of research and innovation opportunities and also attempt to help scientists and researchers to make the jump from the laboratory to the marketplace. Commercialising research results remains a weakness of European research, which is something that Horizon 2020 aims to redress.

Lenovo to Acquire Motorola Mobility from Google

Lenovo and Google have entered into a definitive agreement under which Lenovo plans to acquire the Motorola Mobility smartphone business. With a strong PC business and a fast-growing smartphone business, this agreement will significantly strengthen Lenovo's position in the smartphone market. In addition, Lenovo will gain a strong market presence in North America and Latin America, as well as a foothold in Western Europe, to complement its strong, fast-growing smartphone business in emerging markets around the world.

The purchase price is approximately US$2.91 billion (subject to certain adjustments), including US$1.41 billion paid at close, comprised of US$660 million in cash and US$750 million in Lenovo ordinary shares (subject to a share cap/floor). The remaining US$1.5 billion will be paid in the form of a three-year promissory note.

Lenovo, which in 2005 acquired IBM's PC business and its legendary PC brand, will now acquire world-renowned Motorola Mobility, including the MOTOROLA brand and Motorola Mobility's portfolio of innovative smartphones like the Moto X and Moto G and the DROID™ Ultra series. In addition to current products, Lenovo will take ownership of the future Motorola Mobility product roadmap.

Google will maintain ownership of the vast majority of the Motorola Mobility patent portfolio, including current patent applications and invention disclosures. As part of its ongoing relationship with Google, Lenovo will receive a license to this rich portfolio of patents and other intellectual property. Additionally Lenovo will receive over 2000 patent assets, as well as the Motorola Mobility brand and trademark portfolio.

Motorola Mobility enjoys outstanding brand awareness around the world, and is currently the #3 Android smartphone manufacturer in the U.S. and #3 manufacturer overall in Latin America.

"The acquisition of such an iconic brand, innovative product portfolio and incredibly talented global team will immediately make Lenovo a strong global competitor in smartphones. We will immediately have the opportunity to become a strong global player in the fast-growing mobile space," said Yang Yuanqing, chairman and CEO of Lenovo. "We are confident that we can bring together the best of both companies to deliver products customers will love and a strong, growing business. Lenovo has a proven track record of successfully embracing and strengthening great brands – as we did with IBM's Think brand – and smoothly and efficiently integrating companies around-the-world. I am confident we will be successful with this process, and that our companies will not only maintain our current momentum in the market, but also build a strong foundation for the future."

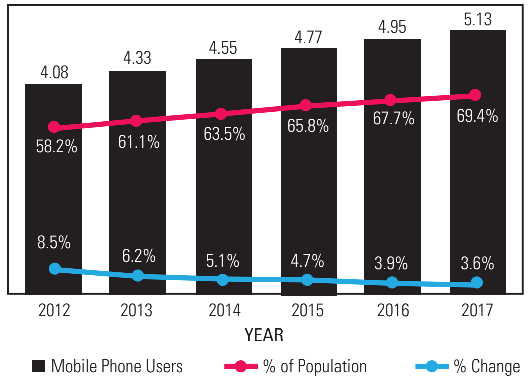
Smartphone Users Worldwide Will Total 1.75B in 2014

eMarketer expects 4.55 billion people worldwide to use a mobile phone in 2014. Mobile adoption is slowing, but new users in the developing regions of Asia-Pacific and the Middle East and Africa will drive further increases. Between 2013 and 2017, mobile phone penetration will rise from 61.1 percent to 69.4 percent of the global population, according to a new eMarketer report, "Worldwide Mobile Phone Users: H1 2014 Forecast and Comparative Estimates."

The global smartphone audience surpassed the 1 billion mark in 2012 and will total 1.75 billion in 2014. eMarketer expects smartphone adoption to continue on a fast-paced trajectory through 2017. Nearly two-fifths of all mobile phone users — close to one-quarter of the worldwide population — will use a smartphone at least monthly in 2014. By the end of the forecast period, smartphone penetration among mobile phone users globally will near 50 percent.

Mobile phone users are rapidly switching over to smartphones as devices become more affordable and 3G and 4G networks advance. Smartphone users currently account for a majority of mobile phone users in 10 of the 22 countries included in the forecast. eMarketer expects this to increase to 16 countries during 2014.

Mobile Phone Users Worldwide, 2012–2017
Billions, % of Population and % Change



Note: Individuals of any age who own at least one mobile phone and use the phone(s) at least once per month

Source: eMarketer, Dec. 2013

Mobile Phone IPS to Create a $10B Market

Indoor positioning systems (IPS) is a term confined to indoor positioning presented on mobile/cell phones, or the like, to create added value services. For example, the derivatives of smart phones taking the form of glasses or eyepieces will have the ability to superimpose all manner of information across the items being viewed. Thanks to the work of U.S. companies APX Labs, Vuzix and others, a service engineer might see "preventative maintenance

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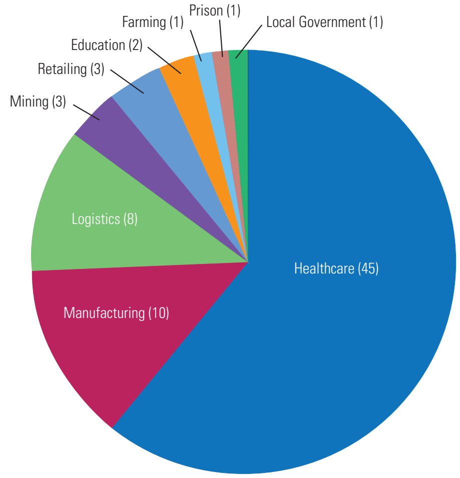
due now" superimposed on their view of a machine in a factory. The position is known in 3D thanks to IPS often combined with real time locating systems (RTLS) by which second generation RFID tags are interrogated by several readers at a time to give location. That technology is usually different from IPS, which seeks ubiquity before accuracy and therefore will use the known location of Bluetooth and WiFi emitters and dead reckoning (inertial navigation) using the gyroscope, barometer and accelerometer in the typical smart phone. Linking RTLS and IPS gives powerful facilities that can revert to satellite navigation outdoors when the phone, smart glasses or other devices are outdoors. From consumers to emergency services and even surgeons, the uses will be many and varied.

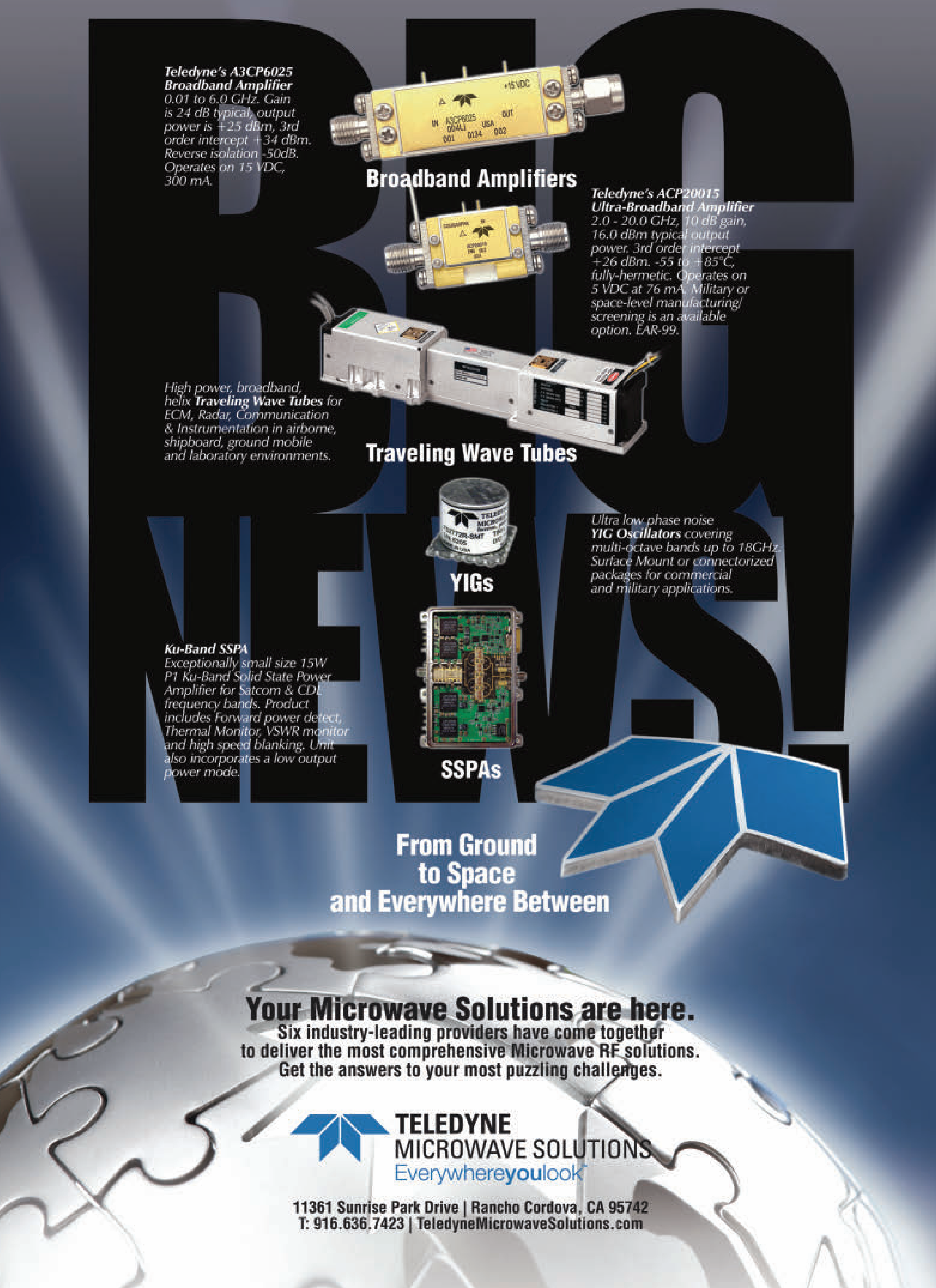
Whereas IPS is only now starting to be widely deployed commercially, Hewlett Packard is servicing an RTLS order for $543 million from the U.S. veterans' hospital group with IBM the unsuccessful bidder. This order was 100 times the size of the previous record order for RTLS. Indeed, IDTechEx forecasts $4.8 billion in RTLS sales worldwide in 2024.

Rather different large companies are clashing over IPS, such as Apple, Microsoft Sony and Google because it will be a source of competitive advantage and of extra earning streams in the mobile phone and similar industries. They also foresee it in their planned smart watches. RTLS is even finding its way into wearable electronics, having started with the ubiquitous pendants that track hospital staff and give their coordinates when they press the button for assistance. Cadi Scientific of Singapore and Harmonic Group of South Africa are new RTLS suppliers alongside U.S. companies RF Technologies, Zebra Technologies and other incumbents.

Survey of 74 Case Studies of RTLS by Application



Source: ID TechEx report "Mobile Phone Indoor Positioning Systems (IPS) and Real Time Locating Systems (RTLS) 2014–2014," www.IDTechEx.com/ips.


BIG NEWS!
Teledyne's A3CP6025 Broadband Amplifier
0.01 to 6.0 GHz. Gain is 24 dB typical, output power is +25 dBm, 3rd order intercept +34 dBm. Reverse isolation -50dB. Operates on 15 VDC, 300 mA.
Broadband Amplifiers
Teledyne's ACP20015 Ultra-Broadband Amplifier
2.0 - 20.0 GHz, 10 dB gain, 16.0 dBm typical output power. 3rd order intercept +26 dBm. -55 to +85°C, fully-hermetic. Operates on 5 VDC at 76 mA. Military or space-level manufacturing/screening is an available option. EAR-99.
High power, broadband, helix Traveling Wave Tubes for ECM, Radar, Communication & Instrumentation in airborne, shipboard, ground mobile and laboratory environments.
Traveling Wave Tubes
Ultra low phase noise YIG Oscillators covering multi-octave bands up to 18GHz. Surface Mount or connectorized packages for commercial and military applications.
YIGs
Ku-Band SSPA
Exceptionally small size 15W P1 Ku-Band Solid State Power Amplifier for Satcom & CDL frequency bands. Product includes Forward power detect, Thermal Monitor, VSWR monitor and high speed blanking. Unit also incorporates a low output power mode.
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Around the Circuit

Laura Glazer, Staff Editor

MERGERS & ACQUISITIONS

Tektronix Inc. announced the acquisition of **Picosecond Pulse Labs**. The move is intended to strengthen the Tektronix portfolio in the growing market for test equipment to support 100G/400G optical data communications research and development. Privately-held Picosecond Pulse Labs, based in Boulder, CO, offers products that include ultra-high-speed pattern generators, the world's fastest pulse generators and highest bandwidth sampler modules. The terms of the transaction were not disclosed.

The **Radio Frequency Interference – End Users Initiative** (RFI-EUI) and the **Satellite Interference Reduction Group** (IRG) announced a merger, helping the two groups to better serve the industry and combat satellite interference together. The merger sees IRG creating an umbrella over RFI-EUI, forming two advisory committees/working groups. The first will be the EUI, covering training, best practices and documentation. The second will deal with carrier ID and will merge the two existing carrier ID working groups of IRG and RFI-EUI. The joined working groups will be chaired by Roger Franklin, CEO, Crystal Solutions and George Melton, director of engineering - Teleport, Turner Broadcasting Systems Inc.

COLLABORATIONS

Airbiquity Inc. and **Baidu** announced a partnership to provide connected car internet services to the Chinese automotive market beginning in first quarter 2014. With this partnership, Airbiquity will integrate Baidu's popular Map, Send-to-Vehicle, and Music Service capabilities into its Choreo™ private cloud connected vehicle services platform and Driver Experience offering supporting connected cars and drivers in China. Airbiquity's Choreo cloud platform and Driver Experience offering connects cars to the cloud while fully integrating the most popular smartphone apps, cloud content and services into vehicle displays, controls and voice recognition systems.

CTS Electronic Component Solutions and **Microsemi Corp.** built and tested a joint reference design to offer high quality products for applications requiring a master clock with a fan-out buffer that deliver ultra-low jitter without compromising performance. Specifically, CTS has paired its crystal clock oscillator with Microsemi's high performance fanout buffers to distribute multiple output clocks with typical jitter in the range of 100 fs for critical circuit applications such as CDR, data storage, Synchronous Ethernet switches, communication transmitters and receivers, and high speed Ethernet PHYs and transceivers.

Modelithics Inc. has teamed with **Mini-Circuits** to develop high-accuracy simulation models of Mini-Circuits' 3.2 × 1.6 mm case-size surface-mount LFCN lowpass filters and HFCN highpass filters. Six new highpass filter models and 15 lowpass filter models will be included in the next release of Modelithics' COMPLETE Library and are currently available for free individual download from the Mini-Circuits MVP page on the Modelithics website. The new filter models mark a significant addition to the Mini-Circuits-sponsored simulation capabilities already available through Modelithics.

RFMD announced that it will play a key role in developing power electronics to support the next generation of clean energy in the U.S. RFMD is a foundry and product design/development partner to **North Carolina State** (NC State) University's Next Generation Power Electronics Innovation Institute, which was awarded a five-year $70 million contract from the Department of Energy to lead next generation power electronics manufacturing. RFMD will offer open foundry services to support the NC State-led program and help accelerate the development of key wide bandgap semiconductor products.

NEW STARTS

Dover announced a plan to spin off certain DCT operating companies into a standalone publicly traded company named **Knowles Corp.** This decision resulted in the split of several business units currently centralized under the Ceramic and Microwave Products (CMP) operating company. While the capacitor companies Dielectric Laboratories (DLI), Novacap, Syfer and Voltronics will be part of the spinoff, the microwave companies BSC Filters, Dow-Key, K&L and Pole/Zero will remain with Dover, forming the Microwave Products Group (MPG). Michael P. Busse, currently the vice president and general manager of DLI, has accepted the position of vice president of business development for MPG.

ACHIEVEMENTS

Boeing has applied new anti-jamming technology to an existing military satellite for the first time, expanding the military's potential to access secure communications more affordably. In the test conducted Dec. 15, Boeing successfully sent a government-developed, protected signal through the sixth Wideband Global SATCOM (WGS-6) satellite. Engineers confirmed that the signal met all targets for accuracy and strength. The demonstration follows a successful transmission of data over the ViaSat-1 commercial satellite in July, showing that the technology offers an affordable option for enhancing anti-jam communications using existing commercial and U.S. government satellites and terminals.

Selex ES, a Finmeccanica company, has flown its SAGE electronic warfare system on an unmanned aerial system for the first time. The system flew on-board a Schiebel CAMCOPTER®S-100 UAS in two separate flight trials after an integration period of just two days. SAGE is a digital Electronic Support Measure (ESM)/Electronic Intelligence (ELINT) system for RF intelligence, surveillance and reconnaissance missions. It enhances situational awareness by passively collecting emitter data from RF

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sources at a tactically significant range, comparing them with an emitter library and then identifying and geolocating any threats.

Agilent Technologies announced the recent installation of an Agilent 5600LS atomic force microscope with scanning microwave microscopy at the Cambridge Graphene Centre (CGC) in the United Kingdom. The CGC, one of the key consortium partners in the Future and Emerging Technologies (FET) Graphene Flagship project, is directed by Andrea Ferrari, professor of nanotechnology at the University of Cambridge. This was chosen as one of only two FET flagship projects by the European Commission. Each project is expected to receive €1 billion over 10 years, half from the European Commission and half from EU member states. The UK has already invested £60 million to create a leading graphene research and technology hub.

Microwave Solutions Inc. announced it has upgraded its certification to AS9100C, the aerospace standard containing requirements for establishing, documenting, implementing and maintaining a quality management system (QMS), and continually improving its effectiveness. The standard provides suppliers with a quality system needed to produce safe and reliable products that are effective and assure customer satisfaction.

Spacek Labs has received ISO 9001:2008 certification for its Quality Management System. Achieving ISO 9001:2008 confirms that premium quality management practices are adhered to and a systematic approach to quality processes and testing is taken to ensure consistent product performance and customer satisfaction.

CONTRACTS

Lockheed Martin received two production contracts totaling $449 million from the **U.S. Air Force** for continued production of the Joint Air-to-Surface Standoff Missile (JASSM) and the Extended Range (ER) variant. The Lot 11 and Lot 12 contracts include production of 340 baseline missiles and 100 ER missiles. The contracts also include systems engineering, logistics support, tooling and test equipment. This is the first time the JASSM program has been awarded consecutive production lots at the same time.

GATR Technologies announced that it has been awarded a five-year indefinite delivery indefinite quantity (IDIQ) contract by the **U.S. Army** Project Manager, Warfighter Information Network-Tactical (PM WIN-T), Product Manager Satellite Communications (PdM SATCOM), Commercial SATCOM Terminal Program (CSTP) Office. This contract ceiling value of $440,045,436 will enable the U.S. Army, the U.S. Marine Corps and other commands and services to procure GATR's WGS certified inflatable satellite antennas (ISA) and associated hardware, services and support.

Exelis has received a $32 million, five-year IDIQ award to supply airborne surveillance radars, spares, support equipment and technical services to the **U.S. Coast Guard**. Integrated on the U.S. Coast Guard's HC-130J Super Hercules long-range surveillance aircraft, the AN/APY-11 multimode radar is designed to support the service's maritime reconnaissance mission, which includes long-range surveillance, search and rescue, drug interdiction, counterterrorism and maritime environmental support. The radar's multifunctionality will augment the U.S. Coast Guard's situational awareness and ability to conduct missions successfully.

Harris Corp. has received $21 million in orders from a NATO country for Falcon® multiband tactical radios. The orders were received during the second quarter of fiscal 2014. The nation is acquiring Falcon III® AN/PRC-117G manpack and AN/PRC-152A handheld radios that will provide special forces and Army soldiers with wideband networking capabilities, as well line-of-sight, ground-to-air and tactical satellite voice and data communications.

Aeroflex Holding Corp. announced the signing of two contracts in its **Aeroflex Microelectronic Solutions** business for over $20 million of high-performance, high-reliability mixed-signal semiconductors. These key contracts demonstrate Aeroflex's ability to leverage its unique intellectual property into market adjacencies. These awards are for a high-end industrial application and for a next generation medical diagnostics company. Aeroflex anticipates beginning to deliver on these contracts during the fourth quarter of fiscal 2014 and expect to complete shipments over the subsequent 24 months.

API Technologies Corp. announced that it has received a $1.4 million order for TPS75 tactical power supplies. The company-designed power systems, which debuted at the Association of the United States Army (AUSA) annual meeting and exposition in October, will be used by the **U.S. Department of Defense** as a lightweight, mobile power supply to support a variety of C4ISR, UAV and mission control applications.

Thales Alenia Space has signed a contract with Russian operator **Gazprom Space Systems** (GSS) to build the Yamal-601 telecommunications satellite, which will provide fixed communications, broadcast and Internet access services. Based on the Spacebus 4000C4 platform, Yamal-601 will carry 18 C-Band transponders, 19 Ku-Band transponders and 26 Ka-Band transponders focusing on Russia. It will weigh more than five metric tons at launch, with 11 kW of payload power and a design life exceeding 15 years. As program prime contractor, Thales Alenia Space is in charge of the design, production, testing and turnkey delivery of the satellite and its associated ground segment.

Raytheon signed a contract with **BAE Systems** to provide South Korea integrated AESA radar, electronic warfare, mission computing technologies and weapon systems integration. As a key subcontractor to BAE Systems, the company will provide a fully integrated avionics suite that includes the Raytheon Advanced Combat Radar (RACR), ALR-69A all-digital radar warning receiver, advanced mission computing technology and weapon systems integration for more than 130 planes.

The **Swedish Civil Contingencies Agency** (MSB) has selected **Airbus Defence and Space** (formerly Cassidian) to

Around the **Circuit**

work on a secure data services pilot for the Rakel nationwide radio communications network. The project aims to complement the existing public safety radio networks by using multiple commercial broadband mobile networks, allowing real-time access to mission-related information and a wide range of advanced multimedia services. The project, which will run until the end of May 2014, is a cooperation between the Swedish Civil Contingencies Agency (MSB), the Swedish National Police, Uppsala ambulance services, Falu municipality and Airbus Defence and Space as the technical supplier.

Huawei has signed an agreement with **Orange Polska** – Orange S.A.'s biggest subnetwork in Northeast Europe – for the supply of second-generation E-Band microwave products over the next two years. As the largest mobile operator in Poland, Orange Polska provides a range of mobile services including GSM, UMTS, and WLAN services. The operator constantly develops mobile broadband services to improve average revenue per user (ARPU) and understands that mobile backhaul network construction is an important part of building core competence.

PEOPLE

▲ *Thomas A. Kennedy*

Raytheon Co. announced that its board of directors has elected Dr. **Thomas A. Kennedy**, to serve as the chief executive officer of Raytheon Co., effective March 31, 2014. Kennedy will succeed William H. Swanson, who has served as the CEO of Raytheon Co. since 2003, and who advised the board of his intention to step down from his position as CEO in March, following his 65th birthday. This change in company leadership was undertaken as part of the board's orderly leadership transition planning process. After March, Swanson will continue to serve as chairman of the board of directors while the company completes the transition to the new CEO. The Raytheon board of directors also elected Kennedy to serve on the Raytheon Co. board of directors.

▲ *Dr. Song Junde*

EDI CON 2014 announced that Dr. **Song Junde**, professor at the Beijing University of Posts and Telecommunications, will serve as the chairman emeritus. Junde, who held the role of honorary chair for the inaugural EDI CON in March of 2013, will once again provide guidance to the event organizers and technical program planning committee in the development of a technical conference focused on advancing microwave technology and the communications industry in China. Junde will also act as a critical liaison to the academic and research communities throughout China. In his role as chairman emeritus, Junde will deliver the welcoming message at the opening keynote plenary session.

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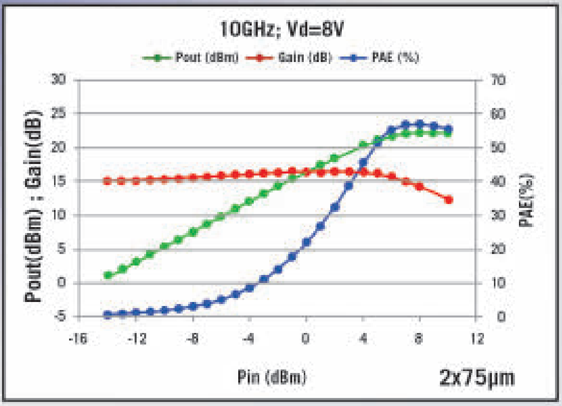
PP25/-21 0.25µm Power pHEMT

- 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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Around the **Circuit**

Anite announced that it has appointed **James Bristow** as global sales director of its handset testing business. Bristow has extensive, specialized experience of the telecommunications industry, most recently serving as Juniper Networks' vice president EMEA for service providers. Prior to Juniper, Bristow held senior management positions at various telecoms companies including Alcatel, 3Com and Bridgewater Systems. He brings to Anite direct knowledge of developing global business with international Service Providers having lived in North America, Asia and Europe.

Maury Microwave Corp. announced the recent hiring of **Marc Schulze Tenberge** as the applications engineering manager based in Ontario, CA. Tenberge holds master's degrees in engineering from the University of Portsmouth and in sciences from North Carolina State University. Tenberge comes to Maury after nine years with RFMD in Greensboro, NC as a test/characterization engineer having worked on IV, CV, PIV, transient, load pull, linearity, RF and microwave small signal, noise, KGD, AM-PM and ruggedness measurements.

REP APPOINTMENTS

Auriga announced the signing of **Elexience** as the company's reseller for France.

Hesse Mechatronics Inc. announced that it has appointed **HTMG** as the company's sales representative for South America.

MITEQ Inc. announced the appointment of **Elina Electronic Engineering Ltd.** as the company's exclusive sales representative in Israel. Elina Electronic Engineering Ltd. will represent MITEQ's Component and SATCOM divisions.

NuWaves Engineering announced it has added **AeroGear Telemetry Inc.** as an authorized representative of its products and design services for the mid-atlantic, southeast and south central regions of the United States, in total covering 17 states as well as the District of Columbia.

PLACES

COMSOL announced **COMSOL Co. Ltd.** as a new subsidiary located in China with the opening of offices in Shanghai and Beijing. The new offices establish COMSOL direct operations in China by providing software sales, exceptional technical support, comprehensive training sessions, hands-on workshops, user conferences, and customer events. The company's expansion into the Chinese market comes in response to the rapidly growing demand for COMSOL Multiphysics® simulation software within the country's diverse high-tech industry and engineering community.

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The Promise of the Tribe

David Vye, *Microwave Journal* Editor

Next month, *Microwave Journal* and parent company Horizon House will host the second annual Electronic Design Innovation Conference (EDI CON) in Beijing, China. Throughout the year, we have been keeping our readers up to date on its developments as related news unfolded, from the announcement of major sponsors to the creation of special expert panels and the emergence of notable technical themes among the accepted papers. With a month left before the event, we have a clear sense of what the conversation in Beijing will focus on and who will be delivering that message.

Starting with the welcome keynote by Chairman Dr. Junde Song of the Beijing University of Posts and Telecommunications, delegates will hear directly from this influential government advisor as he presents China's six major initiatives defining the country's internal information and communication technology direction. Dr. Song has published over a dozen books along with nearly 200 technical papers in English and Chinese on mobile communications and the Internet, the future of communications, CTI/CRM and the VLSI CAD field. Leveraging his current research in mobile internet technology, Dr. Song will also introduce the development of CAD EDA in China and the demand and cultivation of engineering talents on behalf of universities and industry.

Further in the plenary session, the development of 5G systems will be a topic considered by several keynote speakers including Corbett Rowell, director of R&D at China Mobile Research Institute, James Kimery, director of marketing, National Instruments (see his article – The Path to 5G in this past January's *Microwave Journal*) and Josef Wolf, manager of Rohde & Schwarz Spectrum and Network Analyzer Division. Trends in future telecommunications from the perspective of evolving test solutions will be presented by Mario Narduzzi, marketing manager for Agilent Technologies' modular solutions. Narduzzi will offer key insights into how core technologies inside next generation test instruments are redefining measurement speed, accuracy and the ability to address increasingly complex RF/digital characterization for R&D and production – the theme of this month's cover story. As Agilent's former manager for its China operations, Narduzzi will be able to provide his insight into modular test solutions in the context of China's high-frequency electronic design market needs.

Last year, our goal was to demonstrate that the microwave community was ready and willing to support an industry-driven conference and exhibition in an emerging market. With the success of the inaugural event, participating companies proved they can create and present content that working engineers are hungry for. In this issue, we have published this year's three-day technical conference and workshop schedule to give our global readership a sense of what that content looks like. Although these papers target an audience in Beijing, the technology being presented would be equally welcome in Tampa, FL at IMS or at European Microwave Week in Rome, Italy.

This brings me to the tribe. A tribe is defined as any aggregate of people united by ties of descent from a common ancestor, a community of customs and traditions with adherence to common leaders. In the United States, the microwave tribe traces back to the engineers and scientists who gathered at MIT's Radiation Labs in the 1940s to develop RADAR technology. The European microwave tribe has roots back to early theorists such as Maxwell and Hertz and more recently to organizations such as the CEPT and GSM. Universally, our "customs" are defined by classical microwave theory, our "traditions" are chronicled in the trade magazines we read and contribute to and the conferences we attend. Our thought leaders are those who advance the state of microwave technology in ways that earn our collective respect and admiration.

Everyone who regularly attends conferences and industry trade events throughout the year (year after year) experiences the pleasure of engaging with members of our tribe. I certainly enjoy seeing industry folks and former colleagues at IMS each year and I have become increasingly familiar with our European counterparts since attending EuMW regularly. I know an important microwave happening is near when I start recognizing faces at the airport baggage claim, taxi line, hotel lobby, etc. Such encounters provide a reassuring counterbalance to the unease of being on unfamiliar turf.

At last year's EDI CON, I took real pleasure in seeing members of our microwave tribe venturing to Beijing to represent their companies from Europe and the U.S. Adding to this great group of people, I have begun to recognize a few members of the Chinese microwave community thanks to multiple country visits in my role as editor for *Microwave Journal China*. While the entire global tribe of microwave engineers may not speak the same language, I am encouraged that together we all speak the language of MMICs, MIMO and Maxwell. I look forward to seeing many of you in Beijing and wherever else our paths might cross. ■

EDI CON

Tuesday, April 8, 2014

On-Site Registration Opens on April 7, 2014

Time						
09:30 - 10:40	**Welcome Remarks: Plenary Session Featuring:** 2014 Chairman Emeritus, Professor Song Junde, BUPT Keming Feng, General Director, Beijing Institute of Radio Metrology and Measurement Erping Li, Chair Professor and Director of RF and Nanoelectronics Research Center, Zhejiang University Mario Narduzzi, Marketing Manager, Agilent Technologies					
10:40 - 10:50	**EDI CON Exhibition Preview**					
10:50 - 12:00	**Industry Keynotes Featuring 5G Cellular Challenges** Corbett Rowell, R&D Director, China Mobile Research Institute Deng Jie, Director of Marketing, ZTE James Kimery, Director of Marketing, National Instruments Josef Wolf, Director of Spectrum/Network ANA and EMC, Rohde & Schwarz					
12:00 - 13:30	**Delegate and VIP Lunch**					**Press Conference (Starts at 12:30) Press Tour of Exhibition will follow at 13:00**
	General Technical Sessions					
	TU101: Room A (201 A/B)	**TU102: Room B (201 D)**	**TU103: Room C (203 A)**	**TU104: Room D (203 B)**	**TU105: Room E (203 C)**	
13:30 - 13:50	Amplifier Testing: Envelope Tracking Technology, *Frank-Werner Thuemmler, Rohde & Schwarz*	Impedance Synthesis Algorithms for Hybrid Harmonic Load Pull, *Xianfu Sun, Focus Microwaves*	Measurement Requirements for Dynamic Frequency Selection, *Xiang Feng, Agilent Technologies*	Effect of Pre-Selection and Roofing Filters on Over the Air Measurements, *Brian Avenell, National Instruments*	MMIC Low Noise Amplifier Targeting Next Generation Cellular Wireless Infrastructure, *Loo Kah Cheng, Mini-Circuits*	
13:50 - 14:10	Addressing the Challenges of Synchronization in Envelope Tracking Test Solutions, *David Hall, National Instruments*	Mixed-Signal Active Harmonic Loadpull for Wideband and Ultra High Speed Device Characterization, *Mauro Marchetti, Anteverta*	Real-Time Extension to 160 MHz as Powerful Spectrum Analysis Tool for Monitoring Frequency Hopping Signals and for R&D Applications, *Wolfgang Wendler, Rohde & Schwarz*	Digitizer-Based Phase Coherent Measurements for Multi-Antenna Phased Array Applications, *Zhiyin Yun, Agilent Technologies*	New ED-PHEMT Technology for High Integration Application, *Cheng-Kuo Lin, WIN Semiconductors*	
	Workshops					
	WS_TU101	**WS_TU102**	**WS_TU103**	**WS_TU104**	**WS_TU105**	
14:15 - 15:00	**SI Measurements and Channel Characterization - Agilent Workshop:** Signal Integrity Measurements Technologies in 10G-32G Digital System, *Deng-Liang Sun, Agilent Technologies*; and Advanced Techniques for Characterizing a 28 Gb/s SERDES Channel, *Robert Sleigh, Agilent Technologies*	**Rohde & Schwarz Workshop:** The Accurate and Effective Measurement of Power Amplifiers During the Design Phase, *Hongwen Yang, Rohde & Schwarz*	**NI DPD Workshop:** Digital Predistortion Techniques for Mobile PA Test, *James Kimery, National Instruments*	**Spirent Workshop:** MIMO OTA Channel Validation, *Hui Xiao, Spirent*	**CETC 41 Workshop:** Complex Electromagnetic Signal Testing and Analysis Technology, *Wang Feng, CETC 41*	
15:00 - 15:30	**Tea/Coffee Break**					**Exhibition Hours (12:00 - 17:00)**
	WS_TU201	**WS_TU202**	**WS_TU203**	**WS_TU204**	**WS_TU205**	
15:30 - 16:15	**Freescale Workshop:** Enabling the TD-LTE Rollout through Flexible RF Designs, *Eric Westberg, Freescale Semiconductor*	**Anritsu Workshop:** Stable On-Wafer Broadband Device Characterization to 110 GHz and Beyond, *Bob Buxton, Anritsu*	**Mini-Circuits Workshop:** Portable and Production Test Equipment for RF Products and Systems Certification, *Chi Man Shum, Mini-Circuits*	**CST Workshop:** MIMO Antenna System Simulation, *Cier Siang Chua, CST*	**Bonn Elektronik Workshop:** High Power Amplifier for EMC Testing Application, *Gerald Puchbauer, Bonn Elektronik*	
	WS_TU301	**WS_TU302**	**WS_TU303**	**WS_TU304**		
16:15 - 17:00	**MACOM Workshop:** Breaking the Kilo-Watt GaN Boundary, *Damian McCann, MACOM*	**Maury Workshop:** Vector-Receiver Load Pull, *Dong-Liang Yang, Maury Microwave*	**NI Workshop:** Survey of Wireless Transmitter Metrics in Modern Wireless Standards, *David Hall, National Instruments*; and Survey of Wireless Receiver Metrics in Modern Wireless Standards, *David Hall, National Instruments*	**EMSS Workshop:** Board Level Noise Coupling and LTE MIMO Antenna Design, *Peter Futter, EMSS*		
17:00 - 18:00	**Cocktail Reception**					
18:00 - 20:00	**VIP Dinner**					

Details in this conference matrix were correct at the time of going to press. They are subject to change. For up-to-date information visit our website at www.ediconchina.com.

Wednesday, April 9, 2014

EDI CON	Design Track: Room A (201 A/B)	Measurement & Modeling Track: Room B (201 D)	System-Level Measurement/Modeling Track: Room C (203 A)	Systems Engineering Track: Room D (203 B)	Commercial Resources Track: Room E (203 C)	
	WE101	**WE102**	**WE103**	**WE104**	**WE105**	
08:30 - 08:50	An InGaP/GaAs HBT Comparator for a 4GS/s 6-bit ADC, *Jincan Zhang, Xidian University*	The Evolution of Automatic Fixture Removal Techniques, *Ning Cheng, Agilent Technologies*	Evolution of A-GNSS Over-the-Air Test Methodology, *Ron Borsato, Spirent*	FPGA-Based DiSEqC Generator and Analyzer System, *Jian Xu, Qualcomm*	Metal Cylinder Cavities for Harmonic Suppression in Stripline Power Dividers, *Huan-Huan Xie, Xi'an Research Institute of Navigation Technology*	
08:50 - 09:10	Chip Design of a 21.6 GHz Band Low-Power Phase-Locked Loop Using an Injection Frequency Divider Circuit, *Wen Cheng Lai, National Taiwan University of Science and Technology*	New Calibrating Requirements for Modern Wideband Transceivers, *Chunlan Qin, Agilent Technologies*	MIMO OTA Based on Anechoic Chamber for Discriminating Between Good and Bad 2x2 MIMO Antenna Systems, *Lars Foged, Microwave Vision Group*	Global Navigation Satellite Systems and Their Wide Range of Applications, *Frank-Werner Thuemmler, Rohde & Schwarz*	High Frequency PCB Design and Analysis: Cross-Platform Flows/Solutions, *Milton Lien, AWR*	
09:15 - 09:35	High Voltage GaN HEMT Doherty Power Amplifier Utilizing Hybrid Waveform Engineered Design for High Efficiency, *Zhancang Wang, Nokia Solutions & Networks*	Optimizing Chip-Module-Board Transitions Using Integrated EM and Circuit Design Simulation Software, *John Dunn, AWR*	Radiated Two-Stage Method for MIMO Throughput Test Demystify, *Liu Kefeng, General Test Systems*	Group Delay Measurement of a Satellite in Orbit, *Thilo Bednorz, Rohde & Schwarz*	High Speed and High Power Connector Design, *Klaus Krohne, CST*	
09:35 - 09:55	A High Voltage GaN HEMT Inverted Doherty Power Amplifier Utilizing Harmonic Manipulation, *Zhancang Wang, Nokia Solutions & Networks*	Evolution of 3D RF System Simulation, *Rickard Petersson, ANSYS*	Radiated Two-Stage OTA Test Method for MIMO Device Performance Evaluation, *Ya Jing, Agilent Technologies*	Characterization of Satellite Frequency Upconverters, *Thilo Bednorz, Rohde & Schwarz*	Continuous Innovation to Satisfy Complex Requirements of Signal Interconnect, *Robert Shen, Emerson*	
10:00 - 10:30	**Tea/Coffee Break**					
	WE201	**WE202**	**WE203**	**WE204**	**WE205**	
10:35 - 10:55	A High Power, Multiband Doherty Power Amplifier for Wireless Infrastructure Transmitter Applications, *Jarod Geng, Freescale Semiconductor*	On Select Modeling Approaches for GaN-Based High Electron Mobility Transistors, *Qiang Chen, Agilent Technologies*	Measurement of Radio Links in the E-Band with Spectrum Analyzers and External Harmonic Mixing, *Wolfgang Wendler, Rohde & Schwarz*	Prototyping Massive MIMO, *James Kimery, National Instruments*	Temperature Variable Attenuator Performance at High Frequencies, *Moamer Hasanovic, EMC/Florida RF Labs*	
10:55 - 11:15	A Broadband Power Amplifier Design via Simplified Real Frequency Technologies, *Chengcheng Xie, Agilent Technologies*	Stability Analysis of Microwave Circuits, *Stephane Dellier, AMCAD*	Test Modules and Multipliers for Cost Effective Millimeter Wave Measurements, *Kent Whitney, Millitech*	Understanding Bluetooth Low Energy and Its Testing, *Yvonne Liu, Agilent Technologies*	GaN-on-Diamond: The Next GaN, *Justin Saeheng, Element 6*	
11:20 - 11:40	Linearization Techniques for High Power Applications, *Qin Shen-Schultz, Auriga*	Performance Comparison and Complexity Reduction of DPD Models, *Tong Li, Agilent Technologies*	Generating and Analyzing Wideband Signals in the mmWave Range, *Zhigang Ma, Rohde & Schwarz*	Modern Measurement Methods for Enhanced Radar Systems, *Feng Chen, Rohde & Schwarz*	PCB Materials for High Frequency Applications, *Art Aguayo, Rogers Corp.*	
11:40 - 12:00	Optimizing Linearity Measurements, *Chris Chiccone, National Instruments*	Integrated Simulation Flow for Envelope Tracking Technology in PA Design, *Xindong Xue, Agilent Technologies*	RFP™ Frequency Planning Synthesis Tool for Wireless Systems Design, *Peter Xu, AWR*	NI-AWR Integrated Framework for Radar Design, *Gent Paparisto, AWR/National Instruments*	Qualification of RF PCBs as Part of Production Testing, *Josef Koeppl, Rohde & Schwarz*	
12:00 - 13:30	**Lunch Break**					
	Forums & Workshops					
	PA_WE101	**WS_WE102**	**WS_WE103**	**WS_WE104**	**WS_WE105**	
13:30 - 14:15	**GaN Panel:** Featuring MACOM, Freescale, TriQuint, Microsemi and Nitronex *Sponsored by Richardson RFPD Moderated by Pat Hindle,* Microwave Journal	**Peregrine Workshop:** The Rise of UltraCMOS: Addressing the Toughest RF Challenges, Complementary to GaN, *Jack Lu, Peregrine Semiconductor*	**Signal Monitoring and Spectrum Analysis Workshop:** Extend Real Time Spectrum Analysis Applications using Vector Signal Analysis, *Qin Zhang, Agilent Technologies;* Transient Signal Monitoring with the MUSIC Algorithm Implemented in FPGA, *Huimin Shi, Agilent Technologies*	**CST Workshop:** Simulation and Measurement: Complementary Design Tools, *Klaus Krohne, CST*	**LeCroy Workshop**	**Exhibition Hours (10:00 - 17:00)**
	WS_WE201	**WS_WE202**	**WS_WE203**	**WS_WE204**	**WS_WE205**	
14:15 - 15:00	**RFHIC Workshop:** GaN Transistor Solution for Telecommunication Market, *JaeHo Lee, RFHIC;* High Efficiency GaN Hybrid Amplifier for Small Cell Application, *JaeHo Lee, RFHIC*	**OMMIC Workshop:** 100 nm GaN/Si Technology for mmW Applications, *Marc Rocchi, ERA/OMMIC*	**COMSOL Workshop:** Shaping Emerging RF Technologies through Multiphysics Simulation, *Jiyoun Munn, COMSOL*	**AWR Workshop:** Implementing Reference Designs in Microwave Office Software, *Francis Leong, AWR;* NI-AWR Integrated Framework for WLAN 802.11ac, *Gent Paparisto, AWR/National Instruments*	**MIMO OTA Workshop:** MIMO OTA Testing, *Mark Sargent, CTIA - The Wireless Organization;* Driving OTA Standards in APAC, *Lin Guo, ETS-Lindgren*	
15:00 - 15:30	**Tea/Coffee Break**					
	WS_WE301	**WS_WE302**	**PA_WE303**	**WS_WE304**	**WS_WE305**	
15:30 - 16:15	**GaN PA Design Seminar: Part 1** Intrinsic Cree GaN HEMT Models Allow More Accurate Waveform Engineered PA Designs, *Ray Pengelly, Cree*	**Mitron Workshop:** How to Select Cable Assemblies Based on the Applications, *Wei Liu, Mitron*	**MIMO OTA Test Panel:** MIMO OTA Driving Industry Testing and Standards, *Sponsored by Spirent*	**ANSYS Workshop:** CAE Simulation of Active Antenna Array, *Haiqiang Ding, ANSYS*	**Rohde & Schwarz Workshop:** Testing of VoLTE Video Over LTE, *Liu Chang, Rohde & Schwarz*	
	WS_WE401	**WS_WE402**	**WS_WE403**	**WS_WE404**	**WS_WE405**	
16:15 - 17:00	**GaN PA Design Seminar: Part 2** Class F Power Amplifier Design within AWR Microwave Office Software and Featuring Cree Technology, *John Dunn, AWR*	**Agilent Workshop:** Use Customizable Modular Instrument and System Design Tool to Enable Fast Prototyping, *Yu Zuo, Agilent Technologies*	**Richardson RFPD Workshop:** Small Cell *Jason Su, Richardson RFPD*	**WLAN Production Test Workshop:** Increase WLAN Manufacturing Test Throughput with Multi-DUT Test, *Erik Johnson, National Instruments*	**Taconic Workshop:** Flexible Printed Circuit Materials Work in Medical Environments, *Wingkin Li, Taconic*	

EDI CON

Thursday, April 10, 2014

	Design Track: Room A (201 A/B)	RF/MW Measurement/ Modeling Track: Room B (201 D)	EMC/EMI & HSD Measurement/ Modeling Track: Room C (203 A)	Systems Engineering Track: Room D (203 B)	Commercial Resources Track: Room E (203 C)	
	TH101	**TH102**	**TH103**	**TH104**	**TH105**	
08:30 - 08:50	Broadband Circularly Polarized Microstrip Antenna Production, *Huang Shanshan, School of Electronic and Optical Engineering, NUST*	Noise Parameter System Verification Using Passive Noise Standards, *Aihua Wu, Hebei Semiconductor Institute*	Impact of RF Solid State Switch in Phase Noise and Jitter Test Measurement on the ATE, *Yean Feng Chek, Texas Instruments*	Data Compression Methods to Stream Highest Bandwidth Radar Pulses, *Beate Hoehne, Agilent Technologies*	ETSI MIMO Wireless Device Regulatory Test System, *Brian Chi, Agilent Technologies*	
08:50 - 09:10	Dual Circularly Polarized Monopulse Tracking Feed for Cassegrain Reflector Antenna at S-Band, *Rajesh Chivukula, Larsen & Toubro*	Revisiting the Uncertainty Calculation of Y-Factor Noise Figure Measurement, *Guoquan Lu, Agilent Technologies*	Simulation and Measurement of Power Supply Common-Mode Rejection, *Hongmei Fan, Cisco*	500 MHz Analysis Bandwidth for Wideband Applications Like Pulse Analysis for RADAR Signals or Multi Carrier Group Delay Measurement for Satellite Communication, *Wolfgang Wendler, Rohde & Schwarz*	Performance of the Dual Polarized Spatial Channel Model Including: Ergodicity, Spatial and Temporal Characteristics, *Hui Xiao, Spirent*	
09:15 - 09:35	Antenna Performance of LTE Enabled Handheld Tablets, *Peter Futter, EMSS*	Comparison of Noise Figure Measurement Between Y-Factor Method and Cold-Source Method, *Di Liu, Agilent Technologies*	FFT-Based Time-Domain EMI Measurements: Benefits, Challenges and CISPR Emission Standard References, *Volker Janssen, Rohde & Schwarz*	Measurement of I/Q Mismatch in MIMO-OFDM Transmitters, *Ziquan Bai, Agilent Technologies*	**Agilent Forum:** A Broadband Power Amplifier Design and Broadband DPD Measurement, *Xiongbin Liao, Agilent Technologies*; Digital Predistortion Measurement for HF Power Amplifier, *Jinbiao Xu, Agilent Technologies*	
09:35 - 09:55	Systems Approach to Advanced Active Antenna Architecture Critical for Performance Gains in Wireless LTE Devices, *Quanxin Wang, Ethertronics*	Efficient Noise Extraction Algorithm and Wideband Noise Measurement System from 0.3 to 67 GHz, *Van-Hoang Nguyen, Focus Microwaves*	Practical Guide to Making Advanced Jitter Measurements, *Min Jie Chong, Agilent Technologies*	Phase Coherent Signal Creation with up to Twelve Channels with High Performance Multi-Channel AWG, *Beate Hoehne, Agilent Technologies*		
10:00 - 10:30	**Tea/Coffee Break**					
	TH201	**TH202**	**TH203**	**TH204**	**TH205**	
10:35 - 10:55	Innovative Approach to Design of an Electrically Small Cassegrain Reflector Antenna, *Ranadeep Saha, Larsen & Toubro*	A Computer Centric Pulse Creation and Measurement Method for the Characterization of High Power RF Devices, *Yong Liu, Philips*	High Speed DDR Memory Debug and Characterization with a Mixed Signal Oscilloscope, *Min Jie Chong, Agilent Technologies*	Near Field Communication Overview and Measurements, *Xiang Zhou, Rohde & Schwarz*	Advances in Quasi-Optical and Free-Space mm-Wave and THz-Region Materials Measurements, *Jon Martens, Anritsu*	
10:55 - 11:15	Compact X-Band Microstrip Patch Antenna Design for Radar Application, *Manoj Dwivedi, Bharat Electronics*	Pulsed IV/RF Measurements Techniques and Tips, *Qin Shen-Schultz, Auriga*	Synchronization of Multiple Oscilloscope Measurement Systems to Sub-ps Levels, *Brig Asay, Agilent Technologies*	Analog RF Test Methodology and Architecture for NFC Devices, *Dharmendra Lingaiah, National Instruments*	Mixed Domain Analysis: Tektronix Innovations in the Field of Radio Frequency, *Sun Yong, Tektronix*	
11:20 - 11:40	New Simulation Approach for Antenna Array Design, *Hao Li, ANSYS*	Electro-Thermal Analysis of RF/Microwave Planar Devices with ANSYS Multiphysics, *Yong Yuan, ANSYS*	Automate Multilane Gigabit Serial Testing, *Min Jie Chong, Agilent Technologies*	FDD-LTE Radio Spectrum Emission Mask Analysis and Optimization, *Ming Huang, Nokia Solutions & Networks*	S-Band Modules and Pallets with Reduced Size and Weight for Next Generation Traditional and Latest Phased Array RADAR Applications, *Damian McCann, MACOM*	
11:40 - 12:00	A Very-Near-Field Measurement Technique to Test Large Antennas in the Lab, *Erkan Ickam, EMSCAN*	An Integrated Electro-Thermal MMIC/RFIC Design Flow, *YuFu Li, AWR*	Uncertainty and Stability in True Differential-Drive Measurements, *Jon Martens, Anritsu*	A Comparison of the EMVCo and ISO10373-6 Power Calibration Method, *Feng Liu, VI Service*	DC to the mmW Range Ultra-Compact High Precision Power Measurements using Android Mobile Devices, *Wei Dong, Rohde & Schwarz*	**Exhibition Hours (10:00 - 15:00)**
12:00 - 13:30	**Lunch Break**					
	Featured Panels					
	WS_TH101	**WS_TH102**	**WS_TH103**	**WS_TH104**		
13:30 - 14:15	**AWR EM Design Workshop:** Combining Planar and 3D EM Simulators for RF System Board: Techniques for Better Results, *John Dunn, AWR*	**RF Semiconductor Workshop:** High Performance RF and mmWave Designs on Silicon-Based Technologies, *Yuan Quan, MOSIS*; GaN HEMT Transistor for the Amplifier in the Base Station of LTE, *Naiqian Zhang, Dynax*	**Rohde & Schwarz Workshop:** Analysis of RADAR Pulses with 500 MHz Analysis Bandwidth and Real-Time Spectrum Analysis, *Wolfgang Wendler, Rohde & Schwarz*	**Radar Simulation Workshop:** An Automatic Phased Array Radar Calibration Solution, *Ben Niu, Agilent Technologies*; Universal Reconfigurable Architecture Design Radar System Simulation, *Cheng Wang, Agilent Technologies*		
	PA_TH401	**PA_TH402**	**PA_TH403**			
14:15 - 15:00	**Semiconductor Panel:** Aligning RF Semiconductor Technology to End-Use Applications, Featuring Freescale, OMMIC, Peregrine and TriQuint Semiconductor *Moderated by: Zhancang Wang, Nokia Solutions & Networks*	**EDA Design Flow Panel:** Featuring Agilent, ANSYS, AWR, CST and Sonnet *Moderated by: David Vye,* Microwave Journal	**Telecommunications Panel:** Trends in Future Telecommunications Systems and Their Engineering Challenges, Featuring Agilent, Spirent, R&S, Anritsu and NI *Moderated by: Guangyi Liu, China Mobile Research Institute*			

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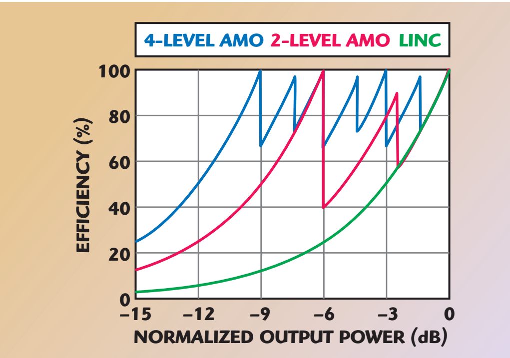
GaN Devices and AMO Technology Enable High Efficiency and Wide Bandwidth

Raymond Pengelly and Ryan Baker
Cree Inc., Research Triangle Park, NC
Mattias Astrom and Joel L. Dawson
Eta Devices, Cambridge, MA

As wireless communications expand in bandwidth, number of users and geographic coverage, there is a growing demand for higher efficiency in the power amplifier portion of base station transmitters. Wireless power amplifiers consume more than half the total power required to operate a base station. Reducing that consumption through higher efficiency offers several benefits, starting with the obvious benefit of lower operating cost. While a lower utility bill is a significant advantage, less waste heat means reduced equipment cooling requirements and increased reliability. With less concern about temperature rise, a wireless operator has more flexibility in locating the new base stations required to support the dramatic increase in wireless data usage provided by 4G and future generations.



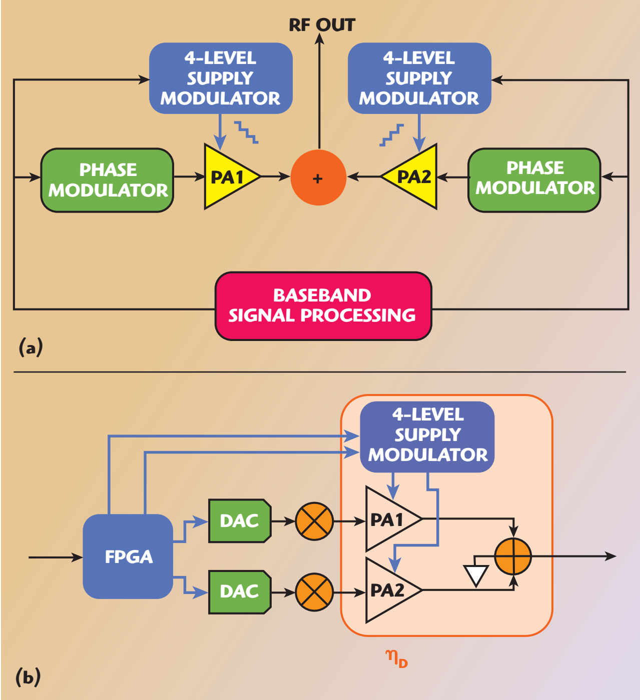
▲ *Fig. 1 Theoretical efficiency of AMO modulation with four amplitude levels, compared to two-level AMO and "one-level" outphasing (or LINC – linear amplification with nonlinear components).*

But higher efficiency must be accompanied by the wider bandwidth and high linearity demands of 4G wireless signals. To address this issue, recent startup Eta Devices Inc. is commercializing a technology developed at MIT: asymmetric multilevel outphasing (AMO). AMO combines the high linearity of outphasing with efficiency-enhancing, multilevel, discrete switched drain bias. Discrete switched drain biasing is the key to supporting wide bandwidths while maintaining high efficiency, and is the greatest advantage of this technique over traditional envelope tracking. ***Figure 1*** illustrates how AMO achieves efficiency improvement over outphasing alone.

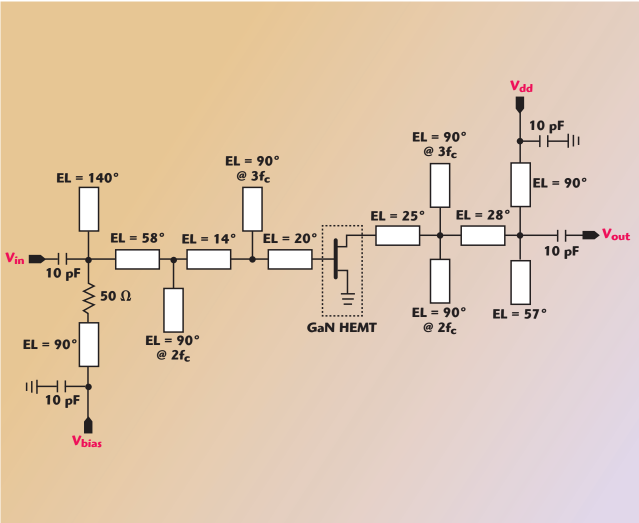
In any outphasing system, maximum efficiency is obtained from the individual power amplifiers' performance. In their high power amplifier designs, Eta Devices uses GaN HEMT devices, which have demonstrated practical peak drain efficiencies exceeding 80 percent. GaN technology was selected for its improved performance over existing silicon devices, which struggle to exceed 70 percent peak drain efficiency under similar conditions.

Along with high performance RF amplifiers, the power supply switching system must also be optimized for low-loss switching with minimal transients. System timing is critical, requiring management of the delay in each signal and control path. And once properly synchro-

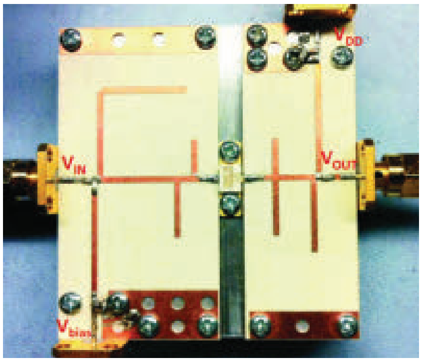
nized, Eta Devices' proprietary digital predistortion (DPD) techniques are critical to achieving the demanding adjacent channel power ratio (ACPR) specifications for 4G systems. This architecture has been implemented at a variety of power levels and applications, from 1 W PAs for handsets and WLAN transmitters to 100 W PAs for base stations, and with a variety of semiconductor materials, including GaN, GaAs and silicon.



▲ *Fig. 2 Block diagram of AMO.*



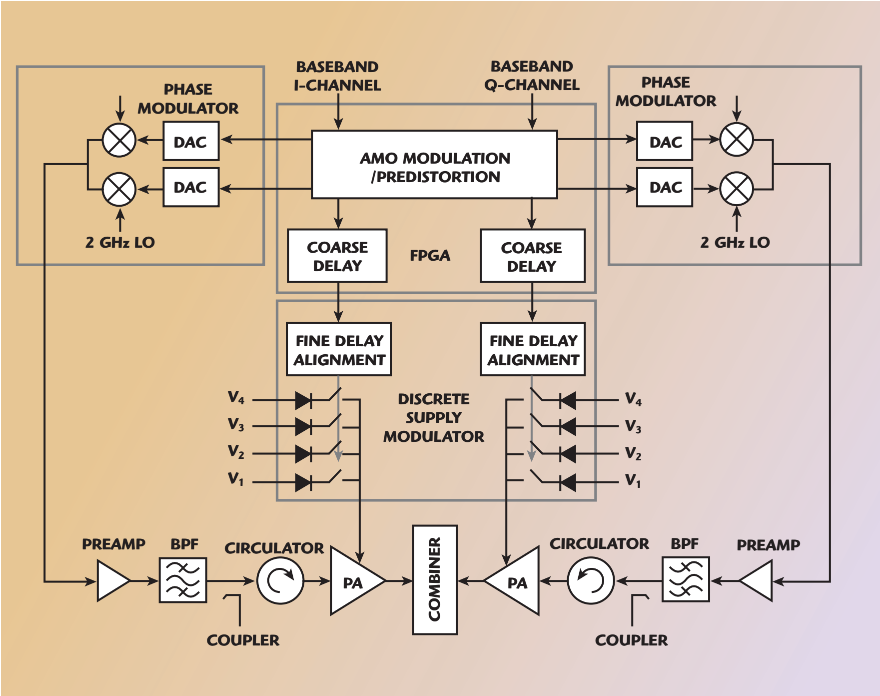
▲ *Fig. 3 Circuit schematic of the 10 W Class E 1.95 GHz test circuit.*[2]



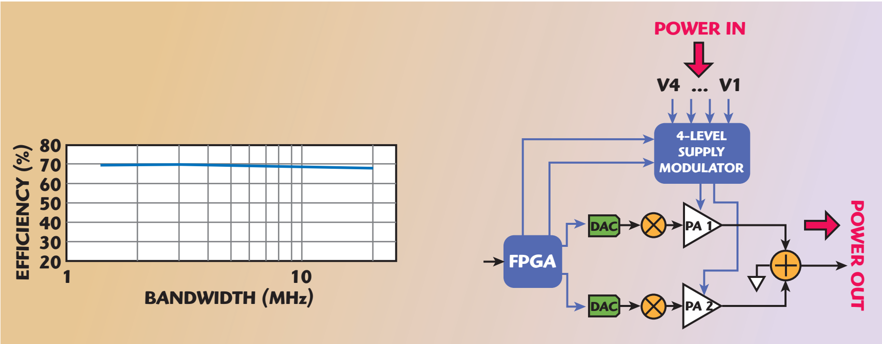
▲ *Fig. 4 Photograph of the Class E GaN amplifier.*

AMO VS ET OPERATION

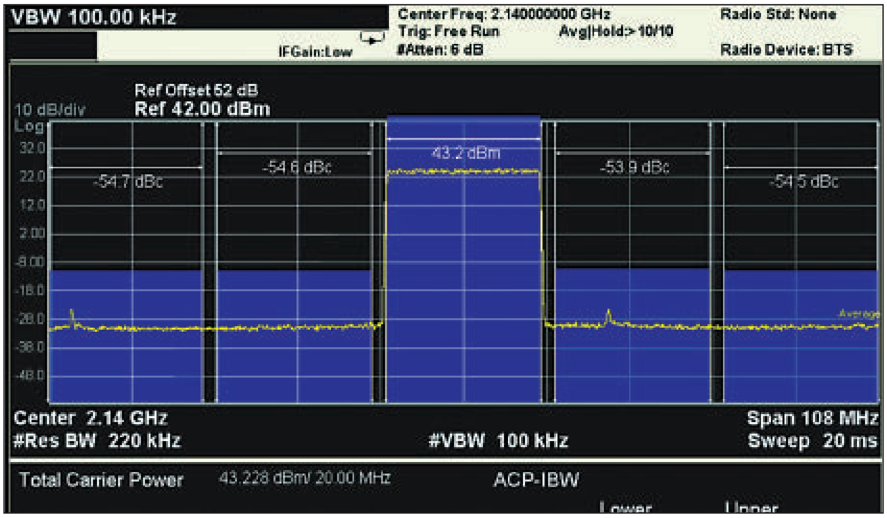
Two well-known methods for achieving linear amplification with nonlinear power amplifiers are outphasing and envelope tracking (ET). Outphasing uses two phase-modulated amplifiers operating at constant amplitude. The input signal is converted to the proper phases and presented to the amplifiers, whose outputs are combined so that reinforcement and cancellation of the phase components results in a signal that replicates the input accurately. In practice, outphasing requires a power combiner that provides a consistent load for each PA, isolation between the amplifiers, and high power handling capability. These characteristics can be difficult to achieve, especially over a wide bandwidth. Another limitation of outphasing is that signals with high peak-to-average power ratios (low average power output) result in reduced efficiency since much of the amplifiers' power is wasted and dissipated by a resistive load.



▲ *Fig. 5 Test transmitter block diagram.*



▲ *Fig. 6 Efficiency versus bandwidth at 2.14 GHz, 100 W peak power, 7 dB PAPR and ACPR > 45 dBc.*



▲ *Fig. 7 Spectral performance for a 20 MHz BW, 7 dB PAPR transmission. The carrier frequency is 2.14 GHz, and the output power is 100 W peak.*

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ET splits the RF signal into separate phase angle and amplitude components. The PA operates in saturated mode, typically one of the switching modes such as Class E. Phase modulation is applied to the RF drive while the DC supply to the PA is modulated with the amplitude envelope, thus phase and amplitude are both restored at the output. ET, despite its popularity, is challenged by the increasing bandwidth requirements of 4G and WLAN standards. The crux of the problem for ET is the supply modulator, which must excel in many different aspects of performance. It must handle a lot of power, be extremely efficient, be highly linear, be high resolution, inject very little noise into the system, and support wideband modulation. Modern wireless standards demand increased bandwidth without relaxing any of the other performance demands, putting the future of ET-only solutions in doubt.

The design challenges of outphasing and envelope tracking are addressed by AMO, which combines the most desirable features of outphasing and envelope tracking for improved performance. A block diagram of AMO is shown in ***Figure 2***, where Figure 2a shows the basic functions, and Figure 2b illustrates a typical implementation scheme. It begins with signal processing that delivers phase modulated signals to the power amplifiers, which have multilevel supply modulators. The outputs are combined for an amplified signal with high linearity that maintains the high efficiency of the nonlinear PAs.

While the physics of AMO solutions is conducive to high bandwidth modulation at high efficiencies, it does come at the price of non-traditional DPD solutions which are at the core of this AMO implementation. Although the structure of the DPD is non-traditional, the computational resources required do not differ from that of traditional DPD. Thus, there is no hidden power cost associated with increased digital complexity that would undermine the overall efficiency gains. In summary, AMO allows a tradeoff to address the limitations of outphasing and envelope tracking behaviors, resulting in a system with the best characteristics of each.

GaN DEVICE AND PA DESIGN

The efficiency of the core switch-mode PA determines the maximum system efficiency of techniques like outphasing, ET and AMO. For present day wireless communications amplifiers, most of the highest efficiency production devices are fabricated using GaN processes. For example, the GaN HEMT devices[1] used in a prototype developed at MIT[2] are specified at 65 percent (3.6 GHz) and > 70 percent (2 GHz) typical efficiency at their maximum saturated output power. The PA circuit diagram is shown in ***Figure 3***, and ***Figure 4*** is a photo of the assembled amplifier. For AMO applications, the PA is designed to have good performance over the range of drain voltages to be delivered by the stepped-switching supply modulator.

OVERALL PERFORMANCE

A complete transmitter (see ***Figure 5***) includes several additional system components. Baseband I and Q signals are delivered to a digital

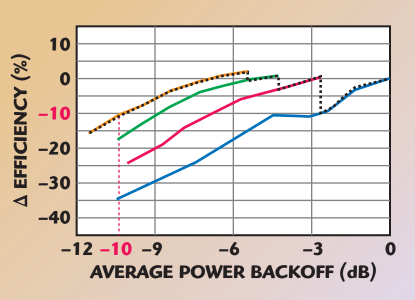
predistortion (DPD) and modulation signal processor implemented with an FPGA. In this system, DPD is implemented with a lookup table constructed from measured static nonlinearity of the transmitter for the various combinations of DC levels at the PA. Outphasing channel phase modulation data is delivered to digital-to-analog converters and phase modulators for the two PAs. Amplitude modulation data, with coarse delay correction, drives the supply modulator circuit. RF preamplifiers provide the necessary drive levels, and at the output a combiner sums the PA outputs into a single RF output.

PERFORMANCE SUMMARY

AMO combines the desired attributes of outphasing and envelope tracking obtained with either method alone. ***Figure 6*** shows efficiency versus bandwidth performance for the four-level AMO test transmitter. The AMO system architecture using Class E GaN PAs, combined with the latest DPD implementation, delivers an average, modulated drain efficiency of 70 percent at 1 MHz bandwidth, with only a slight reduction to 68 percent at 20 MHz bandwidth. Supply modulator losses are included in the efficiency measurement.

Figure 7 shows the spectral energy in adjacent channels with the latest DPD implementation. At 20 MHz channel bandwidth, ACPR performance is > 54 dBc while maintaining 68 percent efficiency. Measured data for efficiency versus backoff is shown in ***Figure 8***. While these devices have 70 percent modulated drain efficiency (including modulator losses) at maximum average output power, the performance at backoff is arguably more important. This is because network operators almost never operate their base stations at maximum average output power. Instead, it is normal to operate at 30 to 50 percent of the maximum. Figure 8 shows that this device system loses only 10 percent efficiency for 10 dB backoff from maximum average power. For a signal with a 7 dB PAPR, this is actually a 17 dB backoff from peak power.

This technology continues to expand its capabilities, focusing on support of both LTE and MC-GSM, enabling software-defined radio, and meeting the challenges of expanded bandwidth standards such as WLAN. ■



▲ *Fig. 8 Measured efficiency at backoff (ACPR > 45 dBc). The four individual drain voltages are shown, with the dotted line illustrating how 4-level AMO achieves system efficiency over the entire power backoff range.*

References

1. CGH40010 data sheet, Cree Inc., available at www.cree.com/rf/.
2. P. Godoy, S.W. Chung, T. Barton, D. Perrault and J. Dawson, "A Highly Efficient 1.95 GHz, 18 W Asymmetric Multilevel Outphasing Transmitter for Wideband Applications," *IEEE International Microwave Symposium Digest*, June 2012.

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	(MHz)	(dB)	(W)	(W)		
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ZHL-5W-1	5-500	44	8	11	995	970
• ZHL-100W-GAN+	20-500	42	79	100	2395	2320
• ZHL-50W-52	50-500	50	40	63	1395	1320
• ZHL-100W-52	50-500	50	63	79	1995	1920
LZY-1+	20-512	43	37	50	1995	1895
• ZHL-20W-13+	20-1000	50	13	20	1395	1320
• ZHL-20W-13SW+	20-1000	50	13	20	1445	1370
LZY-2+	500-1000	46	32	38	1995	1895
NEW ZHL-100W-13+	800-1000	50	79	100	2195	2095
ZHL-5W-2G+	800-2000	45	5	6	995	945
ZHL-10W-2G	800-2000	43	10	13	1295	1220
ZHL-30W-252+	700-2500	50	25	40	2995	2920
ZHL-30W-262+	2300-2550	50	20	32	1995	1920
ZHL-16W-43+	1800-4000	45	13	16	1595	1545
ZVE-3W-83+	2000-8000	36	2	3	1295	1220
ZVE-3W-183+	5900-18000	35	2	3	1295	1220

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Jon Martens, *Anritsu Co., Morgan Hill, CA*
Jeffrey Hesler and Alex Arsenovic, *Virginia Diodes Inc., Charlottesville, VA*

Electronic applications are being developed at frequencies in the several hundred gigahertz (GHz) and even terahertz (THz) regions. Today, most of the work is at the research stage for applications in electronic, chemical, biological and material development. Many organic compounds have molecular resonances above a few hundred GHz, which are being studied for use with spectroscopy for chemical and biological applications. Device improvements in these frequency ranges have also led to a considerable amount of research in networking and radar systems. Although atmospheric absorption resonances make certain applications challenging, there are windows throughout the THz region (see ***Figure 1***) that allow free space applications such as radar, security and radio astronomy.

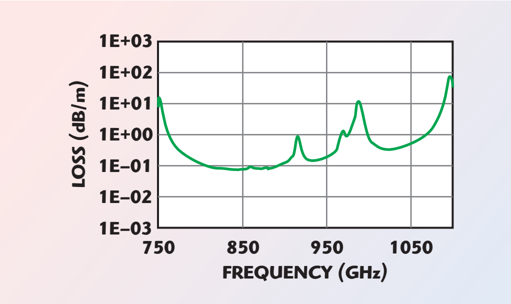

Fig. 1 Atmospheric windows in the THz region.

As new applications develop, there is a growing need for improved material measurement capabilities in the THz region. Lower frequency measurements scaled to higher frequencies were used to support early developmental work; however, these are limited by S-parameter measurement uncertainties and changes in the material parameters. Today, free-space and quasi-optical measurements in the THz region have become more practical. Anritsu and Virginia Diodes Inc. (VDI) are teamed up to deliver a measurement solution that enables the development of many of applications. This article discusses the use of a vector network analyzer (VNA) with THz frequency extenders to accurately characterize materials using a quasi-optical measurement technique.

MEASUREMENT SETUP

The test solution may be configured in several ways for quasi-optical measurements. The measurements can be performed using a VNA two-port technique (S_{21}) or a one-port technique (S_{11}). ***Figure 2*** shows four configurations using both techniques. The collimated beam configurations (see Figure 2a/c) require fairly large material samples that can be difficult to obtain. While the two-port focused beam (see Figure 2b) allows for smaller sam-

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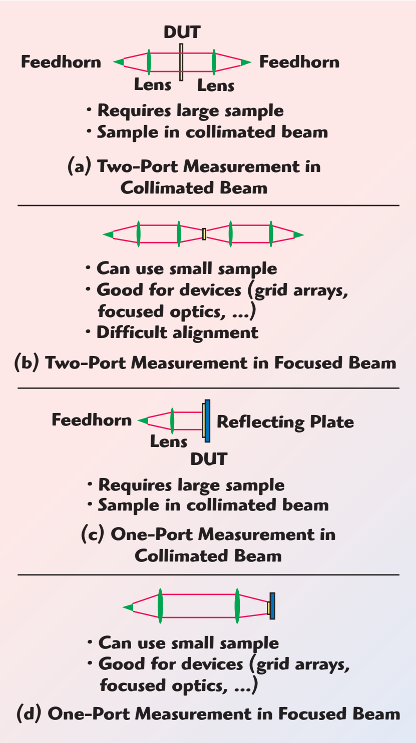
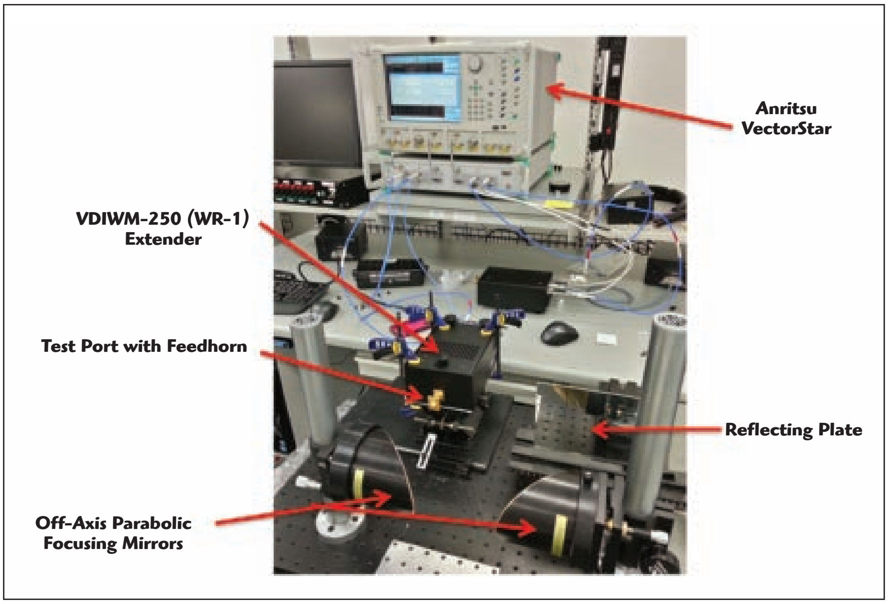
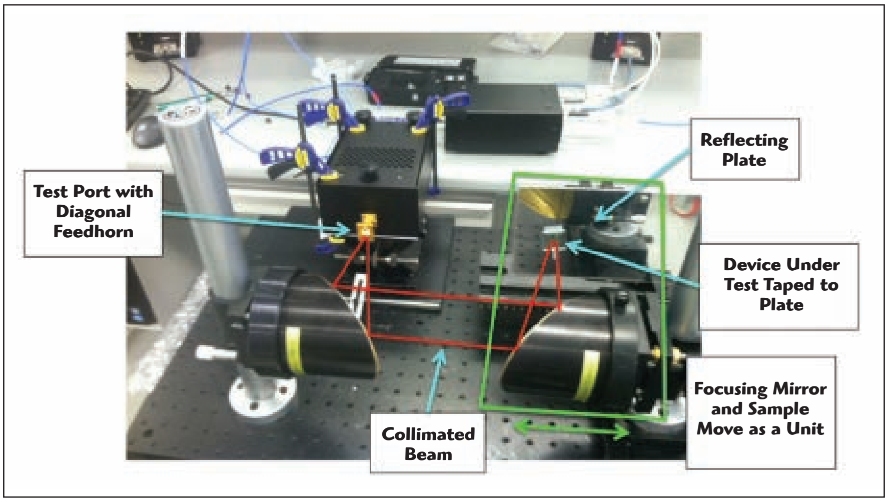


▲ *Fig. 2 One- and two-port quasi-optical measurements configurations.*



▲ *Fig. 3 One-port focused beam quasi-optical measurement test setup.*



▲ *Fig. 4 Focusing mirror and reflecting plate/material sample.*

ples, the alignment can be very challenging. The one-port method (see Figure 2d) allows for both a smaller sample size and easier alignment. The one-port method is the configuration used for the measurements described in this article.

Figure 3 shows the measurement test setup. The Anritsu VectorStar VNA controls the test process and provides both the stimulus and response signals. The VDI WM-250 (WR-1) extender module upconverts the signal to the 750 to 1100 GHz frequency range. A feedhorn antenna is attached to the waveguide output of the extender. The radiated signal illuminates the mirror pair (right angle turns) and the beam is focused on the reflecting plate shown on the right side of the picture. The test samples are taped to the reflecting plate.

The VNA (20, 40, 50 and 70 GHz versions) forms the basis for many millimeter wave measurement test solutions. The base VNA can be combined with the 3743A mm-wave modules for broadband coverage from 70 kHz to 125 GHz or used with VDI modules for measurements up to 1 THz. The VNA offers calibration and de-embedding flexibility, making it easier to perform more elaborate and accurate free-space calibrations. It offers excellent stability at these frequencies to minimize phase changes, enabling accurate determination of a material's permittivity. The VDI WM-250 (WR-1.0) VNA extender offers a dynamic range of up to 60 dB, a magnitude stability of ±1 dB and a phase stability of ±15°. Its compact size allows it to be placed in close proximity of the focusing mirrors.

In our configuration, the focusing mirror and reflecting plate/material sample move as one. This allows the focal point to stay relatively fixed while the collimated portion is lengthened (see ***Figure 4***), providing a more linear phase offset.

OVERDETERMINED LEAST SQUARES CALIBRATION

The setup is calibrated using the overdetermined least squares calibration technique, as implemented in the Python module scikit-rf.[1,2] This technique uses more than the minimum number of calibration standards and solves for the parameters in a least-squared sense. By using multiple standards, the residual errors can be analyzed to provide a measure of calibration quality.

The calibration standards are a series of five delayed reflections with known delay distances. The metal reference plate is at the focal point of the quasi-optical system. As shown in Figure 4, the metal plate and focusing mirror are both mounted on the same stage. This stage is then translated along the direction of the collimated beam using a micrometer to generate the set of delayed reflection calibra-

tion standards. A piece of 45 degree angled absorber is used as a matched load.

The overdetermined calibration provides a directly interpretable estimate of achievable measurement quality by looking at the measured S-parameters of the calibration standards (see ***Figure 5***). Use of more than the minimum set of standards provides a more stable solution to the system of equations over a broad bandwidth, and better accuracy. ***Figure 6*** compares the remeasured reflective standards to the load standard, providing an estimate of the smallest measurable return loss given the calibration quality.

REDUCING MULTIPATH WITH TIME DOMAIN GATING

In the quasi-optical setup there are a number of inherent multipath reflections (see ***Figure 7***). These multipath signals combine with the desired signal and often result in large ripples across the measured data. The VNA can transform the swept frequency domain data into the time domain to enable the use of time domain gating. ***Figure 8*** shows the time domain result, which can be used to set time domain gating. Transforming

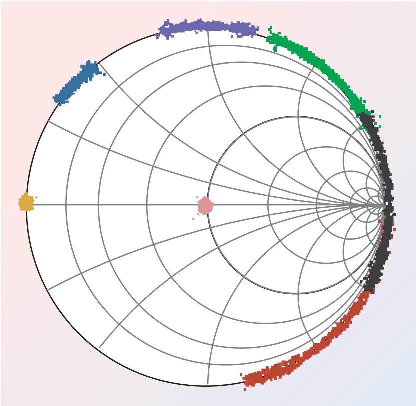


Fig. 5 Measured S-parameters of the calibration standards on the Smith Chart.

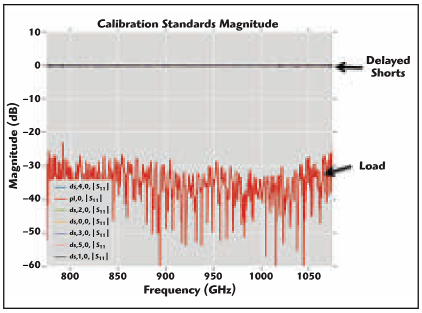


Fig. 6 The test setup shows accurate measurements for the calibration standards.

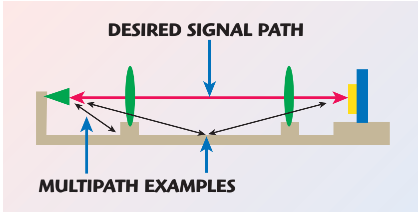


Fig. 7 Undesired multipath signals that exist along with the desired signal path.

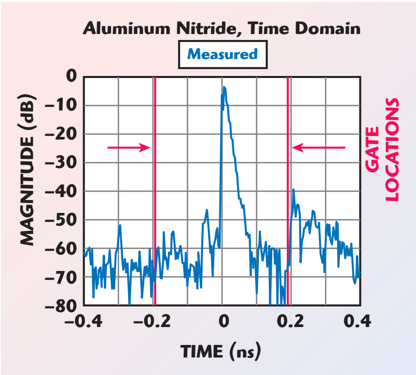
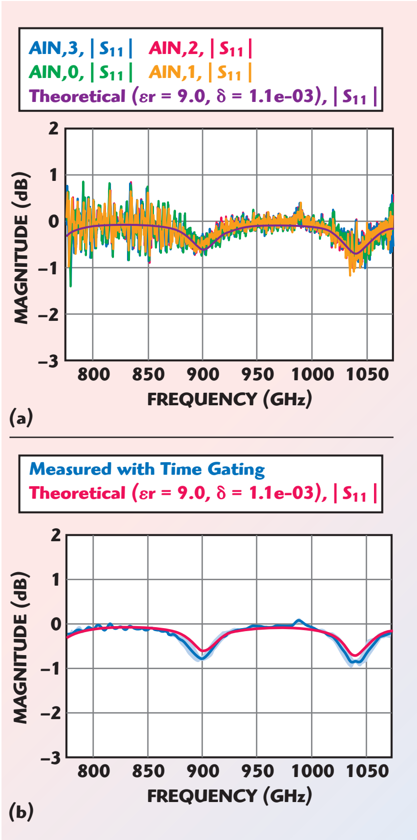


Fig. 8 Swept frequency domain data transformed into the time domain to enable use of time domain gating.

the data into the time domain enables removal of most multipath reflections. Through the use of gating, the multipath ripple is significantly reduced, providing measurement results that are close to theoretical (see ***Figure 9***).

MEASUREMENT RESULTS

Aluminum nitride (AlN) and quartz are two dielectric materials commonly used in a number of device processes at these frequencies. Quartz is primarily used as a substrate and AlN is often used as a dielectric or passivation layer. The material samples were taped to the metal reference plate at the focal point of the lens. To estimate the uncertainty associated with the coarse mounting technique, measurements were repeated four times for each sample. In between each measurement, the sample was removed and remounted so that the resultant set of measurements would capture the mounting uncertainty. As shown in the following plots, the repeatability of this method was surprisingly good for such a simple technique.



▲ *Fig. 9 Time domain gating reduces the effects of multipath reflection; no gating (a), with gating (b).*

The known dielectric constant and loss tangent for each material were used to generate theoretical curves for comparison with measured results. Each value was adjusted slightly until the results aligned with the measurements. This guess-and-check method is a simple way to compare theoretical permittivity with that derived from the measurement.

Figure 10 shows measured results for the 0.014" thick AlN sample along with the theoretical expectation. The uncertainty bounds are based on repeatability. Time domain gating was used to reduce the ripple effects from the multipath reflections in the test setup. ***Figure 11*** shows the measured results of the 0.039" thick quartz sample along with the theoretical expectation. Time domain gating was again used to reduce ripple effects from the multipath reflections in the test setup. The cusps are due to the reflections at the front and back of the sample interfering and are expected. The cleanliness of the cusps suggests that the planarity of the sample was good.

CONCLUSION

The quasi-optical one-port measurement solution successfully demonstrates use of the Anritsu VectorStar VNA and the VDI frequency extender to accurately determine the complex dielectric properties of AlN and quartz materials. The measured data shows minimal sensitivity to the repositioning of the dielectric samples and very good repeatability. This technique enables accurate complex permittivity measurements of many technological materials in the THz region. ■

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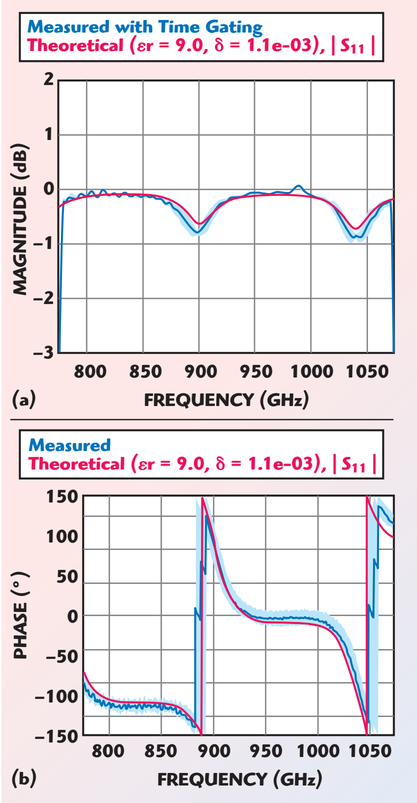
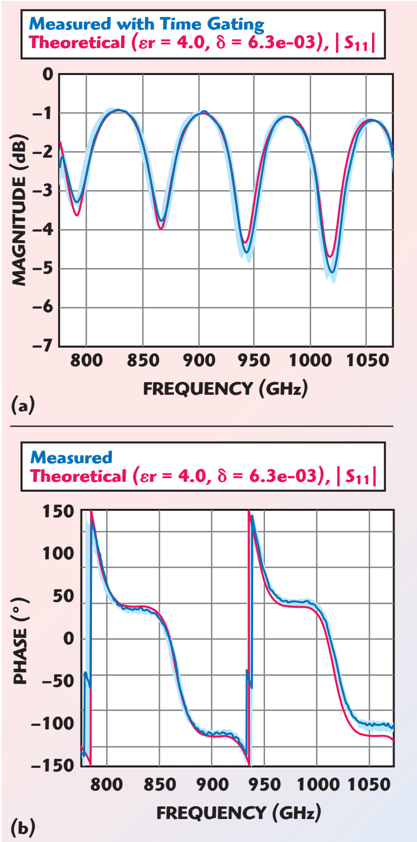


▲ *Fig. 10 Measured vs. theoretical results for a 0.014" thick AlN sample; magnitude (a), phase (b).*



▲ *Fig.11 Measured vs. theoretical results for a 0.039" thick quartz sample; magnitude (a), phase (b).*

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The Impact of Power Amplifier Turn-On Characteristics in Cognitive Radio Networks

Gavin Watkins and Stephen Wang
Toshiba Research Europe Ltd., UK

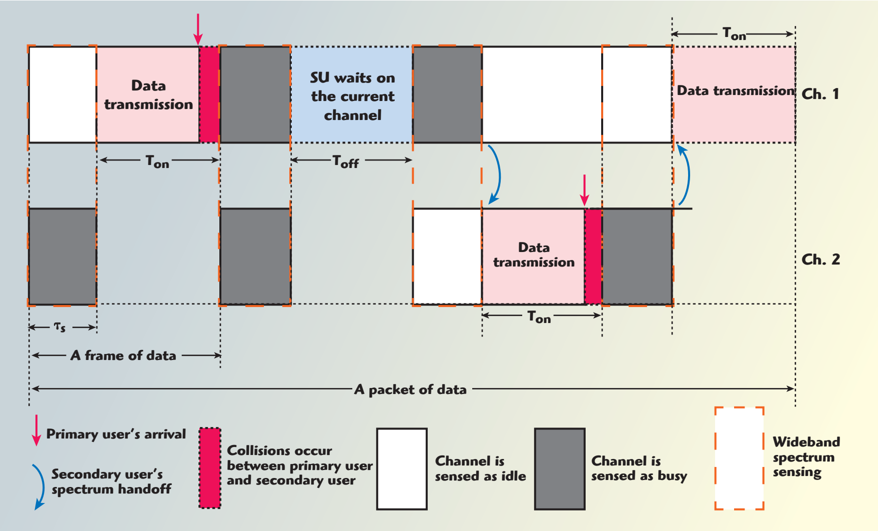
Cognitive radio networks (CRN) often assume that the transmit chain can be instantly switched on and off. In practice, however, there is a delay between DC power being applied to a radio frequency (RF) power amplifier (PA) and the achievement of full output power and linearity requirements. There is also excess power consumption as the PA reaches its static operating conditions. The findings presented here as a result of PA measurements suggest that to guarantee correct operation without any spurious distortion products interfering with other users, a non-negligible delay is required after applying power and before beginning transmission.

CRNs are often regarded as viable options for future mobile communications standards operating over very wide frequency bands.[1,2] In wideband CRNs with multiple channels available for sharing, user throughput can be significantly increased by performing a "spectrum handoff,"[3] in which the user switches to a vacant channel to continue data transmission if the current channel becomes busy (see ***Figure 1***).

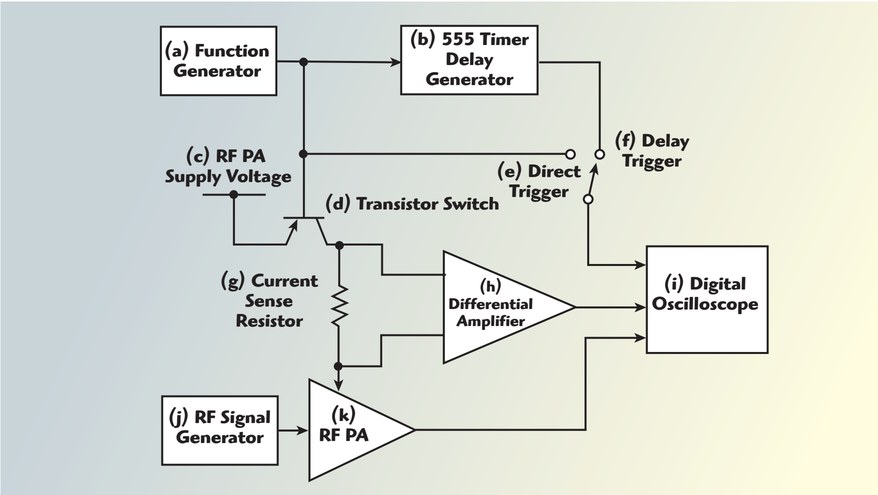
Spectrum sensing is used to check that a particular channel is vacant. If it is, spectrum handoff occurs. As shown in Figure 1, periodic spectrum sensing and access requires intermittent transmission and occasional switching between channels.[3] It is assumed that in the transmit chain, the PA consumes the majority of battery power, particularly if high peak-to-average power ratio (PAPR) standards like 3GPP Long Term Evolution (LTE)[4] are used. To conserve power, the PA is switched off between transmissions instead of simply being placed into a standby mode. Generally, however, PAs are designed to transmit continuously. By being periodically switched on and off, the PA is operating outside of its normal operating mode, and hence static specifications supplied by the manufacturer no longer apply.

MEASUREMENT SETUP

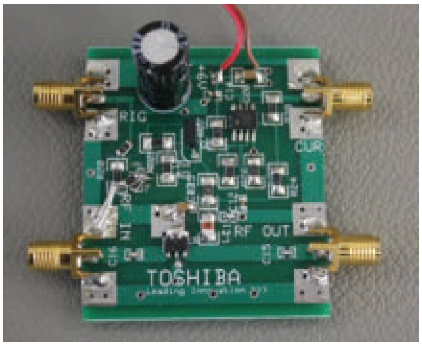
Figure 2 illustrates our measurement approach using a digital sampling oscilloscope. This allows the PA's RF output voltage and current consumption to be simultaneously



▲ *Fig. 1 Spectrum hand-off requiring regular PA switching on and off.*



▲ *Fig. 2 Layout of amplifier turn-on measurement test rig.*



▲ *Fig. 3 Photograph of board for measuring PA turn-on characteristics.*

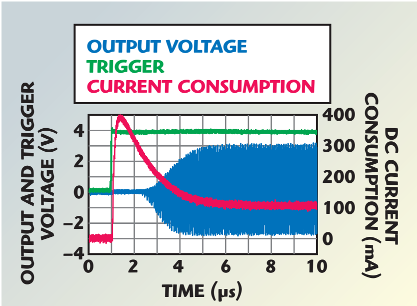
sampled. A function generator (a) produces a trigger signal controlling the transistor switch (d) that applies power to the RF PA (k). The trigger signal can be fed either directly (e) to the digital oscilloscope (i), or via a 10 µs to 100 ms 555 timer delay generator (b) that introduces a variable delay (f). For delays greater than one second, a stopwatch is used and the oscilloscope is manually triggered. The delay enables the PA's output voltage to be sampled at a time offset.

For this work, the PA is an Analog Devices ADL5536[5] with a 1 dB compression point (P1dB) of 20 dBm. An operating frequency of 600 MHz is chosen, which is in the TV white space band frequently touted as a suitable location for CRNs due to its propagation characteristics and usage profile.[6] The PA's current consumption is measured by sampling the voltage across a current sensing resistor (g) with a differential amplifier (h). An RF signal generator (j) produces a two-tone test signal. A photograph of the test board is shown in ***Figure 3***. The RF input is applied to the SMA connector on the bottom left, with the output on the bottom right. The SMA connector at the top left is the trigger input and the one on the top right the current sense output. The ADL5536 is at the bottom of the board and above it is the transistor that applies power when a trigger signal occurs.

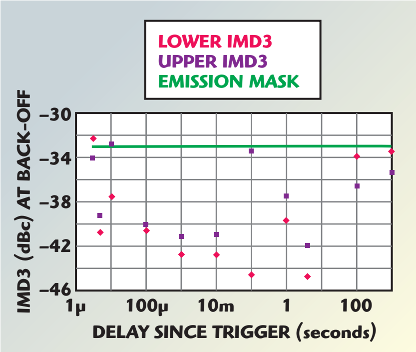
Third order intermodulation distortion (IMD3) generated by the two-tone test[7] is assumed to be equivalent to adjacent channel power (ACP) generated by a wideband signal, i.e., LTE. To make an accurate ACP measurement, it must be averaged over multiple frames. In the case of LTE, the frame length is 10 ms. As will later be seen, the PA's linearity characteristics vary considerably over a 10 ms period. For this work, data is collected over a 2 µs period and the IMD3 is derived by applying a Fast Fourier Transform (FFT) to the samples. It is assumed that the IMD3 does not change appreciatively over 2 µs. A two-tone test with tones at 600 and 610 MHz resulting in IMD3 products at 590 MHz (2 × 600 – 610 MHz) and 620 MHz (2 × 610 – 600 MHz) are accurately resolved by the FFT.

TURN-ON DELAY AND POWER CONSUMPTION

The amplifier's turn-on characteristics with a two tone test are shown in ***Figure 4*** over the first 9 µs of operation after the trigger. The trigger signal (green trace) occurs at 1 µs. The RF input level is adjusted so that under static conditions, the amplifier's IMD3 meets the WCDMA emission mask of –33 dBc.[8] Under these conditions, the output power (P_{out}) is 17.7 dBm. Although the PA starts to produce an output voltage (blue trace) 2 µs after the trigger (at time = 3 µs) it takes a total of 4 µs (at time = 5 µs) before the output voltage reaches its full amplitude. The PA turn-on delay (T_d) for full output power is therefore determined to be 4 µs. The large current spike (red trace) is due to the PA bias-



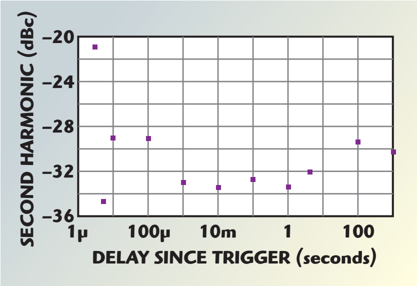
▲ *Fig. 4 Amplifier turn-on characteristics with a two-tone test.*



▲ *Fig. 5 Third order intermodulation distortion (IMD3) of PA.*

ing networks requiring time to settle and charging of the supply decoupling capacitors necessary for stable operation.

Under static conditions, the ADL5536 consumes 106 mA, resulting in a static power consumption (P_{static}) of 530 mW with a 5 V supply. With 17.7 dBm P_{out} the efficiency is therefore 11 percent, which is common for an amplifier of this type under these conditions. By integrating the current consumption between 1 and 5 µs and subtracting P_{static}, the ex-



▲ *Fig. 6 Second harmonic power relative to the fundamental.*

cess power required to turn-on the PA ($P_{turn-on}$) is calculated to be 590 mW. The total power consumption (P_{total}) for the PA during turn-on and data transmission is given by:

$$P_{total} = \frac{T_d P_{turn-on}}{T_{on}} + P_{static} \qquad (1)$$

where T_{on} is the time the PA is switched on. Compared to scenarios published in the literature where a T_{on} of 40 ms[9] or 100 ms[10] is specified, the impact of T_d and $P_{turn-on}$ is insignificant. Only at very small values of T_{on} (say less than 100 µs) does T_d and $P_{turn-on}$ have an impact. It should be noted that the numbers published here are only for the ADL5536. Other PAs will have different values of T_d and $P_{turn-on}$, which must be determined by measurement.

INTERMODULATION DISTORTION DURING TURN-ON

Lower and upper IMD3 fluctuations over time are compared with the –33 dBc WCDMA emission mask in ***Figure 5***. Note that the result at 3 µs is made up from data recorded between 2 and 4 µs, while the PA output power is still ramping up.

The large fluctuation in IMD3 shown in Figure 5 is quite likely due to PA memory effects,[7] which would also account for the asymmetry. Memory effects are distortions influenced not only by the present signal amplitude, but also by its past values. These can include thermal effects due to the amplifier's bias conditions changing as its temperature increases due to power dissipation.

The lower IMD3 fluctuates by over 12 dB and the upper IMD3 fluctuates by over 9 dB before static conditions are achieved. The emission mask is breached by 0.25 dB at 10 µs and at 100 ms it is nearly breached again. Because the data was recorded with a large granularity, it is possible that the emission mask is also breached between measurement points. Based on these results, a CRN should wait at least 10 µs before commencing transmission to avoid breaching the emission mask. However, for complete assurance it should wait 100 ms, which suggests that this particular PA is unsuitable for some published scenarios.[9,10]

HARMONIC DISTORTION DURING TURN-ON

During turn-on (see Figure 4), the output voltage exhibits asymmetric positive and negative excursions. This asymmetry introduces even order harmonic distortion at multiples of the input frequency. Conventional narrowband systems remove harmonic products by filtering, but this is not possible in a broadband CRN operating over multiple octaves[2] where harmonically related spurious products can easily interfere with another user.

The three second-harmonics of the two-tone test were measured:

1200 MHz (2 × 600 MHz), 1210 MHz (600 + 610 MHz) and 1220 MHz (2 × 610 MHz). Their combined power is calculated along with the combined power of the two fundamental tones to determine second harmonic suppression (see ***Figure 6***). As in Figure 5, the first result (at 3 µs) is data recorded between 2 and 4 µs after the trigger signal. Figure 6 shows that the second harmonic is extremely large between 2 and 4 µs after the trigger. It settles down afterward, but continues to fluctuate by almost 6 dB. Even if the PA meets the spurious harmonic emission mask under static conditions, the spike at 3 µs probably does not. A delay of 10 µs would be required before transmission could commence, in agreement with the IMD3 results of Figure 5.

CONCLUSION

This article examines the turn-on characteristics of an RF PA. Measurements show that the PA took 4 µs to achieve full output power, and during that time consumed an extra 590 mW of power in addition to the PA's 530 mW static power consumption. Such an additional delay and power consumption are insignificant when considering examples published in the literature; however, significant spurious distortion products are generated by the PA which cannot be ignored. Both IMD3 and second order harmonic distortion are examined. The data indicates that, at a minimum, a user should wait 10 µs after applying power to the PA before commencing transmission. A conservative practice would increase this to 100 ms. These results are PA dependant; any PA used in a CRN where it is periodically switched on and off (e.g., periodic spectrum sensing and spectrum handoff) should be measured as described.

This work shows that the PA can no longer be treated as a black box. When designing a CRN, an appropriate delay should be included in the protocol for the PA to sufficiently "warm up" and achieve static conditions. In order to prevent spurious products from interfering with other users, no signal should be transmitted during this "warm up" period. The findings in this work are applicable to other applications as well, where PAs are periodically switched on and off. ■

ACKNOWLEDGMENT

The authors would like thank the University of Bristol for the use of test equipment in these measurements.

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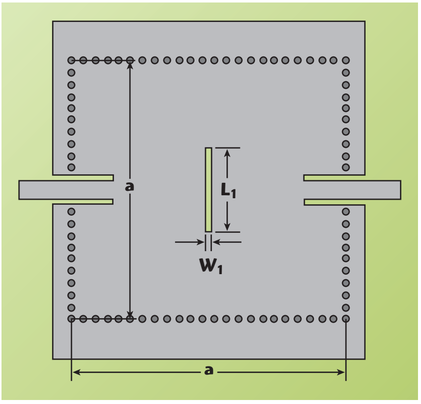
Substrate Integrated Waveguide Dual-Mode, Dual-Band Filter

Xiaowu Zhan, Zongxi Tang, Yunqiu Wu and Biao Zhang
University of Electronic Science and Technology of China, Chengdu, Sichuan, China

This article describes a dual-mode, dual-band substrate integrated waveguide (SIW) filter. The dual-mode resonator is constructed with a slot line on the top metal layer of the SIW cavity. The two-pole dual-passband Chebyshev frequency response is achieved by cascading two resonators, with the center frequency of the second passband independently controlled by the geometric parameters of the slot line. Fabricated using standard printed circuit board technology, the filter is compact, has a high degree of design freedom and is low cost. Its measured S-parameters agree closely with simulation.

To meet various wireless communication requirements, dual-band filters have been proposed as key components in dual-band microwave and millimeter-wave communication systems. Substrate integrated waveguide, which is synthesized on a planar substrate with linear periodic arrays of metallic vias or metallic slots using standard printed circuit board (PCB) or other planar circuit processes, provides an attractive platform for higher Q value, higher power handing and more highly integrated waveguide filters.[1,2]

A number of topologies based on SIW resonators have been studied and developed to realize high Q with a dual-passband response. They can usually be reduced to two general approaches. The first uses several inverter coupled resonators to realize dual-band operation.[3] The dual passbands, however, are too close to each other, and many SIW cavities result in a large circuit size. The second utilizes standard low temperature co-fired ceramic (LTCC) technology to implement multilayered quadruple-folded SIW dual-passband filters.[4,5] The bandwidths of both passbands are independently adjustable, but this method is often too costly. For circuit miniaturization, some dual-mode single passband filters have been designed in SIW technology,[6-8] however, these dual-mode cavities cannot be used to design dual passband filters.



▲ *Fig. 1 Configuration of the dual-mode square SIW cavity with one slot line.*

This article describes the design of a dual-mode SIW resonator that is perturbed by a slot line on the top metal layer of the SIW cavity to achieve a two-pole dual passband response, with the center frequency of the second passband controlled independently by the dimensions of the slot line. The filter circuit is compact in overall size in comparison with traditional single-mode SIW filters.

ANALYSIS OF THE DUAL-MODE CAVITY

The configuration of the dual-mode square SIW cavity with a pair of coplanar waveguide (CPW) I/O feed line is shown in ***Figure 1***. The cavity size is determined by the corresponding resonant frequency. The resonant frequency of the resonant modes (TE_{m0n}) can be calculated using the following equation:[9]

$$f_r = \frac{c_0}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m}{a_{eff}}\right)^2 + \left(\frac{n}{l_{eff}}\right)^2} \qquad (1)$$

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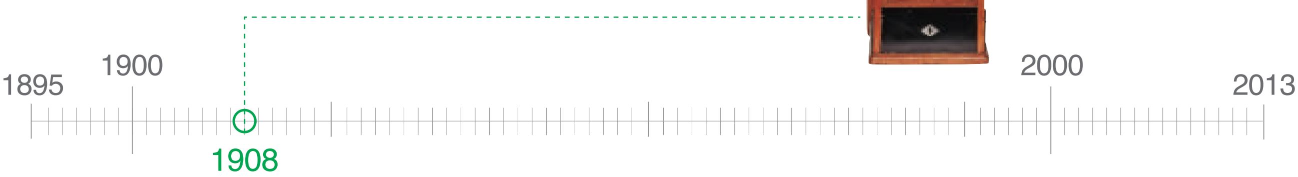

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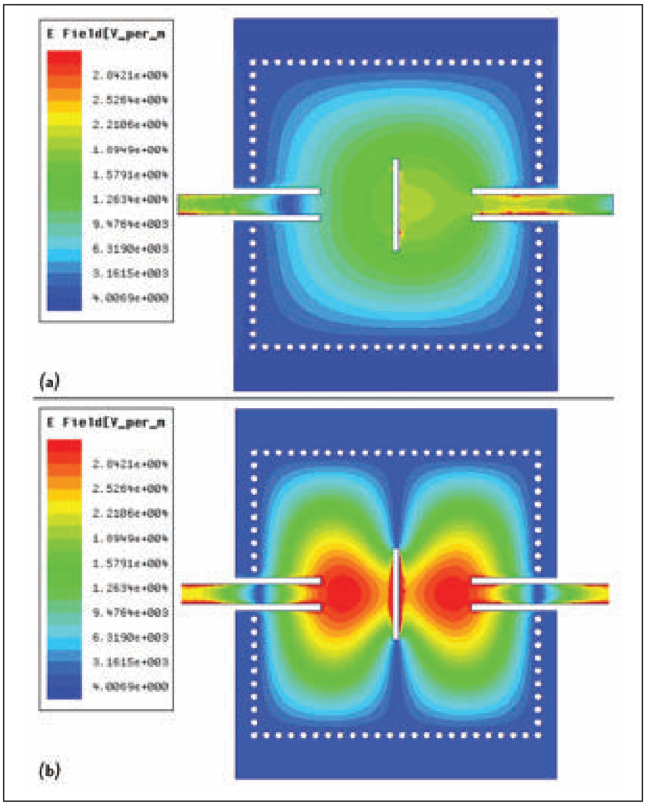
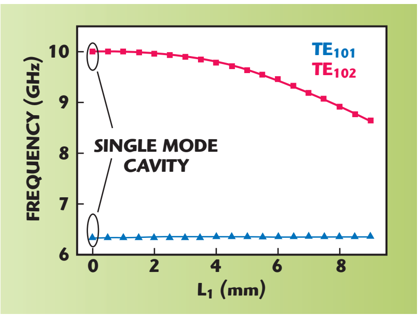


▲ *Fig. 2 Electric field distributions of the TE_{101} mode (a) and TE_{102} mode (b).*



▲ *Fig. 3 Frequencies of the TE_{101} and TE_{102} modes versus slot line length.*

where a_{eff} and l_{eff} are the effective width and length of the dual-mode SIW cavity, respectively, m and n the indices of the modes, ε_r the permittivity of the substrate material, and c_0 the velocity of light in free space.

For a square cavity, the TE_{102} and TE_{201} modes resonate at the same frequency if there is no disturbance. With the addition of a slot line, the TE_{201} is suppressed by the electromagnetic field perturbation caused by the slot, while the resonant frequency of the TE_{102} mode can be controlled by the length of the slot (L_1). The electric field distributions of the two modes (TE_{101} and TE_{102}) at L_1=7.5 mm, W_1=0.5 mm are plotted in ***Figure 2 (a)*** and ***(b)***, respectively. It is apparent that they are concentrated around the center of the SIW cavity and the slot line.

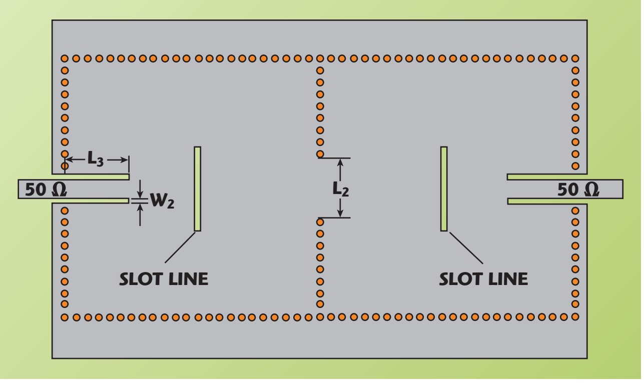
Figure 3 shows simulated results of the dual-mode SIW cavity with variation of L_1. The resonant frequency of the TE_{102} mode trends lower with the increasing length of L_1, while the resonant frequency of the TE_{101} mode remains unchanged. The highest resonant frequency of the TE_{102} mode cannot exceed the first spurious mode of the single-mode cavity (L_1=0 mm).

DUAL-PASSBAND FILTER DESIGN

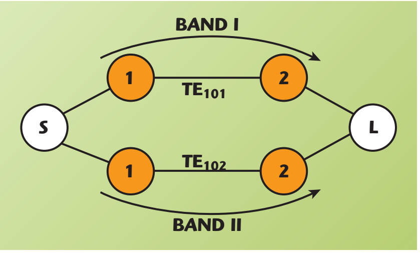
Figure 4 shows the filter's physical structure. The circuit consists of two identical dual-mode cavities. Magnetic coupling between two cavities is realized by an iris in the common post wall. The two resonators are excited by a pair of 50 Ω coplanar waveguide (CPW) I/O feed lines. The TE_{101}- and TE_{102}-modes of the dual-mode resonators are excited in order to realize the first and the second passbands. ***Figure 5*** shows the coupling topology, where "1" and "2" are the first and second cavities, respectively.

Initial lengths and widths of the cavities are determined by setting the center frequency of the first passbands to their design values using Equation 1. The dimensions of the slot line are determined based on Figure 3. To determine the internal coupling coefficients, the two SIW cavity resonators are simulated using a commercial full-wave electromagnetic simulator (HFSS). The coupling coefficient is extracted using the following relation:[10]

$$k = \frac{f_1^2 - f_2^2}{f_1^2 + f_2^2} \qquad (2)$$



▲ *Fig. 4 Two-pole dual-passband SIW filter structure.*



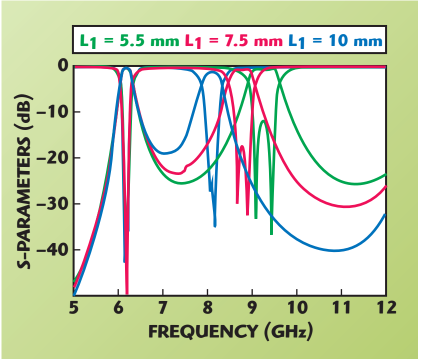
▲ *Fig. 5 Filter coupling topology.*

where f_1 and f_2 are the first and the second cavity resonant frequencies of the TE_{101}- or TE_{102}-mode, respectively, and k represents the coupling coefficient between the two SIW cavity resonators, which have been analyzed by Chen and Wu.[11]

In order to determine the external quality factor, numerical analysis with HFSS is carried out with the dual-mode SIW cavity bandpass resonator connected to two 50 Ω coplanar waveguide (CPW) I/O feed lines. Coupling is controlled by changing the dimensions of the feed lines (L_3 and W_2). The external quality factor Q_e is calculated with the equation:

$$Q_e = \frac{2f_0}{\Delta f_{3dB}} \tag{3}$$

where f_0 is the frequency at which S_{21} reaches its maximum value and Δf_{3dB} is the bandwidth for which the attenuation of S_{21} is 3 dB from its maximum value.



▲ *Fig. 6 Simulated frequency response with L_1 variation.*

The specified center frequencies of the first and second passband are 6.2 and 8.8 GHz, and the specified bandwidths of two bands are 300 and 600 MHz with return losses of 20 dB and 15 dB, respectively. Much work has been done on filter synthesis using coupling matrices.[12] The [N+2] ideal coupling matrix (M) of the first passband and second passband is derived using Equations 4 and 5. The coupling coefficients and external Q_e can be computed from M using Equation 6.

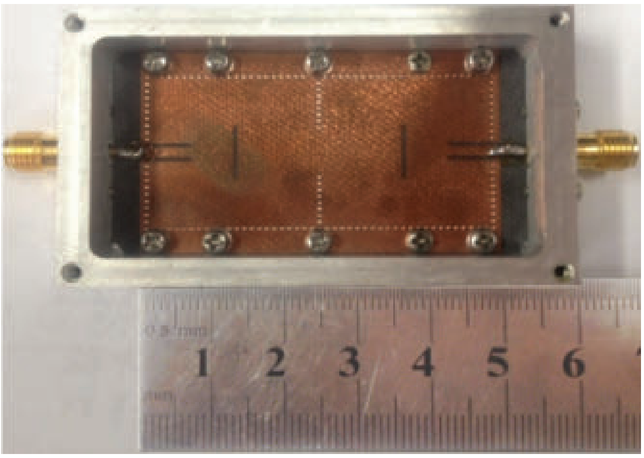
$$M_1 = M_2 = \begin{bmatrix} 0 & M_{S1} & 0 & 0 \\ M_{S1} & 0 & M_{12} & 0 \\ 0 & M_{12} & 0 & M_{2L} \\ 0 & 0 & M_{2L} & 0 \end{bmatrix} \tag{4}$$

$$M_1 = \begin{bmatrix} 0 & 1.225 & 0 & 0 \\ 1.225 & 0 & 1.658 & 0 \\ 0 & 1.658 & 0 & 1.225 \\ 0 & 0 & 1.225 & 0 \end{bmatrix},$$

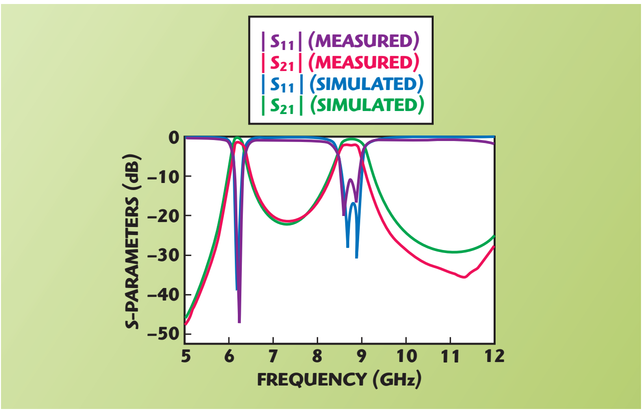
$$M_2 = \begin{bmatrix} 0 & 1.037 & 0 & 0 \\ 1.037 & 0 & 1.287 & 0 \\ 0 & 1.287 & 0 & 1.037 \\ 0 & 0 & 1.037 & 0 \end{bmatrix} \tag{5}$$

$$m_{ij} = FBW(M_{ij}),\ Q_e = \frac{1}{FBW(M_{S1}^2)} \tag{6}$$

The coupling coefficients and Q_e of two passbands are m_{12}=m_{21}=0.0802, Q_e=13.78 for the first passband, and m_{12}=m_{21}=0.8774, Q_e=13.64 for the second passband.



▲ *Fig. 7 Fabricated dual-mode dual-passband SIW filter.*



▲ *Fig. 8 Simulated and measured frequency responses.*

Based on Equations 1 through 6, the initial dimensions of the entire filter are estimated using HFSS. A fine tuning procedure is then employed for optimizing the design. ***Figure 6*** shows the full-wave simulation dual-passband responses with different slot line lengths. The center frequency of the second passband is adjusted independently by changing the length of L_1, with no apparent effect on the first passband.

SIMULATION AND MEASUREMENT

The dual-passband SIW filter with a two-pole Chebyshev response is fabricated on 0.0508 mm thick Rogers RT/Duroid 5880 using a standard PCB process. The linear arrays of metalized via-holes all have diameters of 0.6 mm with a center-to-center pitch of 1 mm. Through simulation and optimization using HFSS, other dimensions are determined to be a=23 mm, L_1=7.5 mm, L_2=6.96 mm, L_3=5.9 mm, W_1=0.5 mm and W_2=0.55 mm. ***Figure 7*** is a photograph of the fabricated dual-mode, dual-passband filter, having overall dimensions of 23 × 46 mm.

An Agilent 8757D network analyzer was used for measurements. ***Figure 8*** compares simulated and measured results. The measured minimum passband insertion losses are 1.1 and 1.6 dB, respectively. Measured 3 dB fractional bandwidths are about 4.6 and 6.3 percent, respectively, for the first and second passbands, and the return losses of the two passbands are better than 12 dB. Slight differences between simulated and measured results may be due to

fabrication tolerances and the added insertion loss of SMA connectors.

CONCLUSION

Two single-cavity, dual mode SIW resonators with slot lines on their top metal layers provide a dual-passband Chebyshev frequency response when cascaded. The center frequency of the second passband can be independently controlled by adjusting the slot line dimensions. The filter is small, has a high degree of design flexibility and is low cost. Agreement between simulated and measured results provides design verification. ■

ACKNOWLEDGMENT

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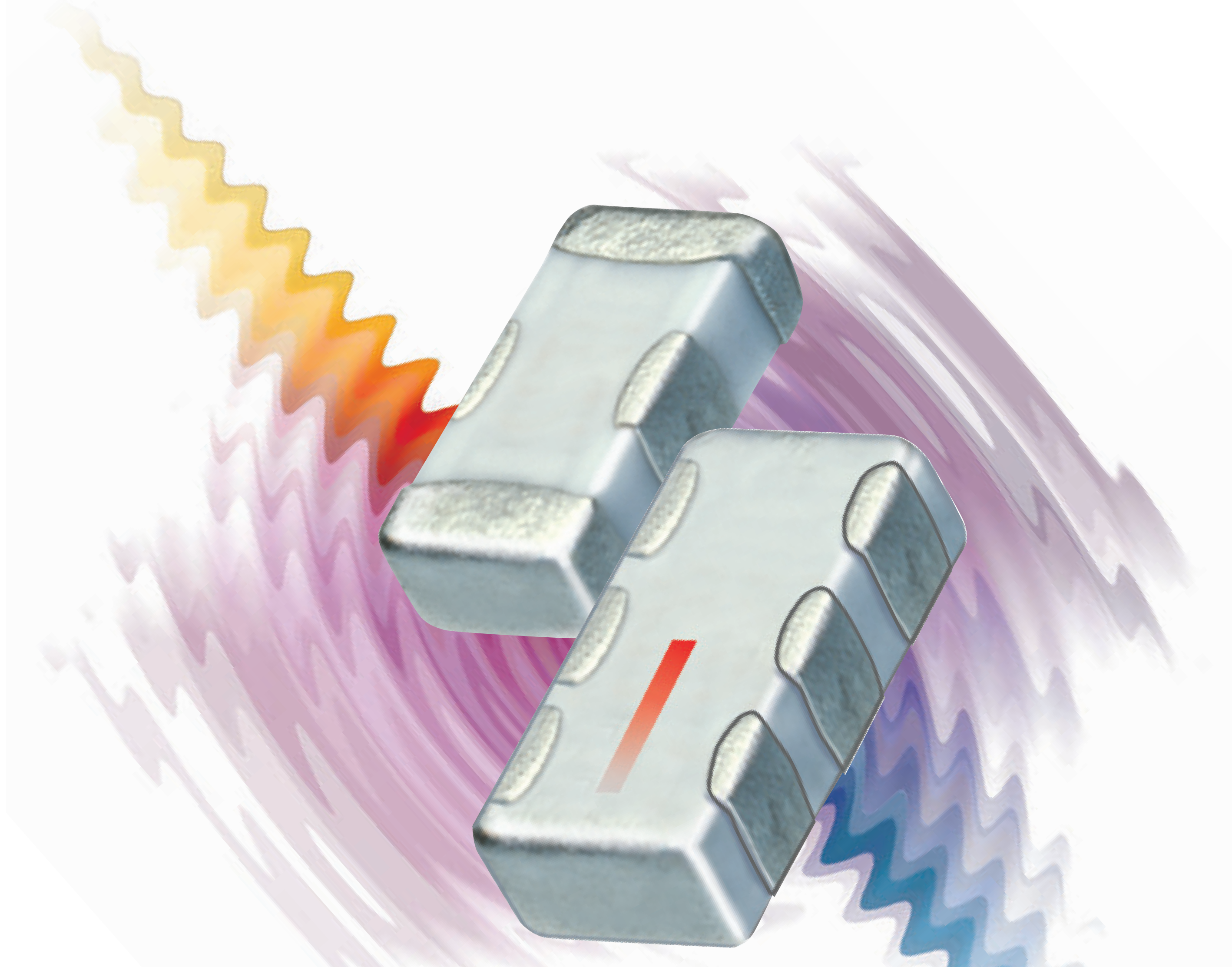

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ExecutiveInterview

An incredible amount of technology is packed into every smartphone and tablet. The list is long and getting longer: new and legacy cellular formats, multiple wireless-connectivity links, GPS capabilities, cameras, music players, Web browsers, and on and on. Putting all this power into the hands of several billion subscribers is overloading the frequency spectrum available within today's wireless infrastructure. In response, the latest cellular standards include techniques such as multiple-input/multiple-output (MIMO) and carrier aggregation (CA). The goal of these advanced techniques is to help operators squeeze more capacity and higher data rates from their existing frequency spectrum.

Looking upstream to the industry's product lifecycle, this environment also presents challenges to those who develop and manufacture the latest chipsets and user equipment (UE). Testing becomes more difficult when it comes time to characterize the performance of transmitters and receivers or check the behavior of an assembled device. Test engineers often turn to a category of instruments known colloquially as "one-box testers" and more formally as "wireless test sets." These solution-specific instruments simplify the process of checking the performance and behavior of chipsets and UEs. Similar to the devices they test, these instruments are becoming increasingly integrated: many include sources for receiver testing, analyzers for transmitter testing, standards-compliant measurements, and a host of built-in functions to support manual, sequenced and automated testing. This one-box approach has proven to be more convenient and time-efficient than the chore of patching together individual instruments and perhaps a PC. Because these testers are often easily upgradable, they are also cost-effective over the long run.

Today's increasingly complex chipsets and UEs require a new generation of instruments designed to meet present needs and provide extensibility to satisfy future requirements. Following in the footsteps of the 8960, Agilent has recently introduced two new additions to its industry-leading family of testers: the E7515A UXM wireless test set and the E6640A EXM wireless test set.

R&D: GAINING CLARITY AT CRUCIAL HANDOFFS

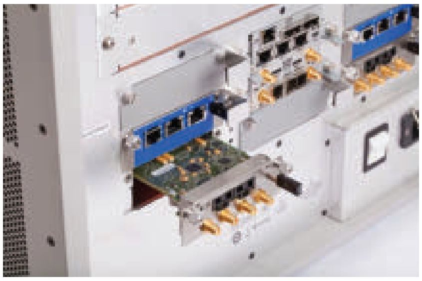
Design and validation are essential stages of the R&D process. At key handoff points, engineers make judgment calls about every design, deciding if a chipset or UE is ready to clear the crucial hurdles imposed by internal specifications, conformance tests and operator requirements. Testing covers areas such as functional behavior and RF performance. Clarity around each decision comes from accumulated in-

sights about standards, technologies, in-house design practices, and more.

DEFINING AN ARCHITECTURE FOR TODAY AND TOMORROW

The Agilent E7515A UXM wireless test set is the most highly integrated signaling test set created for functional and RF design validation in the 4G era and beyond. It provides a wealth of capabilities that enable testing of the newest designs, delivering LTE-Advanced category 6 now and handling increasingly complex requirements in the future.

The foundation of these "now and later" capabilities is an extensible architecture that can evolve as technology changes: the UXM includes upgradable processors, multiple expansion slots and high-speed interconnects (see ***Figure 1***). Through its industry-leading combination of two independent 100 MHz RF transceivers, the UXM enables multiple cells, carrier aggregation, MIMO up to 4×2 and integrated fading. The instrument also provides built-in servers for extensive functional test applications. Building on that, the UXM is a future-ready, multi-format-capable platform that will handle the next advances in antenna techniques, component carriers and data rates.



▲ *Fig. 1 Users can evolve as technology changes with Agilent UXM's extensible architecture.*

The net effect: the UXM enables test engineers to ensure that LTE/LTE-A devices can sustain maximum category 4/6 rates and handle realistic fading and MIMO scenarios. As a result, engineers can wring out every design with integrated fading, flexible receiver testing and trusted transmitter measurements—and the UXM is poised to handle more complex test applications in the future.

With its wealth of integrated capabilities, the UXM lets engineers dive more deeply into functional testing by emulating a wide range of complex operations. For example, with two independent cells built in, the UXM makes it possible to check LTE handover behavior with just one instrument. Connecting a UXM to an Agilent 8960 wireless test set supports verification of the increasing number of inter-radio access technology (IRAT) handover scenarios. The inclusion of Wireshark-based logging software enables thorough analysis of protocol messaging.

The UXM also ensures greater confidence in RF performance with flexible automated testing and industry-proven Agilent X-Series measurement science (see ***Figure 2***). One key area of testing is the full range of 3GPP channel configurations. The UXM provides integrated capabilities and flexible automation software with Agilent's Wireless Test Manager (WTM), making it easy to efficiently step through the full range of 3GPP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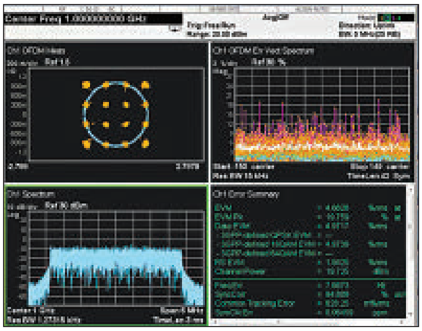
channel configurations for a device-under-test.

To support the development process from early designs to finished products, the UXM supports signaling and non-signaling (i.e., test mode) operation. This lets engineers focus on characterization of RF performance: the UXM pushes aside the protocol barriers and enables the engineer to "just connect" to the device under test.

MANUFACTURING: SOLVING TODAY, EVOLVING TOMORROW

In the wireless industry, successful manufacturing organizations need tools that help them meet ever-tougher goals and tighter schedules. In addition, access to the best resources will help them deal with the technical, business and operational risks that, when managed carefully, ensure success. When these factors are under control, the organization is able to achieve several key goals: ramping up quickly; achieving and optimizing volume production; minimizing the total cost of test; meeting budget; and reducing wastage.



▲ *Fig. 2 Agilent X-Series measurement applications can be used with the UXM wireless test set.*

The measurement challenges generated by today's multi-format, multi-band devices are difficult—and the key to success is finding test methods that are more efficient and more effective. Within this context, the Agilent E6640A EXM wireless test set builds on the non-signaling and sequencing capabilities of Agilent's previous test sets. In addition, the EXM provides a new architecture that expands parallel testing and provides scalability to match changing production needs. To support the fastest testing of the newest chipsets, the EXM is in sync with the latest cellular and WLAN chipsets. It delivers the speed, accuracy and port density needed to ramp up rapidly and optimize full-volume manufacturing of a broad range of multi-format devices, including those that use LTE-Advanced carrier aggregation, 802.11ac WLAN MIMO, and more.

In the new product introduction (NPI) stage, the EXM provides certainty through chipset compatibility and validated test capabilities that directly control chipset functionality. This includes the fastest, most reliable calibration and verification functions offered in each vendor's chipset. The EXM's broad multi-format, multi-port flexibility handles today's complex chipsets while allowing easy upgradability for tomorrow's features. For greater scalability, the EXM can be configured with up to four independent transmit/receive (TRX) channels, each of which is a complete vector signal generator, vector signal analyzer and RF I/O section. To further extend port density, the EXM can be

customized to connect up to 32 DUTs through multi-port adapter (MPA) technology.

The EXM enables manufacturers to easily keep pace with production capability and capacity needs. In addition to its multi-port and multi-format capabilities, the EXM helps maximize throughput and yield with fast and accurate parallel testing of multiple devices. This comes from the ultra-fast data processing and transfers, advanced sequencing and single-acquisition/multi-measurement (SAMM) capability built into the EXM. The flexibility of the EXM preserves initial equipment investments by making it easy to evolve with changing production needs. Each unit can be expanded with up to four TRX modules, and these can be upgraded with higher frequency coverage and wider analysis bandwidth.

For maximum reliability and uptime, the EXM has been tested to survive the rigors of the factory floor. When calibration or repair service is needed, Agilent's global presence ensures fast turnaround times. The EXM is designed, built and supported to ensure success in manufacturing.

The drive for faster data speeds and compelling new services seems likely to continue without end. So does the trend toward ever-denser integration of new capabilities into user devices. To help developers and manufacturers keep pace, Agilent has created two highly integrated wireless test sets—the UXM and EXM—that offer the flexibility and extensibility enabled by modern, modular architectures. Both platforms provide the future-readiness needed to meet present and future requirements, and both offer the investment protection that comes from a platform that is easily reusable and upgradable.

New-generation test hardware offers tremendous benefits, but there's more to the story. Agilent also offers access to a broader set of resources—application engineers, manufacturing test integration teams, worldwide support, and more—that can help developers and manufacturers handle the unknown, stay on track and meet their goals for the newest chipsets and UE.

VENDORVIEW

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Vector Network Analysis with Up to 48 Ports

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The sales volume of smartphones and tablets with wireless Internet connections has already exceeded that of traditional mobile phones and desktop PCs. Multiband front end modules as well as components for GPS, WLAN and Bluetooth applications are an essential part of these new devices. In a mobile phone, the number of signal paths increases with the number of integrated components and technologies. This also increases the number of test ports at which a front end module must be measured in order to ensure the stringent requirements are met, e.g., with respect to insertion loss or selection during production. This makes vector network analysis with more than 20 ports, or even 30 ports in the future, a must.

▲ *Fig. 1 A test solution with 48 ports consisting of one R&S ZNB8 and two R&S ZN-Z84 switch matrices.*

Traditional vector network analyzers (VNA) with four ports still require a significant measurement effort because the user needs to consider which measurement ports on the device under test (DUT) must be measured simultaneously. All unconnected ports on the DUT should be terminated to prevent unwanted signals from influencing measurement results. In addition, the user must screw the DUT on and off again multiple times to measure all DUT ports. This not only increases the test

effort, but also significantly increases measurement times. Increasing the number of test ports on the VNA to match the DUT is the solution to this problem.

NETWORK ANALYSIS WITH MULTIPLE PORTS

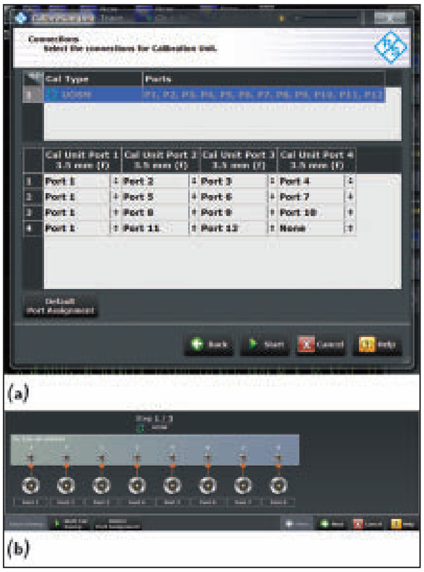
The simplest solution is to use external switches to increase the number of ports on the VNA. It is not enough to merely connect a switch module. The hardware must meet the measurement requirements, and the switching must be synchronized with the measurement sequences of the VNA. This requires a complex control program. Calibration of a setup using external switches is also significantly more complex than for measurements with a two-port or four-port VNA. To measure all S-parameters of the DUT, the external switch module must be full crossbar, allowing unrestricted measurements between all ports.

This setup is complex and expensive but there are practical commercial solutions: Rohde & Schwarz now offers the R&S ZN-Z84, an external switch matrix designed to complement the R&S ZNB network analyzer. The base model is equipped with six test ports. When needed, the number of test ports can be increased in groups of six to provide a total of 24 ports. A four-port R&S ZNB with two 24-port matrices can therefore support 48 test ports as shown in ***Figure 1***. This makes it possible to measure all 48 × 48 S-parameters of the DUT.

UNCOMPLICATED MATRIX SOLUTION

A big advantage of this solution is that it is a plug and play system. All functions required for controlling and

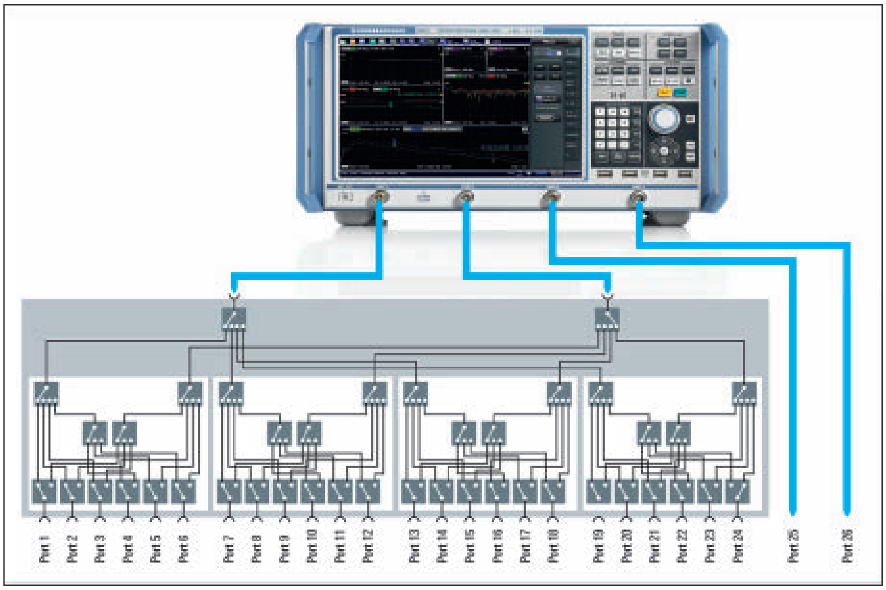
▲ *Fig. 2 The connected switch matrix is shown in the VNA firmware menu. This example shows a 4 ×18 switch matrix.*



▲ *Fig. 3 Overview of the calibration of twelve ports using a four-port calibration unit (a) and the first calibration step using an eight-port calibration unit (b) four calibration steps are necessary.*

using the R&S ZN-Z84 are already integrated in the R&S ZNB firmware (see ***Figure 2***). The switch matrix can be connected to the VNA via USB, LAN or the special Direct Control digital interface, and is automatically detected by the VNA. The matrix ports can be used just as with a standard two-port or four-port VNA.

Calibration is very easy using automatic multiport calibration units. The R&S ZNB firmware detects the calibration units as soon as they are connected via USB. The calibration menu displays which ports on the calibration unit must be connected to which ports on the switch matrix. A higher number of ports on a calibration unit results in fewer required calibration steps. This saves time and reduces errors. Currently, calibration units with up to eight ports are available. ***Figure 3*** offers an overview of the calibration of twelve ports using a four-port calibration unit.

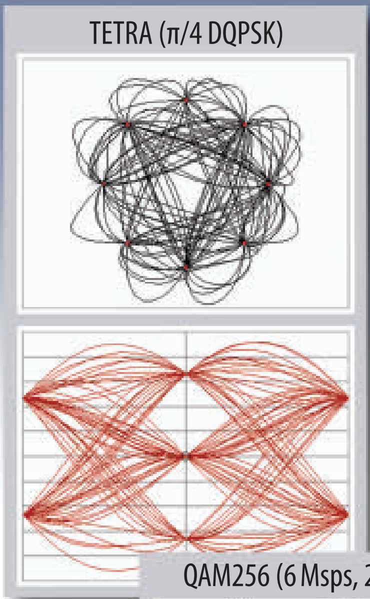


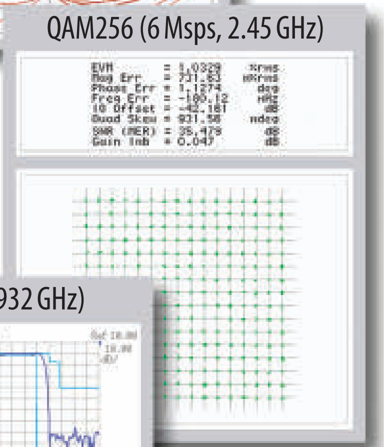
▲ *Fig. 4 A 2 × 24-port matrix connected to a four-port VNA (26 test ports are available to the user).*

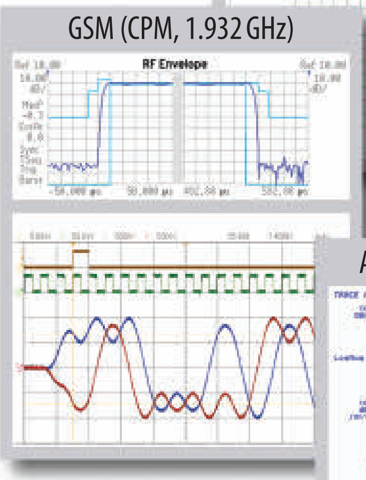
RF CHARACTERISTICS AND HIGH FLEXIBILITY

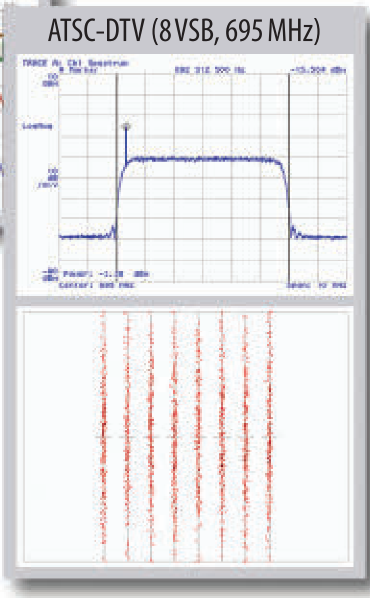
The Rohde & Schwarz solution offers flexibility without compromising the measurement characteristics. The R&S ZN-Z84 switch matrices have a modular design and are available with two or four input ports and with six, twelve, 18 or 24 test ports. This means they can be used with a two-port or four-port R&S ZNB, and up to two switch matrices can be connected to a four-port model. As a result, users can find the ideal combination for their current application.

Vector Signals at the touch of a button









- 2 GHz, 4 GHz & 6 GHz models
- Dual baseband arb generators
- Vector & analog modulation
- I/Q modulation inputs (300 MHz RF BW)
- ASK, FSK, MSK, PSK, QAM, VSB & custom I/Q
- Presets for GSM, EDGE, W-CDMA, APCO-25, DECT, NADC, PDC, ATSC-DTV & TETRA
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The SG390 Series ***Vector Signal Generators*** — taking communications testing to a new level.

The SG390 series has outstanding features and performance: complete vector and analog modulation, dual baseband arb generators, I/Q inputs with 300 MHz RF bandwidth, low phase noise, and an OCXO timebase are all included.

We've also made communications testing quick and easy — everything is available from the front panel of your instrument. Pulse shaping filters, TDMA gating signals, additive white noise, and event markers are all there. Use the built-in pattern or PRBS generators to create data, or upload your own symbol data. Map your symbols to any constellation and transmit at rates up to 6 Msps — it's that simple.

Pricing (U.S. list)

SG392 (2 GHz) ... $5,400
SG394 (4 GHz) ... $6,600
SG396 (6 GHz) ... $8,400

SRS Stanford Research Systems
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When using multiport solutions, simple operation is just as important as good RF characteristics. Besides good test port matching, a low insertion loss of the used switches is particularly critical because it affects the available output power, the sensitivity and the trace noise. A low insertion loss improves long-term and temperature stability and allows longer calibration intervals.

The insertion loss of the R&S ZN-Z84 is between 3 and 5 dB at 2 GHz, depending on the matrix topology. The high 0.1 dB compression point of 20 dBm at 2 GHz for the electronic switches makes it possible to measure active components.

If the level stability and dynamic range are not sufficient when using the matrix, it is possible to combine a 2xN R&S ZN-Z84 switch matrix with a four-port R&S ZNB. This makes two additional test ports available for measuring active components with up to 27 dBm output power or filters with up to 140 dB dynamic range. The flexibility of the solution is shown in ***Figure 4***.

There is an increasing need in production and development for solutions that make it possible to measure multiport components with more than four ports using a network analyzer. The R&S ZNB in combination with the R&S ZN-Z84 switch matrix is the ideal test solution. The matrices increase the number of test ports to 48 ports and permit full-crossbar measurements.

Thanks to the firmware, measurements are as easy to configure as with a conventional two-port or four-port VNA. The system is easily calibrated using a multiport calibration unit with up to eight ports. The system's good RF characteristics, such as a high compression point and low insertion loss, permit measurements using high power levels and a wide dynamic range.

VENDORVIEW

Rohde & Schwarz,
Munich, Germany
+49 89 4129 12345,
www.rohde-schwarz.com.

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Our easy-to-install, easy-to-use GUI will have you up and running in minutes for step-by-step control, full automation, or remote operation. They're fully compatible with most third-party lab software,† adding capabilities and efficiency to existing setups with ease! Visit minicircuits.com today for technical specifications, performance data, quantity pricing, and real time availability – or call us to discuss your custom programming needs – and think how much time and money you can save!

USB Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
NEW USB-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	795.00
USB-1SPDT-A18	1	0.25	1.2	85	10	385.00
USB-2SPDT-A18	2	0.25	1.2	85	10	685.00
USB-3SPDT-A18	3	0.25	1.2	85	10	980.00
USB-4SPDT-A18	4	0.25	1.2	85	10	1180.00
USB-8SPDT-A18	8	0.25	1.2	85	10	2495.00

NEW USB and Ethernet Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
RC-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	895.00
RC-1SPDT-A18	1	0.25	1.2	85	10	485.00
RC-2SPDT-A18	2	0.25	1.2	85	10	785.00
RC-3SPDT-A18	3	0.25	1.2	85	10	1080.00
RC-4SPDT-A18	4	0.25	1.2	85	10	1280.00
RC-8SPDT-A18	8	0.25	1.2	85	10	2595.00

*The mechanical switches within each model are offered with an optional 10 year extended warranty. Agreement required. See data sheets on our website for terms and conditions. Switches protected by US patents 5,272,458; 6,650,210; 6,414,577; 7,633,361; 7,843,289; and additional patents pending.

†See data sheet for a full list of compatible software.

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Antenna Magus Version 5: Synthesis to Meet Specification

Magus (Pty) Ltd.
Stellenbosch, South Africa

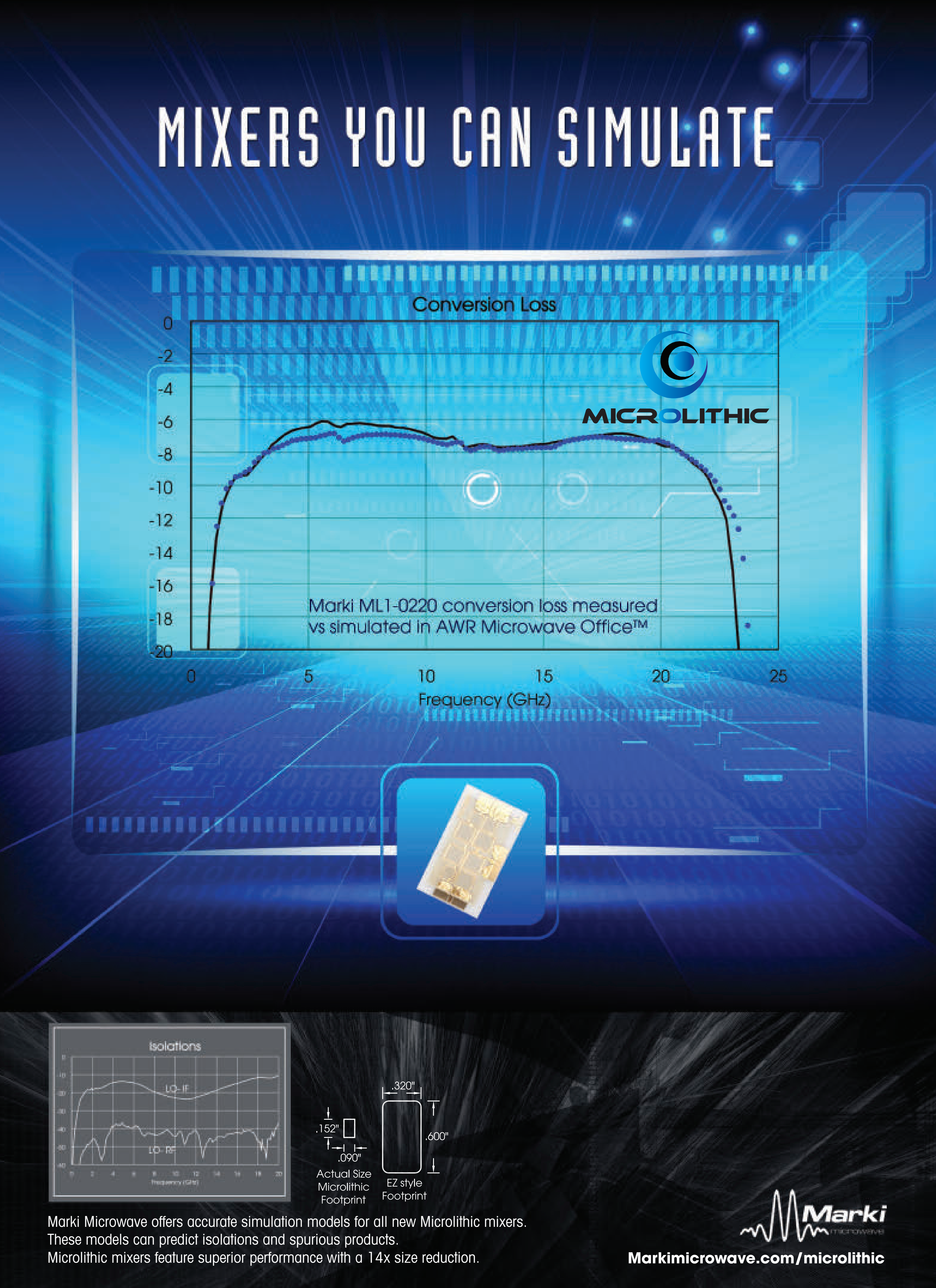
From satellites to motor vehicles; from mobile telephones to radio-telescopes – a vast array of different antenna types are used in almost every modern industry and application. Engineers and system designers are regularly faced with the task of improving and adjusting these antennas or identifying, designing and evaluating new antenna options to meet changing system requirements. Antenna Magus – a commercial antenna design tool, targeted at helping engineers complete antenna design, evaluation and integration projects quickly and reliably – addresses these issues.

ANTENNA DATABASE

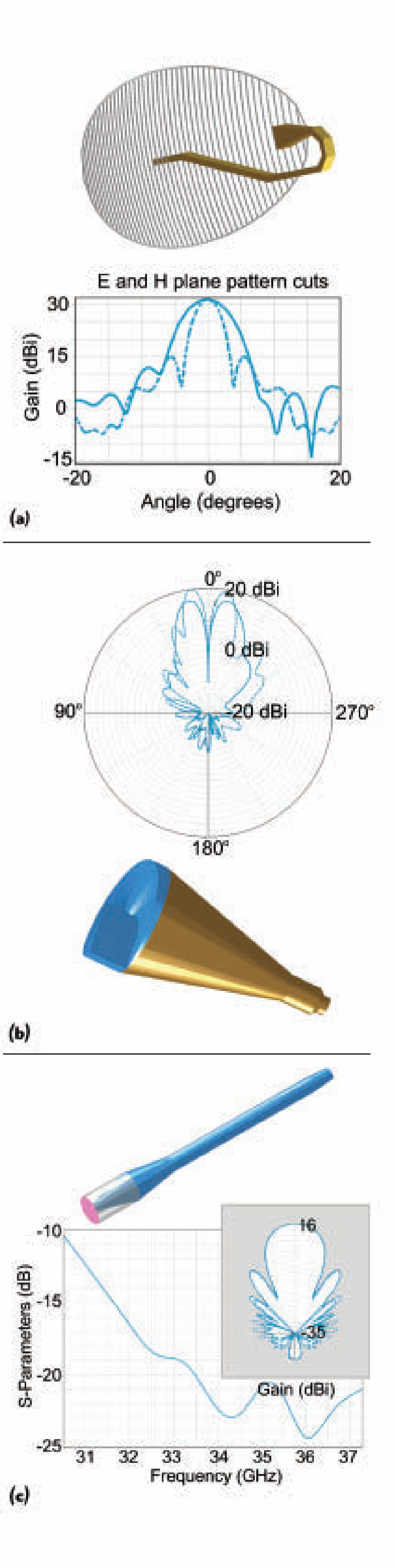
Antenna Magus provides a large searchable database that is regularly expanded and updated. The database currently stands at more than 225 antenna types in the latest version. Each antenna incorporates accurate concise information compiled by an experienced antenna engineer in an easily searchable, standardized format.

Clear diagrams of the physical antenna structure as well as guidelines for antenna customization and references to literature are included. Antennas can be sorted and filtered based on standardized search terms, helping identify candidates according to required performance criteria before embarking on a design.

The best approach for designing an antenna is often ambiguous. Published literature may be unclear or contradictory and therefore provide insufficient information for confident design choices to be made. Antenna Magus incorporates a flexible expert design system that has been thoroughly tested for a wide range of design criteria. This allows engineers to get initial designs suitable for a broad range of applica-


MIXERS YOU CAN SIMULATE
Conversion Loss
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
MICROLITHIC
Marki ML1-0220 conversion loss measured
vs simulated in AWR Microwave Office™
0
5
10
15
20
25
Frequency (GHz)
Isolations
LO-IF
LO-RF
.152"
.090"
Actual Size
Microlithic
Footprint
.320"
.600"
EZ style
Footprint
Marki Microwave offers accurate simulation models for all new Microlithic mixers.
These models can predict isolations and spurious products.
Microlithic mixers feature superior performance with a 14x size reduction.
Marki
microwave
Markimicrowave.com/microlithic

ProductFeature



▲ *Fig. 1 An example of new antenna types from Antenna Magus Version 5.0: A truncated parabolic grid reflector with a 'gooseneck' feed (a), Potter-horn with a spiral dielectric phase-plate or lens used to realize a bore-sight null (b) and a tapered dielectric rod antenna (c).*

tions, including telecommunications, mobile devices, aerospace, satellite, automotive, radio astronomy and defense, in a matter of seconds.

Also, an estimate of the performance of each design can be considered before continuing with prototyping or more detailed 3D modeling. In estimating the performance, assumptions are made and approximations are used where possible to dramatically reduce analysis time while still maintaining reasonable accuracy.

The dimensions calculated by the Antenna Magus Design algorithms may be adjusted within a bounded range after design. The resultant structure can be re-analysed. This approach allows efficient comparison of designs as well as investigation of how localized changes to specific parameters affect performance.

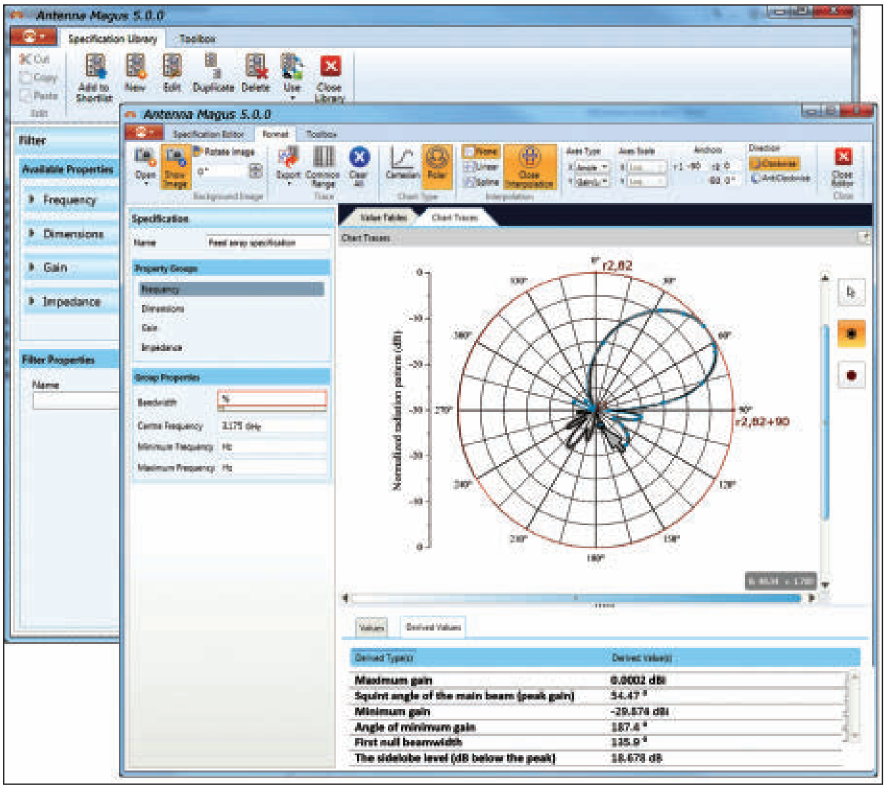
AUTOMATIC CAD MODEL EXPORT

Modern computational electromagnetic (CEM) analysis tools play an integral role in the design process. Antenna Magus does not aim to replace these tools, but rather complements them in the overall design and analysis process. Once an initial design that warrants further investigation has been completed in Antenna Magus, a parametric and 'ready-to-run' model of the as-designed antenna can be exported in formats that can be opened seamlessly in leading CEM tools.

The generated model provides a reliable starting point for the investigation of structural modifications (adding holes in substrates or including feed-matching structures) and environmental effects (such as EMC coupling or placement studies) required to arrive at a final design. Each model leverages the best methods and parametric modeling approaches available in the analysis tool and is validated against reference data or measurements.

NEW FEATURES

Besides the addition of new antenna types to the database, Antenna Magus has introduced many new capabilities. These include tools that allow users to add their own antenna topologies with related information to the database, a powerful array synthesis tool and libraries of commercially available waveguides and substrates.



▲ *Fig. 2 The chart-tracing tool inside the Specification Library showing the automatic extraction of radiation performance values from a scanned image. The extracted values can be used to define a design specification.*

In the second quarter of 2014, the release of Antenna Magus Version 5 will see further functionality as well as new antenna types (such as those illustrated in ***Figure 1***) added to the database. One focus of the new features is to ensure that Antenna Magus caters to a wider range of design requirements by introducing tools to help the designer use the information that he or she has. Intelligent design choices for required input values that are not known by the designer will be made automatically. Information (such as sketches, estimated performance plots and parameter values) can also be exported to the clipboard or a file, making material generated during the design process more accessible.

SPECIFICATION LIBRARY

In the new Specification Library, detailed specifications for many industries and applications will be included. These may be used to quickly find antennas that are candidates for that application and to populate the design inputs for any antenna – accelerating the design process. Users may add specifications describing the requirements of their own applications to the Specification Library and use them in the same way.

The Specification Library includes advanced tools to help capture information regarding the specification requirements. One such tool is the chart-tracing tool which allows digitization of data and automatic extraction of fundamental quantities (such as sidelobe-level or 10 dB bandwidth) as shown in ***Figure 2***.

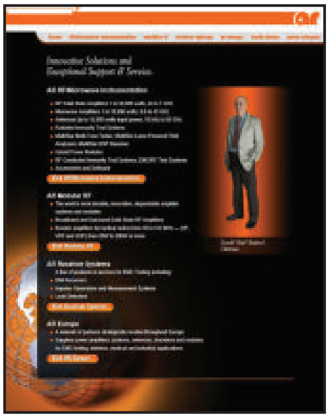
Also, an automatic update mechanism, making it easier to keep up to date with the latest antennas and designs, will be released in Version 5. This mechanism will allow the user to check for new updates on the Antenna Magus website. Available updates can be downloaded and installed automatically from inside the Antenna Magus interface.

Antenna Magus is an extensive and flexible antenna synthesis package, with a continuously expanding set of easy-to-use, powerful, flexible tools focusing on the needs of engineers involved with the design and modeling of antennas.

Magus (Pty) Ltd.,
Stellenbosch, South Africa
+27 21 880 0565,
www.antennamagus.com.

New Website

VENDORVIEW

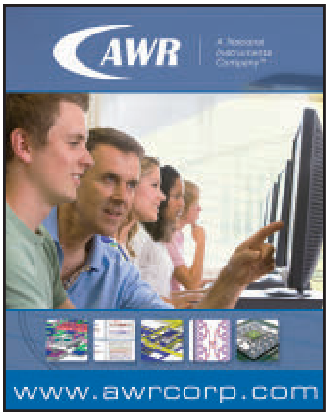


AR RF/Microwave Instrumentation has made numerous changes to enhance both its corporate and RF/Microwave Instrumentation website by giving them a more modern look and feel, while offering easier navigation and more comprehensive information. The menu system and flash spotlights have been redesigned to work with various touch screen tablets and mobile devices and enhanced streamlining of code makes the menus much more search engine friendly and easier to read. Please check out the newly redesigned AR RF/Microwave Instrumentation website at www.arww-rfmicro.com/html/00000.asp or the corporate website at the link below.

AR RF/Microwave Instrumentation,
www.arworld.us

University Portal

VENDORVIEW



AWR Corp., a National Instruments Company, added a new university portal directly on its main navigation menu. The university portal provides focused, in-depth content to the company's rapidly-growing academic user base. Clearly and concisely organized with dedicated areas for students, faculty and graduates, the new portal is easy to navigate and readily delivers information that the academic community needs.

AWR Corp.,
www.awrcorp.com/university

Updated Site

VENDORVIEW

Crane Aerospace & Electronics Microwave Solutions has updated its website. More information has been included in the Product Finder and Part Number Index. Visit the site for more info.

Crane Aerospace & Electronics,
www.craneae.com/mw

Case Notes

VENDORVIEW

CST's electromagnetic simulation software is used for applications such as antennas, filters, EMC analysis, cable harnesses and PCBs, to name a few. On the CST's success story web page, companies from various industries describe the improvements to their product development process after using CST STUDIO SUITE®. The success stories detail various design challenges and showcase the techniques implemented to obtain improved results. All articles can be downloaded for free at the link below.

CST-Computer Simulation Technology AG,
https://www.cst.com/case-notes

PA Website

VENDORVIEW

Empower RF Systems' website provides a comprehensive look at the company's products and capabilities. Homepage content is organized by target markets and additional search capabilities enable the user to find recommended power amplifier products for specific frequency coverage (up to 6 GHz) and output power levels from tens of watts up to multi-kW. Convenient tabs and additional features also direct the user to media presence, upcoming tradeshows, inventory program with Richardson RFPD, product introductions and a unique virtual demo.

Empower RF Systems,
www.empowerrf.com

Data Center Microsite

The LiSA data center microsite contains everything you need to know about the LiSA brand and its portfolio. Discover more about the wide range of products and services HUBER+SUHNER offers in just a few clicks. You will also find up-to-date regional contact and technical information, news and in-depth documentation of extraordinary data center solutions. This web platform ensures that visitors are always kept up-to-date with an evolving portfolio with ease and simplicity.

HUBER+SUHNER,
www.lisasolutions.com

Phase Adjusters

Part Number	Connectors	Frequency Range (GHz)	VSWR max.	Insertion Loss max. (dB)	Phase Shift min. (°)	No. of Turns	Phase Shift Deg/GHz/Turn	Time Delay min. (psec.)	Time Delay max. (psec.)	Temperature (°C)	Weight max. (g)
LS-0002-YYYY[1]	div.	DC - 2	1.2:1	0.3	85	37	1.15	393	516	-65 to +125	98-220[2]
LS-0103-6161	Nf	DC - 3	1.15:1	0.4	540	cont.		1826	2328		700
LS-0203-6161				0.9	1080			3693	4694		1200
LS-0012-YYYY[1]	div.	DC - 12	1.3:1	0.8	520	37		406	530		114-234[2]
LS-0112-XXXX[3]	SMA	DC-12.0	1.25:1	0.4	230	16.5	1.2	238	293	-65 to +125	70
LS-A112-XXXX[3]											47
LS-0212-1121											70
LS-A212-1121											47
LS-0118-XXXX[3]		DC-18.0		0.6	350						70
LS-A118-XXXX[3]											47
LS-0218-1121											70
LS-A218-1121											47
LS-0118-5161	N							300	355	-65/+70	105
LS-U118-5161										-65/+165	
LS-0018-YYYY[1]	div.	DC - 18	1.5:1	1.0	770	37	1.15	406	530	-65 to +125	98-220[2]
LS-0121-XXXX[3]	SMA	DC-26.0	1.30:1	0.8	500	16.5	1.2	238	293		70
LS-A121-XXXX[3]											47
LS-0221-1121											70
LS-A221-1121											47
LS-0321-1121			1.31:1		500	35	0.6	236.7	290.5		30
LS-0170-1121			1.26:1	0.26	127	13.5	0.36	109.2	122.8		9
LS-S008-1121			1.50:1	0.4	155	10	0.6	118.6	135.1		20
LS-P140-KFKM	2.92 mm	DC-40.0	1.2:1	0.6	590	12	1.2	168	208	-65 to +65	51
LS-0140-KFKM			1.4:1								49
LS-P150-HFHM	2.40 mm	DC-50.0	1.3:1	0.8	400	7		172	195		55
LS-0150-HFHM			1.5:1								53
LS-P165-VFVM	1.85 mm	DC-63.0	1.4:1	0.8	600	8		167	195		55
LS-0165-VFVM			1.5:1								53

[1] div.: Connector Configuration available: SMA, male and female; N, male and female; TNC male and female
[2] Weight depends on connector configuration
[3] SMA Connector Configuration available: male/female; male/male; female/female; female/male

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PhaseShiftersTable

WebUpdate

Filters Website

KR Electronics invites visitors to explore its new website. The new site is designed with improved navigation and functionality. Customers can access data sheets for nearly one thousand previously designed filters or request a custom filter online. Visit the new site and provide your feedback using the customer feedback form.

KR Electronics Inc.,
www.krfilters.com

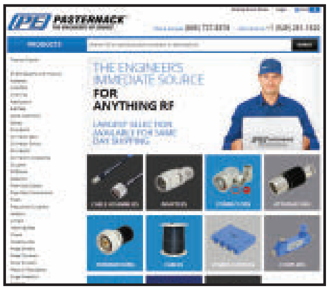
Microwave Components Site

VENDORVIEW

Mercury Systems launched a new website for companies pursuing innovative, affordable technology and a range of products that meet virtually any RF or microwave component need. The new site highlights Mercury's most sought after products and expanded capabilities in the RF and microwave market, essential for next-generation sophisticated AESA radar, EW, electronic countermeasures and satellite communications subsystem solutions. The site is one more way Mercury ensures that commercial and defense customers can find the capabilities and systems they need for their advanced solutions.

Mercury Systems Inc.,
rf.mrcy.com

Redesigned Website



Pasternack launched its new website which boasts best-in-class site search functionality, one-page checkout and an updated user-friendly interface. The new site is the first major redesign since the company's 2012 website overhaul. Most noticeable to the user is the simplified, stripped down look and feel of the new homepage. Pasternack's main objective was to provide engineers and buyers the easiest, most intuitive process for searching and finding any of the company's +40,000 RF components and cable assemblies with as few clicks as possible.

Pasternack,
www.pasternack.com

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POWER DIVIDERS

RoHS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ.)	Input Power (Watts) [Max.] +	Package
2-WAY								
CSBK260S	20 - 600	0.28 / 0.4	0.05 / 0.4	0.8 / 3.0	25 / 20	1.15:1	50	377
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1 / 2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1 / 4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	2	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1 / 3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	2	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	20	330
3-WAY								
S3D1723	1700 - 2300	0.2 / 0.35	0.3 / 0.6	2 / 3	22 / 16	1.3:1	5	316
4-WAY								
CSDK3100S	30 - 1000	0.7 / 1.1	0.05 / 0.2	0.3 / 2.0	28 / 20	1.15:1	5	169S

+ With matched operating conditions

HYBRIDS

RoHS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ.)	Input Power (Watts) [Max.]	Package
90°								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1 / 3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6 / 0.9	1 / 3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4 / 6	23 / 18	1.40:1	5	102SLF
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1 / 3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2 / 0.3	0.2 / 0.4	2 / 3	22 / 18	1.20:1	50	226
180° (4-PORTS)								
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5 / 4	23 / 18	1.25:1	5	301LF-1

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS

RoHS

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] +	Package
KFK-10-1200	10 - 1200	40 ±1.0	±1.5	0.4 / 0.5	22 / 14	150	376
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322
KEK-1317	13000 - 17000	30 ±1.0	±0.5	0.4 / 0.6	30 / 15	30	387

* Add suffix - LF to the part number for RoHS compliant version.
+ With matched operating conditions

Unless noted, products are RoHS compliant.

SYNERGY® MICROWAVE CORPORATION

Phone: (973) 881-8800 | Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Web: WWW.SYNERGYMWAVE.COM
Mail: 201 McLean Boulevard, Paterson, NJ 07504

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FEATURING VENDORVIEW STOREFRONTS

Base Station Tester

Aeroflex Ltd. launched an extended version of its TM500 industry-standard base station tester capable of emulating several thousand LTE user equipments, fading channel models and LTE-A CA functionality in a benchtop unit. The TM500 Test Mobile delivers more leading edge LTE-A development capability with a higher UE density than any other solution on the market. LTE-A CA was first supported on the TM500 in early 2012, and has since been used by operators worldwide to demonstrate the real-world performance of CA technology in field environments.

Aeroflex Ltd.,
www.aeroflex.com.

PCB Analyzer

Agilent Technologies Inc. introduced the E5063A PCB analyzer for printed circuit board impedance test in manufacturing. The solution offers technology breakthroughs in accuracy, repeatability and reproducibility. The analyzer also provides a dedicated user interface with broader language support, and more robustness against electrostatic discharge for PCB manufacturing environments. Tighter impedance tolerance is a direct result of increasing data rates; more accurate impedance test solutions for PCB manufacturing is now required to achieve signal integrity.

Agilent Technologies Inc.,
www.agilent.com.

Cable and Antenna Analyzer

Anritsu introduced the Microwave Site Master S820E, the world's first handheld cable and antenna analyzer with frequency coverage up to 40 GHz. In addition to providing the widest frequency coverage of 1 MHz to 40 GHz, the Site Master S820E offers field technicians, engineers and wireless network installers industry-leading dynamic range, directivity, and durability so they can conduct highly accurate measurements during the installation, maintenance, and troubleshooting of microwave communications systems. Additionally, Anritsu announced the Site Master S820E will feature VNA measurement functionality.

Anritsu Co.,
www.anritsu.com.

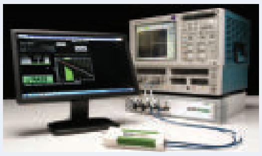
SDR Platforms

Ettus Research, a National Instruments company, introduced the USRP X300 and USRP X310 high-performance, modular software defined radio (SDR) platforms. Both platforms combine two RF transceivers covering DC to 6 GHz with up to 120 MHz bandwidth and a large user-programmable Kintex-7 FPGA. The USRP X300 and USRP X310 both feature multiple high-speed interface options, including PCI Express, dual 10 Gigabit Ethernet and dual 1 Gigabit Ethernet and is available in a convenient desktop or rack-mountable half-wide 1U form factor.

Ettus Research,
www.ettus.com.

Loss Testing Platform

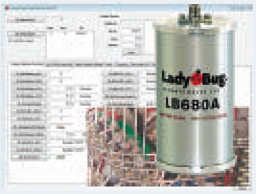
Introbotix announced ACCU-Prober with TVNA™, a new configuration of the popular high frequency loss testing platform. TVNA is



an Introbotix developed test method that utilizes high frequency TDR measurements to produce insertion and return loss data. In studies, data produced with TVNA showed an excellent correlation with measurements taken by a traditional network analyzer. TVNA is also probe independent and can be used with any comparable probe solution, such as microwave probes or launch connectors.

INTROBOTIX,
www.introbotix.com.

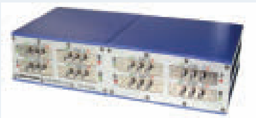
Test Harness



LadyBug Technologies' latest enhanced test harness helps programmatic users, such as ATE builders, to interrogate and control any of LadyBug's broad line of sensors. The full featured RF power sensor control system includes source code in C++ and C# and is available at no cost from the downloads section of LadyBug's website. The included source code helps to shorten system development time for custom test systems, built-in applications and other purposes.

LadyBug Technologies,
ladybug-tech.com.

8-Switch Matrix



Mini-Circuits' USB-8SPDT-A18 is a general purpose USB controlled RF switch matrix containing eight electro-mechanical SPDT, absorptive fail-safe RF switches constructed in break-before-make configuration and powered by +24 V DC with a switching time of 25 mSec typical. The eight switches can be set as: eight independent SPDT switches, a 2 × 8 switch, a SP5T switch and a transfer switch, two transfer switches and many other configurations. The RF switches can be operated remotely using the supplied GUI program, or programmed by the user using the included API DLL com object.

Mini-Circuits,
www.minicircuits.com.

Portable Test Sets

The R&S®CTH family of portable radio test sets was designed for fast and easy testing of analog FM radios in the field. Both test sets perform frequency and power measurements on transmitters and receivers. The R&S®CTH200A also finds cable faults between the radio and the antenna and performs over the-air measurements. Users can check the functionality of their radios just before they are put into operation. The compact, battery-operated, 4.05" × 7.95" × 1.45" test sets only weigh about 1.2 lb.

Rohde & Schwarz,
www.rohde-schwarz.com.

Test and Debug Solution

Tektronix announced the industry's first compliance test and debug solution for Quad Small Form-factor Pluggable (QSFP+) compatible products. Based on Tektronix DPO/DSA/MSO70000 oscilloscopes, the new QSFP+ solution includes all the necessary components to design, test and validate QSFP+ designs including HCB fixtures and test automation and debug software tools. QSFP+ is a compact, hot-pluggable transceiver used for data communications applications. It interfaces a network device motherboard such as for a switch, router, media converter or similar device to a fiber optic cable.

Tektronix Inc.,
www.tektronix.com.

Digital Attenuators

Vaunix has announced the addition of two new models to its family of LDA series digital attenuators. This product family now offers attenuators with up to 120 dB of programmable attenuation through 6000 MHz. The LDA-102E and LDA-602E have input power of up to 2 W. The LDA-102E offers frequency coverage of 0.1 to 1000 MHZ while the LDA-602E ranges from 400 to 6000 MHz. Programmable for ATE applications, the attenuators can also be used in WiMAX, 3G, 4G, LTE, DVB fading simulators and engineering and production test labs.

Vaunix Technology Corp.,
www.vaunix.com.

USB & Ethernet Programmable ATTENUATORS

0–30, 60, or 90 dB 1 MHz to 6 GHz from $395

Mini-Circuits programmable attenuators give you more options and more freedom with both USB and Ethernet control. Available in versions with maximum attenuation of 30, 60, and 90 dB with 0.25 dB attenuation steps, all models provide precise level control with accurate, repeatable performance for a wide range of test applications. Our unique designs maintain linear attenuation change per dB over the entire range of attenuation settings. Supplied with user-friendly GUI control software and everything you need for immediate use out-of-the-box, Mini-Circuits programmable attenuators offer a range of solutions to meet your needs and fit your budget. Visit minicircuits.com for detailed performance specs, great prices, and off-the-shelf availability!

RoHS compliant

	Models	Attenuation Range	Attenuation Accuracy	Step Size	USB Control	Ethernet Control	RS232 Control	Price $ ea.
	RUDAT-6000-30	0 – 30 dB	±0.75 dB	0.25 dB	✓	-	✓	$395
NEW	RCDAT-6000-30	0 – 30 dB	±0.75 dB	0.25 dB	✓	✓	-	$495
	RUDAT-6000-60	0 – 60 dB	±1.00 dB	0.25 dB	✓	-	✓	$625
	RUDAT-6000-90	0 – 90 dB	±1.70 dB	0.25 dB	✓	-	✓	$695
NEW	RCDAT-6000-60	0 – 60 dB	±0.30 dB	0.25 dB	✓	✓	-	$725
NEW	RCDAT-6000-90	0 – 90 dB	±0.40 dB	0.25 dB	✓	✓	-	$795

Mini-Circuits®

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

NewProducts

Components

2-Way Power Divider

VENDORVIEW

The AM1500PD902 two-way power divider cover 800 to 2200 MHz with insertion loss of 0.5 dB, isolation of at least 18 dB, amplitude balance of 0.5 dB, phase balance of 5°, and VSWR of 1.4:1. It handles 100 W CW, uses Type-N female connectors and measures 2.1" × 2.1" × 1".
Anatech Electronics Inc.,
www.amcrf.com.

Low Frequency Attenuators

Coaxial Components Corp. introduced DC to 4 GHz attenuators. By utilizing an innovative alternative to high-cost stainless-steel production, Coaxicom's attenuators provide a cost-effective solution for general applications and in-field use. The low-frequency attenuator line is available in Type N (5910) and SMA (3910) series with an average power rating of 2 W. The attenuators are available in reverse polarity, between series adapters, as well as 50 or 75 Ω. These new attenuator models are RoHS and REACH compliant.
Coaxial Components Corp.,
www.coaxicom.com.

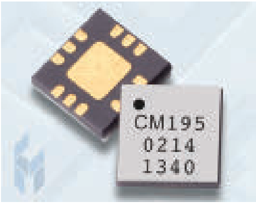
Power Inductors

Coilcraft's new compact PFD3215 series coupled chip power inductors provide high efficiency and excellent current handling in a rugged, low-cost part. The dual-wound PFD3215 features a 1:1 turns ratio and is designed for use in a variety of circuits including flyback, multi-output buck and SEPIC. These versatile inductors can also be used as two single inductors connected in series or parallel, as a wideband transformer or as a common mode choke.

Coilcraft CPS,
www.coilcraft.com.

Non-Reflective Switch

VENDORVIEW

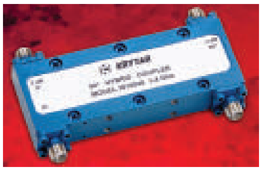


Custom MMIC introduced a new DC to 18 GHz SPDT non-reflective switch, the CMD195C3, housed in a 3 × 3 mm RoHS-compliant SMT package. The CMD195C3 has an insertion loss of 2.25 dB at the low end of its bandwidth, which then reduces monotonically to 1.5 dB at the higher frequencies. The positive slope in insertion loss versus frequency allows for several of the CMD195C3s to be cascaded together without the need for additional gain equalization circuitry.
Custom MMIC,
www.custommmic.com.

Variable Attenuators

Fairview Microwave's line of variable step attenuators come in 3 and 6 GHz frequency models and several different connector configurations including SMA and N type connectors with side or rear mount positions. Several of these attenuators are hot-switchable, meaning attenuation can be changed on the fly without powering down the system, allowing test data to be read continuously. Several models with varying attenuation adjustments are available including 0 to 12 dB attenuation in 1 dB steps and 0 to 40 dB attenuation in 10 dB steps.
Fairview Microwave Inc.,
www.fairviewmicrowave.com.

Hybrid Couplers



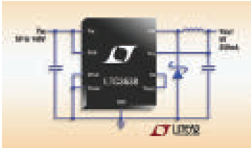
KRYTAR's 90° hybrid couplers are designed to perform many functions, including splitting and combining signals in amplifiers, switching circuits, and antenna beam-forming networks used in a wide range of commercial and military applications. KRYTAR's new hybrid coupler, model 3010040, delivers excellent versatility from 1 to 4 GHz with excellent phase and amplitude matching. Typical specifications include amplitude imbalance: ±0.6 dB; phase imbalance is ±6°; isolation is >17 dB; maximum VSWR: 1.30; insertion loss is <1.0 dB.
KRYTAR Inc.,
www.krytar.com.

Ferrites

A new line of ferrites from Leader Tech offers electronics manufacturers an extremely cost-effective alternative for controlling unwanted EMI/RFI interference. The company's CE83 material ferrites are available in multiple solid and split core styles to fit data and power cables with diameters ranging from 0.138" to 0.500". The new formulation is optimized for problem frequencies between 10 MHz to 1 GHz and delivers peek impedance at 300 MHz.
Leader Tech,
www.leadertechinc.com.

Buck Converter

VENDORVIEW



Linear Technology announced the LTC3638, a 140 V input-capable high efficiency buck converter that delivers up to 250 mA of continuous output current. It operates from an input voltage range of 4 to 140 V, making it ideal for telecom, industrial, avionic and automotive applications. The LTC3638 utilizes internal synchronous rectification and a programmable hysteretic-mode design to optimize efficiency over a broad range of output currents. It delivers efficiencies as high as 88 percent and requires only 12 µA of quiescent current, maximizing battery run time.
Linear Technology Corp.,
www.linear.com.

Microlithic Mixer

Marki Microwave's newest mixers, the ML1-1850 and ML1-1644 offer DC to 24 GHz and DC to 21 GHz (3 dB) IF response with RF/LO bands of 18 to 50 GHz and 16 to 44 GHz, respectively. Designed to scan the DC to 18 GHz band in tuner applications, both low-loss mixers cover the entire band with less than 10 dB of conversion loss. They feature 35 dB typical LO-RF isolation and excellent spur cancellation, including 56 dBc of typical 2xIF spurious suppression.
Marki Microwave Inc.,
www.markimicrowave.com.

SP9T Switch

Mesa Microwave Corp. has a new high power SP9T switch. It features 100 W, 950 to 1050 MHz, isolation of 45 dB, and a temperature range of -55° to +85°C.
Mesa Microwave Corp.,
www.mesamicrowave.com.


#SuperMobility
Live for Super
Super Mobility Week— a new mega event for the new wireless industry—will present the most cutting-edge intelligence for today's mobile lifestyle. Learn how mobile can super-size your business through new revenue opportunities, deeper customer engagement and the hottest products available on the market.
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Super Mobility Week
powered by CTIA
CTIA2014 THE Mobile Marketplace
MobileCON Powered by CTIA
4G americas
4G WORLD
CCA
IFA
M2M
NAHB
PARKS ASSOCIATES
TOWER & SMALL CELL SUMMIT
WIRELESS REPAIR EXPO
WLSA
September 9, 10 & 11, 2014
Sands Expo & Convention Center / Las Vegas
SuperMobilityWeek.com

NewProducts

Converters

Norden Millimeter has designed and is manufacturing a configurable line of down and up converters that cover the 2 to 18 GHz frequency band using Norden standard building blocks. These converters can be customized to cover the 2 to 8 GHz, 2 to 18 GHz, 6 to 18 GHz, 8 to 12 GHz and 8 to 18 GHz. The converters were designed to operate with a 0.5 or 1 GHz instantaneous bandwidth. The converter IF center frequency can be set between 1 and 4 GHz.

Norden Millimeter,
www.nordengroup.com.

Power Dividers

Pasternack Enterprises introduced a brand new line of Wilkinson power dividers (also referred to as Wilkinson power splitters). These multi-octave power dividers cover popular communications bands from 0.5 to 2.7 GHz including 3G and 4G, plus WiFi bands and are well suited for applications such as in-building distributed antenna systems (DAS) or test environments. Pasternack is offering two Wilkinson designs covering 0.5 to 2 GHz and 0.7 to 2.7 GHz bands.

Pasternack Enterprises Inc.,
www.pasternack.com.

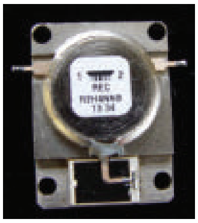
Absorptive Switch

Pulsar Microwave Corp.'s new PIN diode switch, P/N SW16AD-32, covers the frequency range of 0.5 to 10 GHz with 5 dB max insertion loss and 60 dB isolation. The maximum RF input power is +23 dBm and the switching time is 100 nanoseconds. TTL Schottky diodes are utilized with ±5 V DC at 400 mA required. Outline dimensions are 8.5" × 3.5" × 0.6".

Pulsar Microwave Corp.,
www.pulsarmicrowave.com.

Drop-In Isolator

VENDORVIEW



Renaissance has developed a new low cost, high power, drop-in isolator to protect expensive amplifiers from unwanted reflected power levels at S-Band frequencies. Covering 2.7 to 2.9 GHz, this isolator provides a VSWR of 1.25:1 at input and output ports with loss of 0.4 dB and isolation of 20 dB over -30° to +85°C. Optimized for aeronautical communication and navigation systems, this isolator can be provided in phased matched sets.

Renaissance/HXI,
www.rec-usa.com.

High Power Switch

RLC Electronics' high power switch line provides proven reliability, long life and outstanding electrical performance in SP2T-SP6T and DPDT (transfer switch) configurations. The switch features extremely low insertion loss and VSWR over the entire DC to 9.75 GHz range, while maintaining high isolation. The unit can handle average power requirements of approximately 600 to 700 W at 6 GHz and over 1000 W at 2 GHz. It can be provided in latching self-cutoff or pulse latching mode, in addition to failsafe.

RLC Electronics,
www.rlcelectronics.com.

Active Multiplier

VENDORVIEW

Model SFA-923963618-10SF-S1 is a W-Band X6 active multiplier with center frequency at 94 GHz with minimum ±2 GHz operational bandwidth. The active multiplier converts 15.33 to 16.0 GHz/+5 dBm input signal to deliver 92 to 96 GHz frequency band with more than +18 dBm power.

The active multiplier exhibits better than 60 dBc superior harmonic suppression performance. It draws 780 mA current from a +6 V DC power supplier.

SAGE Millimeter Inc.,
www.sagemillimeter.com.

Lead Isolator

VENDORVIEW

Skyworks Solutions Inc. introduced a 2110 to 2170 MHz single junction, robust lead isolator in an industry leading, small footprint, 11 × 11 mm surface mount package. The SKYFR-000727 is ideally suited for various wireless/cellular infrastructure applications including small-cell designs where space constraints exist. Designed for automated SMT placement, the isolator's insertion loss is less than 0.30 dB over an operating temperature range of –40° to +100°C. In addition, it is beryllium oxide free.

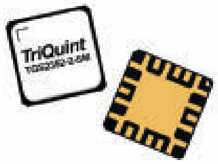
Skyworks Solutions Inc.,
www.skyworksinc.com.

Lowpass Filter

Spacek Labs model LPF1-86-11 is an E-Band lowpass filter in WR-12 waveguide. It has a pass band of 71 to 86 GHz with an insertion loss of 1.5 dB typical and 2 dB maximum. The reject

band is 91 to 140 GHz, with 20 dB rejection at 91 GHz and 35 dB minimum over the rest of the band. This series of filters can be made from 18 to 110 GHz.
Spacek Labs Inc.,
www.spaceklabs.com.

GaN Switches



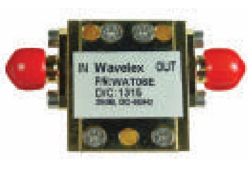
RFMW Ltd. announced design and sales support for a pair of high power GaN SPDT switches from TriQuint. The TGS2352-2-SM covers frequencies from 500 MHz to 12 GHz and handles input power up to 20 W while the TGS2353-2-SM extends frequency coverage to 18 GHz and handles up to 10 W of input power. Both offer switching speeds <35 nS and control voltages of 0/-40 V. Both switches are offered in a 4 × 4 mm QFN package featuring an AlN ceramic base.
TriQuint, distributed by RFMW Ltd.,
www.triquint.com.

Directional Coupler

Model DDH 4016 is a highly reliable, broadband dual directional coupler, ready for quick-turn and volume production. Operating in the 1 to 6 GHz frequency range and rated at 250 W CW, the DDH 4016 is designed for use across multiple broadband test applications. This low loss unit provides insertion loss of 0.2 dB max, VSWR (ML) of 1.20:1, coupling flatness of ±0.5 dB, and directivity of 18 dB. Package size is 2.67" × 1.75" × 1.12".
TRM Microwave,
www.trmmicrowave.com.

Attenuator

Richardson RFPD Inc. announced immediate availability and full design support capabilities for a new 30 dB, SMA-connectorized attenuator from Wavelex. The WAT06E precision attenuator operates from DC to 6 GHz, with 50 Ω impedance, with up to 30 dB attenuation, and features 20 W continuous wave (CW) RF power handling and 1.2:1 VSWR. It is ideally-suited for wideband power attenuation, high power measurement, high power IP measurement, and RF bench test applications.



Wavelex, distributed by
Richardson RFPD Inc.,
www.wavelex.com.

Low Pass Filter

Werlatone introduced its new line of high power, absorptive filters with the Model AF9350. This UHF, low pass filter covers the 10 to 500 MHz band, and has an average power rating of 400 W CW. The AF9350 incurs a rejection of 45 dB minimum at the 750 to 3000 MHz band and power rating of 25 W CW from 501 to 5000 MHz. This compact design measures just 4.5" × 1.75" × 1.13" and is ideal for military and commercial applications.
Werlatone,
www.werlatone.com.

Cables and Connectors

Mini-DIN Adapters

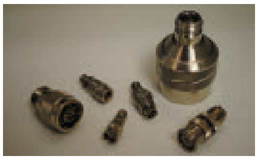
The Amphenol Connex line of low PIM mini-DIN, or 4.1/9.5, adapters are ideal for wireless applications requiring consistent electrical performance, low return loss and low IMD. This series has been engineered to exceed wireless industry performance standards and to match the physical performance expectations of its larger predecessor, the 7/16 connector. The 4.1/9.5 adapters are available with Type-N and 7/16 DIN connector interfaces. These coaxial adapters feature precision machined brass bodies and contacts.
Amphenol Connex,
www.amphenolconnex.com.

Low-PIM Adapters

P1dB Inc. introduced a full line of low-PIM adapters within its P1LP-ADP line. Available for 7/16 and Type N within-series applications and 7/16 between-series (Type N and SMA) applications, the high-performance line of adapters complements P1dB's high quality low-PIM cable assemblies. The bodies of the adapters are silver plated phosphorus bronze and offer the same low-PIM performance as silver without fear of tarnishing. Contacts are either silver-plated beryllium copper or silver plated beryllium copper over phosphorus bronze.
P1dB Inc.,
www.p1db.com.

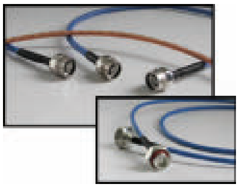
New**Products**

Push-On Adaptors



Response Microwave Inc. announced the availability of a new series of quick connect male adaptors that expedites general DUT testing. The new units are available in SMA18, SMA27, N, 7/16, TNC and TNCA interfaces and operate incrementally over the DC to 27 GHz range. Typical electrical performance offers insertion loss of 0.3 dB and VSWR of 1.2:1 max. Units mate to any standard female and offer a unique detent coupling mechanism that does not degrade electrical performance. Durability through 500 mating cycles revealed no physical degradation.
Response Microwave Inc.,
www.responsemicrowave.com.

PIM Rated Jumpers



Times Microwave Systems announced the availability of its full line of PIM rated jumper cables, including PIM rated jumpers for plenum applications. PIM testing includes the important dynamic testing in order for cables for provide good PIM performance after installation. All Times Microwave PIM assemblies are 100 percent tested for static and dynamic PIM and verified to provide stable PIM performance prior to shipment. These cables include SPP™ – Plenum rated and UL listed; SPF™ – Fire retardant for riser use; and SPO™ – outdoor rated.
Times Microwave Systems,
www.timesmicro.com.

Low PIM Adapters

Trilithic Inc. has released a new series of DC to 6 GHz, low PIM adapters with -168 dBc PIM at

1800 MHz, 43 dBm per tone with VSWR: 1.2:1 maximum. Connector configuration is 7/16 DIN male to N female. Inner contact: silver plated Be-Cu. Connector body: Silver/Tri-metal plated brass. Dielectric: PTFE. RoHS compliant. Contact factory for price and delivery.
Trilithic Inc.,
http://rfmicrowave.trilithic.com.

Amplifiers

Hybrid PA

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 typical gain with excellent gain flatness, low noise figure and low inter-

modulation distortion for military and wireless applications. The unit offers over voltage and RF input overdrive protection, and has 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.

SSPA

COMTECH PST introduced a new high power density solid state RF module quickly becoming available in today's marketplace. Comtech's latest development continues to expand on its

proven innovative integrated RF GaN power amplifier designs by further increasing the RF power density. Consistent with its planned technology development roadmap, Comtech introduced the latest in GaN-based 6 to 18 GHz RF amplifier. This highly integrated design is ideal for use in communication, electronic warfare and radar transmitter systems where space, cooling and power are limited.
COMTECH PST,
www.comtechpst.com.

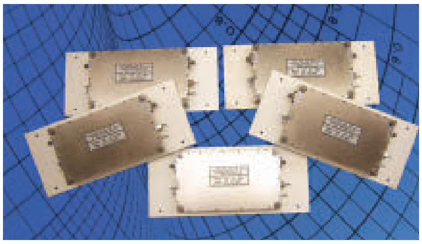
NewProducts

Driver Amplifier

Eclipse Microwave's EMD1211 is a GaAs MMIC general purpose driver amplifier. This amp module is ideal for applications that require a typical output of +30 dBm at 10 GHz while requiring only 300 mA from a +12 V supply. Gain flatness of this device is less than 2.0 dB from DC to 20 GHz. The EMD1211 comes in a small connectorize module ideal for commercial and industrial applications.

Eclipse Microwave,
www.eclipsemicrowave.com.

TTL Amplifier



MSH-4627908-TTL is a 10 W amplifier optimized for the operating frequency range of 5.2 to 5.8 GHz with 28 dB min of gain and 6 A max fully matched to 50 Ω. TTL provides fast blanking and is customizable. This model is suitable for a range of applications which include test systems, defense or aerospace, and can be easily modified to meet your requirements. It is designed to meet MIL-STD-883 and is manufactured in compliance with AS9100.
Microwave Solutions Inc.,
www.microwavesolutions.com.

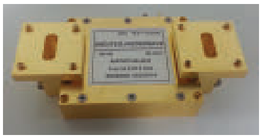
Pulse Amplifier

RFHIC introduced its new GaN power amplifier, RRM2735160-35. This amplifier can revamp existing solutions or be designed for cutting-edge uses. Supremely designed for radar systems operating in the 2.7 ~ 3.5 GHz range, this high performance amplifier utilizes state-of-the-art GaN-SiC transistors, achieving 35 dB gain (typical) with drain efficiency of 40 percent (typical). It is also matched for 50 Ω input/output.

RFHIC,
www.rfhic.com.

Power Amplifier

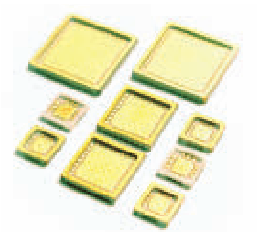
Model AHP2475-03-3433-W42 is a temperature compensated waveguide power amplifier offering 34 dB linear gain and 33 dBm typical output power at 1 dB gain compression point over the frequency range from 24.0 to 25.5 GHz with excellent gain flatness as well as good temperature stability. The amplifier requires a single DC power supply +8.5 ~ 10.0 V. The package size of the amplifier is 1.7" × 1.2" × 0.40".



Wenteq Microwave,
www.wenteq.com.

Packages

QFN Packages



High temperature co-fired ceramic (HTCC) QFN packages from Barry Industries feature low-loss broadband transitions for superior performance over frequency. They are tested to 40 GHz. HTCC construction provides for enhanced mechanical strength and higher thermal conductivity compared with LTCC. These hermetically sealable air cavity packages conform to JEDEC MO-220 footprints. Lids are available from the factory.
Barry Industries Inc.,
www.barryind.com.

Sources

TCXO

The new Connor-Winfield CSBxx Series are surface mount, 5 × 7 mm, 3.3 V, LVCMOS or clipped sinewave temperature compensated crystal oscillators (TCXO) designed to be emergency beacon frequency references requiring tight ±0.2 ppm frequency stability and frequency slope control of only ±0.7 ppb/min. The low power dissipation of 6 mW allows it to power up immediately with an accurate frequency. Class 1 devices operate over -40° to 55°C and Class 2 devices operate -20° to 55°C.
Connor-Winfield,
www.conwin.com.

VCO

Crystek's CVCO55CC-3850-3850 voltage controlled oscillator (VCO) operates at 3850 MHz with a control voltage range of 0.5 ~ 4.5 V. This VCO features a typical phase noise of -110 dBc/Hz at 10 kHz offset and has excellent linearity. Output power is typically +7 dBm. Engineered and manufactured in the USA, the model CVCO55CC-3850-3850 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 8 V, with a max. current consumption of 35 mA. Pulling and pushing are minimized to 1 MHz and 0.2 MHz/V, respectively.
Crystek Corp.,
www.crystek.com.

Frequency Synthesizer

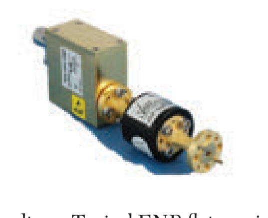
VENDORVIEW

PMI Model No. PFS-618-CD-1 is a high speed frequency synthesizer that operates over the frequency range of 6 to 18 GHz. This model covers the complete 6 to 18 GHz frequency in 100 kHz steps with an output power of +10 dBm minimum. The unit is accurate to within ±1 MHz and settles within 1 usec maximum. This model features low SSB noise and a low spurious output of -55 dBc maximum. Harmonics are kept below -30 dBc.

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

Waveguide Noise Sources

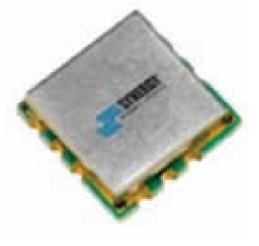
QuinStar Technology Inc. introduced the QNS-FB15LE series of waveguide noise sources. The QNS series waveguide noise source comes in standard (Q,U, V, E and W) full waveguide bands. The QuinStar QNS series noise sources have 15 dB ENR with 0.015 dB/°C of noise power output stability over temperature and 0.15 dB/1 percent over bias voltage. Typical ENR flatness is ±0.5 dB over any 10 GHz region and ±1.25 dB over the full band. QuinStar also offers QIF series full band matching isolators as an option.



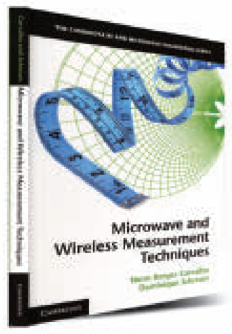
QuinStar Technology Inc.,
www.quinstar.com.

Miniature VCO

The DCO200400-5 is a broadband miniature VCO covering from 2 to 4 GHz and sized only at 0.3 inches square. This tiny VCO boasts low noise of -90 dBc/Hz at 10 kHz offset, making it ideal for hand-held test equipment and microwave point-to-point radio applications. The output power of -2 dBm minimum comes from a bias requirement of only +5 V at 46 mA (max). Tuning requirement for the full band is 0.5 to 18 V. Second harmonic is suppressed by 12 dB minimum.



Synergy Microwave Corp.,
www.synergymwave.com.



Microwave and Wireless Measurement Techniques

Nuño Borges Carvalho and
Dominique Schreurs

This book is a good introduction to high frequency measurement from typical metrology parameters for common wireless and microwave components to the implementation of measurement benches. The book covers how to interpret and measure most of the parameters described in a microwave component's datasheet, understand the practical limitations and theoretical principles of instrument operation, and combine several instruments into measurement benches for measuring microwave and wireless quantities.

Microwave and Wireless Measurement Techniques includes several practical examples such as demonstrating how to measure intermodulation distortion, error vector magnitude, S-parameters and large signal waveforms. With recent advances in software-defined radio and in future cognitive radio, measurements in time/frequency and analog/digital domains have become a very important problem to RF and microwave engineers. The book covers various types of measurements and their advantages and disadvantages. Each chapter ends with a set of exercises, allowing readers to test their understanding of the material covered and making the book equally suited for course use and for self-study.

This book aims to give young engineers and researchers a preview of their adventures in microwave, wireless systems and circuits measurement. It can be used in connection with a graduate class on measuring wireless system or a professor can select parts of the book for a class on wireless systems. It is also well suited as an introduction to engineers in the field but more of a basic review for experienced professionals.

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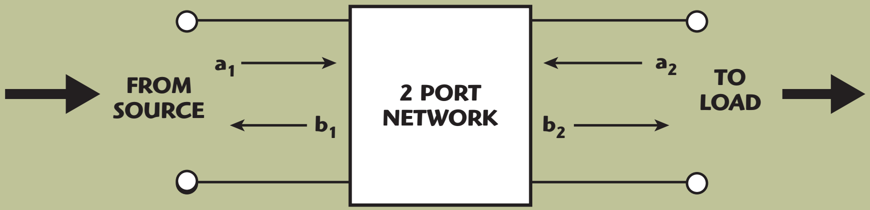
STEM Works

Net·work An·a·ly·zer [net-work] [an-l-ahy-zer]

Network analyzers measure the incident, reflected and transmitted energy, that is launched onto a transmission line, reflected back down the transmission line toward the source (due to impedence mismatch), and successfully transmitted to the terminating device. Network analyzers are commonly used to measure S-parameters, but there are other network parameter sets such as y-parameters, z-parameters and h-parameters. Network analyzers are often used to characterize two-port networks such as amplifiers and filters, but they can be used on networks with an arbitrary number of ports.



a: incident wave
b: reflected wave
$b_1 = S_{11}a_1+S_{12}a_2$
$b_2 = S_{21}a_1+S_{22}a_2$

1950. Rohde & Schwarz introduces the Zg diagraph, the world's first vector network analyzer allowing users to directly measure S-parameters. With its Smith chart display for microwave engineers, the ZDU model (30 to 300 MHz), followed by the ZDD (300 to 2400 MHz) was primarily used on TV broadcasting antennas and to test special cables in telecommunications.

1965. Wiltron introduces the 310 VNA with frequency ranges from 1 to 2, 2 to 4 and 4 to 8 GHz. Narrow band backward wave oscillators were used as the signal source. Plug-in monitors provided rectangular or Smith chart display.

1967. Hewlett-Packard introduces the 8410 network analyzer with swept capability to 12 GHz. This integrated multiple box bench-top system provided engineers with transmission, reflection and impedance data in a single two-dimensional representation.

1984. The 26.5 GHz HP-8510 VNA is released. The instrument includes a synthesized source, error correction, time domain and pulse measurements. An HP-1B data bus is used for automatic operations.

1987. Wiltron introduces the 40 GHz 360 VNA system with color display and lower frequency range extended down to 10 MHz. Wiltron's Founder William Jarvis pushed his engineers to develop a competitive instrument to HP. HP introduces a one-box VNA, the HP-8753.

1988. Rohde & Schwarz introduce the 8 GHz ZVT8 which includes 8 measurement ports.

2000. Anritsu (formerly Wiltron) introduces a VNA series with a frequency range up to 65 GHz. HP (now Agilent) releases its PNA with a range up to 50 GHz.

2006. R&S introduces the ZVA with four internal phase coherent sources up to 67 GHz. It is the first VNA with four internal sources up to 67 GHz for fast two-tone measurements on amplifiers and mixers.

2008. Agilent introduces NVNA software which transforms one of the company's four port PNA-X VNA systems into a nonlinear VNA.

2012. Anritsu introduces a VNA family with 70 kHz to 125 GHz noise figure measurement capability, enabled in part by a unique receiver optimized for measurements from 30 to 125 GHz.

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D8454	8-Way	370-450	10,000	0.25	1.30:1	3 1/8" EIA, N Female
D9710	8-Way	1000-2500	2,000	0.3	1.40:1	1 5/8" EIA, N Female
D9529	8-Way	2305-2360	1,000	0.2	1.15:1	7/16 Female, N Female
D9528	8-Way	2305-2360	2,000	0.2	1.15:1	7/8" EIA, N Female
D5320	12-Way	470-860	500	0.3	1.30:1	All N Female
D9194	16-Way	2305-2360	1,000	0.2	1.15:1	7/16 Female, SMA
D9527	16-Way	2305-2360	2,000	0.2	1.15:1	7/8" EIA, N Female
D9706	16-Way	2700-3500	6,000	0.35	1.35:1	Waveguide, N Female
D6857	32-Way	1200-1400	4,000	0.5	1.35:1	1 5/8" EIA, TNC

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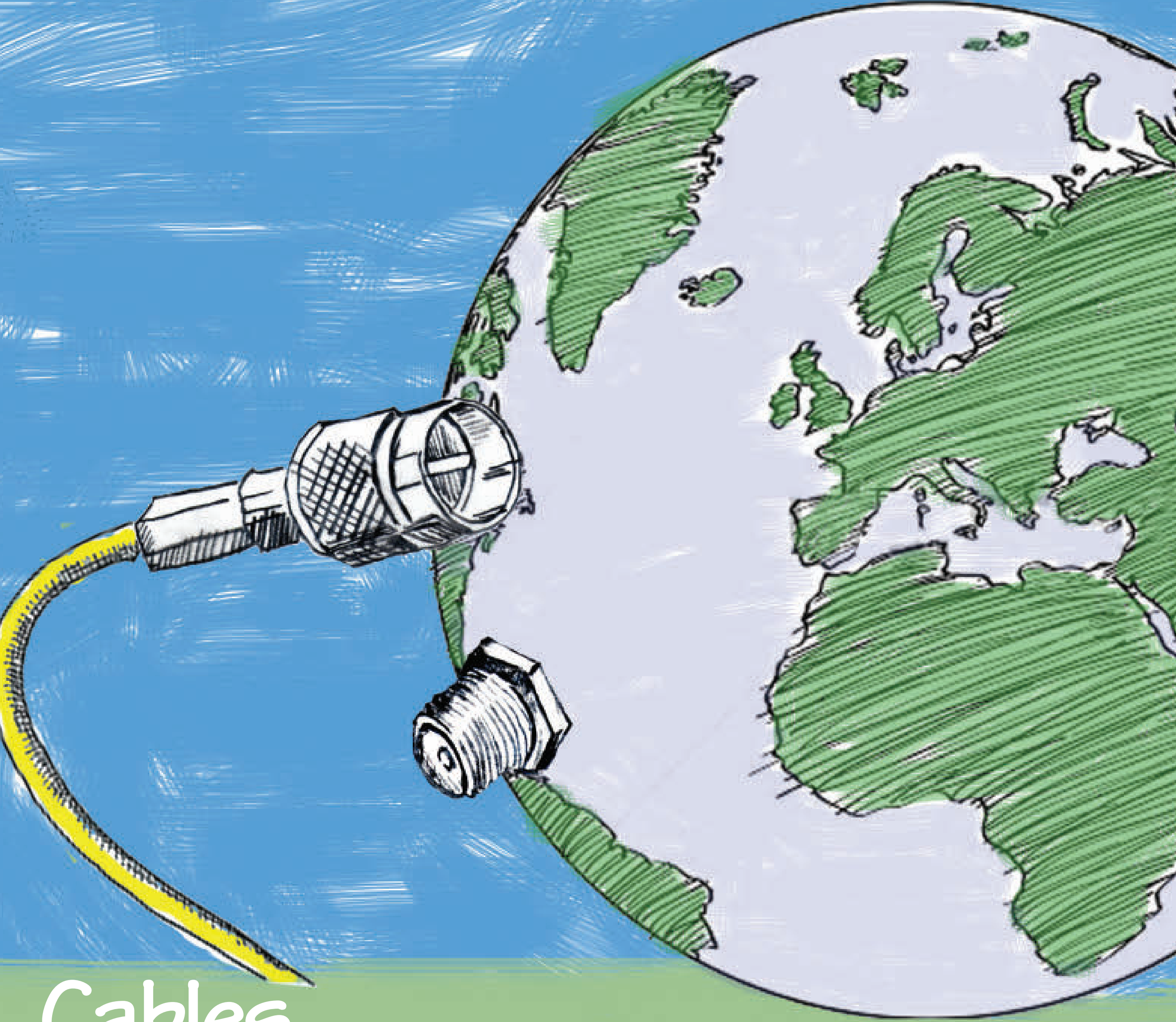

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RF Cable and Connector Outlook

Richard Mumford and Pat Hindle
Microwave Journal ***Editors***

To evaluate the cable and connector market on the ground, *Microwave Journal* has taken a snapshot of activity from manufacturers in the U.S. and in Europe who offer a frontline perspective of the outlook for the market in 2014, expectations for growth and drivers impacting product development.

MARKET OUTLOOK FOR 2014

Spectrum Elektrotechnik's view is that in general there will not be significant change compared with recent years, while Huber + Suhner envisages moderate growth. W. L. Gore & Associates (Gore) states, "Uncertainty in the global economy and government cutbacks are affecting the amount of investment in research and innovation, particularly in smaller companies. We believe that this will have an impact in two major areas — the supply chain and innovation. To remain competitive in the market, established suppliers will need to advance the development of new materials, products and technologies."

Gore continues, "Also, we believe that there will be more emphasis on selecting solutions that last longer, therefore, saving time and money over the life of projects or systems. This focus on products that survive the test of time will be the driving force behind innovation, with more customers requesting information about durability testing in their application environments."

SPINNER's focus is primarily related to jumpers (cable assemblies) which are the company's core business and general connectors, with both being predicted to grow in 2014. SPINNER comments, "The tremendous effort to build mobile broadband networks has definitely increased the demand for both connectors and jumpers. We see a rising demand for mid-sized connectors to support more compact housings for BTSs and antennas as well as better PIM that primarily addresses the replacement of N connectors, which has mainly been driven by the U.S. so far."

Mobile communications is also seen as a factor by Molex Inc., which states, "Higher data rates and demand for functionality are major drivers for growth in mobile wireless telecommunications and networking. As an industry, we can expect continued expansion in sales of mobile and wireless devices, in tandem with high rates of technology refresh. Key markets for RF/microwave are growing across the board at a robust pace, including a strong rebound in the automotive industry. The sales pipeline is full across wireless markets, spurred by high volume and high value solutions and tools to make it easier for customers to more quickly bring new products to market."

AREAS OF GROWTH

Concentrating on the company's core markets, SPINNER predicts, "The jumper market

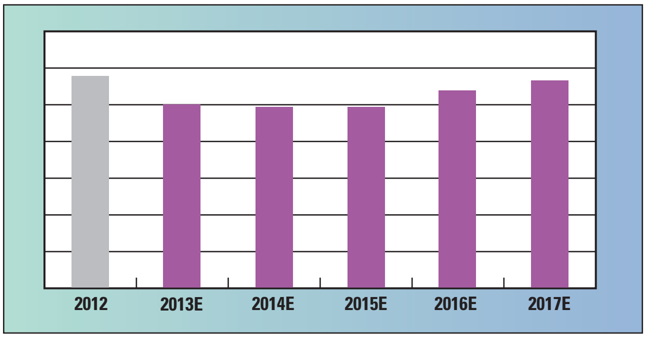


Fig. 1 RF jumper cables for BTS, 2012-2017 (Source: EJL Wireless Research).

will grow and at the same time jumpers will become longer. There is also a tendency for LF1/2" to increase market share compared to SF1/2". The ongoing introduction of BBUs and RRUs will reduce the need for feeder lines, which will be reflected in longer jumpers being used between RRUs and antennas."

EJL Wireless Research also supports that feeder cables are declining in use as they are being replaced by fiber optic cables. The jumper cable stability and future growth is supported by EJL Wireless Research as it sees RF jumper cable demand remaining stable due to remote radio head (RRH) deployments on BTS sites. Its market projection for feeder cables is shown in ***Figure 1*** with flat demand in 2013-15 but some growth expected in 2016-17.

EJL Wireless Research analyzed the feeder and jumper cable size for BTS for 2012. ***Figures 2*** and ***3*** show the size breakdown and total market size for feeder and jumper cables, respectively. About half of the feeder cable diameters are 1¼" or larger with a total market size of $380.7 million. On the other hand, close to half of jumper cables are ½" or less, to provide flexibility, with a total market size of $280.3 million.

With regard to connectors, SPINNER maintains, "From the perspective of quantity, connector growth will be dominated by 7-16 in 2014. Nevertheless, most growth percentage wise (market share) will be with 4.1-9.5 and 4.3-10. The 4.1-9.5 will grow more significantly in North America based on carrier announcements to replace N with 4.1-9.5. 4.1-9.5 based products such as BTS and antennas which have been adapted to 4.1-9.5 and installations have started in Q1 2014.

"While North America is currently primarily focusing on 4.1-9.5 deployments, the rest of the world is looking forward to 4.3-10 with high expectations (and we cannot say North America is not). We have developed 4.3-10 and the system is currently undergoing standardization. Once this is finalized and major carriers/OEMs have introduced them on their equipment, we expect the floodgates to open for this new connector system."

EJL Wireless Research confirms the dominance of 7/16 in as shown in ***Figure 4***. Almost 70 percent of DIN/N connectors for BTS in 2012 were ½" or smaller with a total market of $213.9 million. EJL Wireless Research also analyzed the BTS connectors by type which is shown in ***Figure 5***. This shows the dominance of ½" or smaller DIN straight connectors. EJL Wireless Research also sees a trend that RF connectors are beginning to see mini-DINs and MCIC types for cables/antennas that are driven by TD-LTE deployments in China and the U.S.

Molex sees: "Significant development work to add RF features in everything from appliances to automobiles. In the immediate future, we foresee new technologies such as 4K HDTV and cameras to deliver to savvy consumers the higher resolution experience that will gain mass market appeal as content grows."

With its wide range of cable and connector products, Huber + Suhner sees most growth in the transportation sector, particularly public transport, military and space applications, and to facilitate communication infrastructure changes. In its field of application, Spectrum Elektrotechnik states, "The most growth we expect is for phase matched cable assemblies and hermetically sealed connectors and adapters."

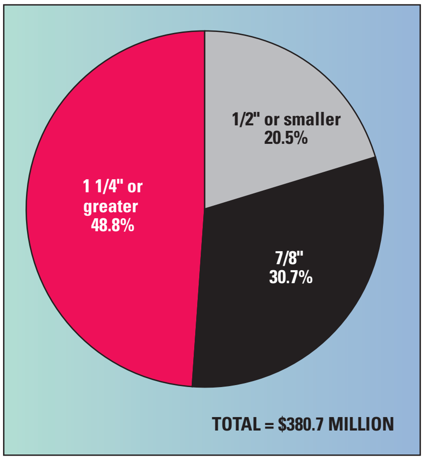


Fig. 2 2012 RF feeder cables for BTS by diameter (Source: EJL Wireless Research).

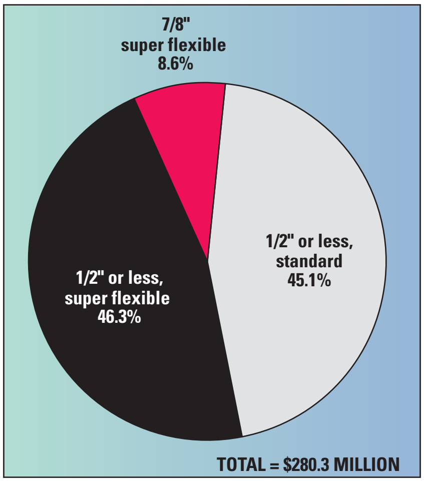


Fig. 3 2012 RF jumper cables for BTS (Source: EJL Wireless Research).

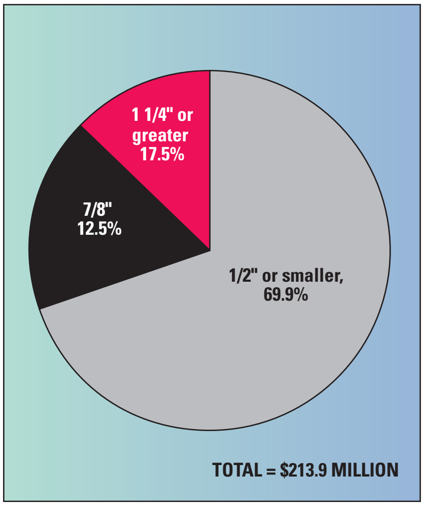


Fig. 4 2012 RF DIN/N connectors for BTS by size (Source: EJL Wireless Research).

Gore envisages environmental factors being important, commenting: "As industries continue to deal with tightening budgets, the biggest area of growth we see for microwave/RF applications is the demand for reliable components — especially cable assemblies — that withstand demanding environments. For example, portable analyzers are increasingly being used in the aerospace and telecommunications industries to facilitate testing out in the field. These analyzers need cable assemblies that can withstand the extreme environmental conditions as well as frequent handling during use. Specific applications that are emerging — and will be a focus for many — include radar systems, millimeter-wave applications, and automotive radar."

With regard to geographical growth, Molex views its global network at the forefront of today's RF/microwave technologies, providing complete support at every phase of the product life cycle. The company says, "Asia represents the fastest regional growth market with proliferation of consumer, networking, cellular mobile products and automotive demand on the rise. In Europe and North America, there is an increasing demand for connectivity across many platforms, driving a need for greater bandwidth to support handheld devices, notebook computers, WiFi access points and other networking activity."

Gore identifies new players in the market, stating, "As the mobile phone and wireless service providers continue to reduce hardware costs and improve system reliability, large underserved markets like Africa may rival China in terms of growth."

Huber + Suhner predicts the potential for growth being in the established markets of North America, Western Europe and APAC. Spectrum Elektrotechnik is concerned that the impact of Germany and several other European companies cutting their military budget, while the "U.S. is stagnating" could mean limited growth. However, SPINNER sees the introduction of 4.1-9.5 in North America as being significant while the rest of the world starts to adapt to LF1/2" jumpers.

DRIVERS FOR PRODUCT DEVELOPMENT

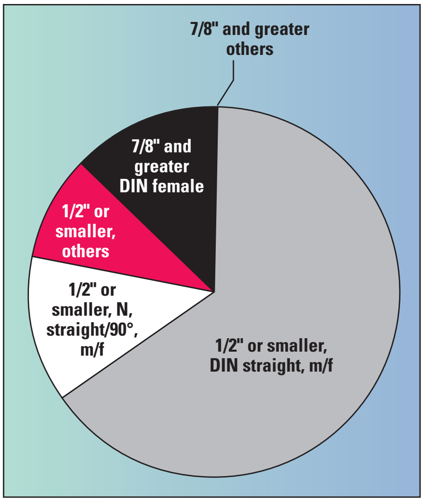
Success is dependent on developing the right product at the right time for the right market. However, achieving that goal is reliant on a multitude of factors.

Gore's current approach is to: "Continue to focus on delivering reliable electrical and mechanical integrity in demanding environments. In the aerospace industry, for example, cables need to withstand abrasion, cut-through, and routing during installation and maintenance as well as vibration, flexibility, and extreme temperatures during operation.

"Aircraft manufacturers are continuing to look for solutions that lower the total weight and cost of cable assemblies and improve their installation process, all without compromising signal integrity over the life of the aircraft. This translates to a demand for lighter, tougher, more durable cable technologies that minimize the need for frequent cable replacements."

SPINNER takes the view that, "The jumper market is developing more and more into a project driven installation business, which is driving us to offer the highest possible flexibility to our customers, facilitated by focusing on fast and customized manufacturing. Flexible means, manufacturing different jumper types with individually configured connectors and cable length within a few days. To achieve this, the focus is not just on product development, but also the development of our manufacturing plants and processes to ensure quick turnaround time while maintaining high quality."

The company also believes that with the introduction of LTE, low PIM has become even more critical alongside the increasing need for miniaturization since BTS and antenna housings are quite often dominated by the size of the connector system. SPINNER says, "Our customers see most of the problems in the field going back to incorrect installation or inappropriate material usage; this is why we developed a more robust and less error-prone 4.3-10 connector system. Basically, SPINNER is committed to 4.3-10 that support the key factors of PIM, size and reliability."



▲ *Fig. 5 2012 RF connectors for BTS by type (Source: EJL Wireless Research).*

Low PIM requirements have been a growing concern over the last few years as system requirements have tightened up as the industry learned more about its effects. System integrators are now requiring very low PIM specifications and might move to even lower levels that could push many cable/connector manufacturers out of the this market. Current industry standards require PIM levels of about -150 dBc or better, but some in the industry have hinted that they might require levels as low as -160 dBc in the future. This will also impact testing as designing test systems that are capable of accurately measuring down to the level will be difficult. Read "Passive Intermodulation Characteristics" by Murat Eron of the Wireless Telecom Group in this issue for more specifics about PIM and how it affects cable design and systems.

Focusing on the specific needs of its customers and its product offering, Spectrum Elektrotechnik sees a key driver being "phase adjustable self-locking connectors with a wide adjustment range, e.g., 280° at 18 GHz."

Huber + Suhner identifies key drivers being to provide energy ef-

ficiency and the production of environmentally friendly product with the elimination of hazardous substances and the adherence to safety standards. It also sees increased bandwidth and the subsequent demand for higher frequencies being significant, along with the need to reduce weight and size, requiring miniaturization.

Miniaturization is also a consideration for Molex as are the requirements of OEMS. The company states, "Based on proven connector technologies, specialty ganged, stacked, backplane and other multi-port I/O solutions that group connectors in a common housing are gaining traction among OEMs looking to streamline designs and save space in many different systems. Miniaturization has enabled better designs in smart products, earbuds, music players, streaming video and audio devices.

"Low frequency microcoaxial RF solutions represent a high volume market, especially for ultra-miniature stamped connectors. Microcoaxial RF connectors are a low-profile (available down to 1 mm mated height) wire-to-board solution – ideal for embedding in small, handheld wireless devices such as mobile phones, radio-communication equipment, GPS systems, tablet computers and a plethora of content streaming consumer applications."

SUMMARY

Most companies see the BTS cable assembly market being stable with flat to moderate growth in the coming years. There seems to be a shift away from feeder cables due to the ongoing introduction of BBUs and RRUs plus some replacement by fiber optical cables. The jumper cable market is expected to experience moderate growth due to the deployment of remote radio heads. There seems to be a market push for higher quality cables that are more durable and have lower PIM. As more LTE networks are deployed, PIM becomes more important and requirements are likely to become even more stringent forcing cable assembly manufacturers to improve quality and testing procedures. While the 7/16 RF connector dominates the current BTS market, other connector types are being introduced and are expected to grow in popularity. RF connectors are beginning to see the use of mini-DINs and MCIC types for cables and antennas driven by TD-LTE deployments in China and the U.S. ■

ACKNOWLEDGMENT

Thanks to EJL Wireless Research who provided the data and graphics for the market analysis and projections in addition to inputs on market trends (www.ejlwireless.com, info@ejlwireless.com).

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NEW Precession Test 75Ω (CBL)	DC-3	N, F	2-6	-55/+105
Armored (APC)	DC-18	N	6.0-15	-55/+105
Low Loss (KBL-LOW)	DC-40	2.92	1.5-6.6	-55/+85
Phase Stable (KBL-PHS)	DC-40	2.92	1.5-6.6	-55/+85

All models 50Ω except as noted.

*Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within six months of shipment. This guarantee excludes cable or connector interface damage from misuse or abuse.

† Custom lengths available by special order.

‡ SMA female connectors featured on some models, or via special order.

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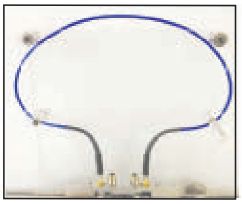

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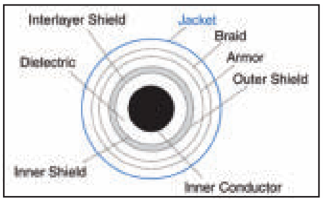

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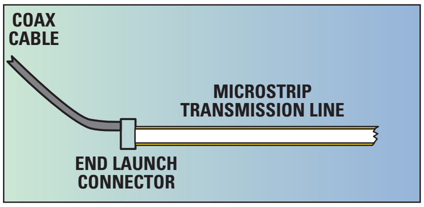
Signal Launch Methods for RF/Microwave PCBs

John Coonrod
Rogers Corp., Chandler, AZ

Transferring high frequency energy from a coaxial connector to a printed circuit board (PCB) is often referred to as a signal launch and it can be difficult to characterize. How efficiently energy is transferred can vary a great deal from one circuit structure to another. Factors such as the PCB material, its thickness and the operating frequency range affect performance, as well as the connector design and its interaction with the circuit material. With an understanding of the issues, including the differences in signal-launch configurations, and by reviewing some examples of ways to optimize RF/microwave signal launches, performance can be improved.

Achieving an effective signal launch is design dependent, with broadband optimization typically more challenging than narrowband. Design of a high frequency launch usually grows in difficulty with increasing frequency, and can be more problematic with thicker circuit materials and more complicated circuit constructions.



▲ *Fig. 1 Signal launch from a coaxial cable and connector to a microstrip.*

SIGNAL LAUNCH DESIGN AND OPTIMIZATION

A signal launch from a coaxial cable and connector to a microstrip PCB is illustrated in ***Figure 1***. The electromagnetic (EM) fields traveling through the coaxial cable and connector have a cylindrical orientation while the EM fields in the PCB have a planar or rectangular orientation. When the fields transition from one propagating medium to another, they change orientation to accommodate the new environment, causing anomalies. The transition depends upon the type of medium; whether a signal launch is being made, for example, from a coaxial cable and connector to microstrip, grounded coplanar waveguide (GCPW), or stripline. The type of coaxial connector also plays an important role.

Optimization may involve several variables. Understanding the EM field orientation within a coaxial cable/connector can be useful, but the ground return path must also be considered as part of the propagating medium. It is often beneficial to achieve smooth impedance transitions from one propagating medium to another. Knowing the capacitive and inductive reactances at impedance junctions can provide

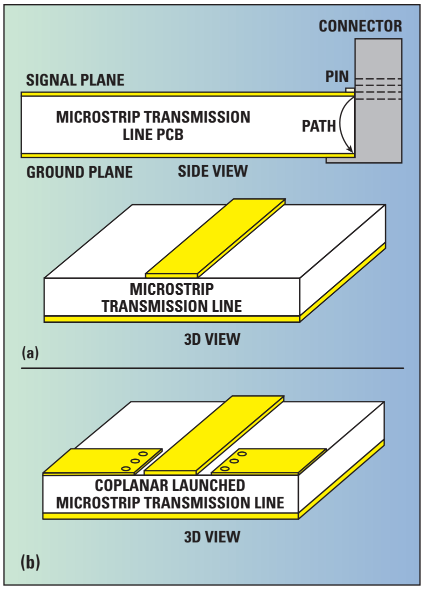


Fig. 2 Representation of a thick microstrip transmission line circuit and the lengthened ground return path back to the connector (a), a grounded coplanar launched microstrip circuit (b).

insights into the expected behavior. When three-dimensional (3D) EM simulation is available, current-density mapping can be used. In addition, best practices associated with radiation loss can serve as guidelines.

Although the ground return path between a signal launch connector and a PCB may not appear to be an issue, the ground return path from the connector to the PCB are ideally continuous and uninterrupted; this may not always be the case. There is typically some small surface resistance between the metal of the connector and the PCB. There may also be small conductivity differences between the solder that joins the different parts and the metal of those parts. These small differences usually have minor effects at lower RF and microwave frequencies, but they can significantly affect performance at higher frequencies. The actual length of the ground return path can play a role in the quality of launch that is achieved with a given connector and PCB combination.

As ***Figure 2a*** illustrates, when EM energy transitions from a connector pin to the signal conductor of a microstrip PCB, the ground return path back to the connector housing can be lengthy for a thick microstrip transmission line. Using a PCB material with a relatively high dielectric constant can exaggerate the problem by leading to a longer electrical length in the ground return path. Any lengthening of this path can result in frequency-dependent issues typically linked to a localized difference in phase velocity and capacitance. Both are related and affect the impedance in the transition area and cause differences in return loss. Ideally, the length of a ground return path should be minimized, with no impedance anomalies in the signal launch area. Note that the grounding point of the connector in Figure 2a is shown only on the bottom of the circuit. This is a worst-case scenario. Many RF connectors have grounding pins on the same layer as the signal. In that case, the PCB will have ground pads there, as well.

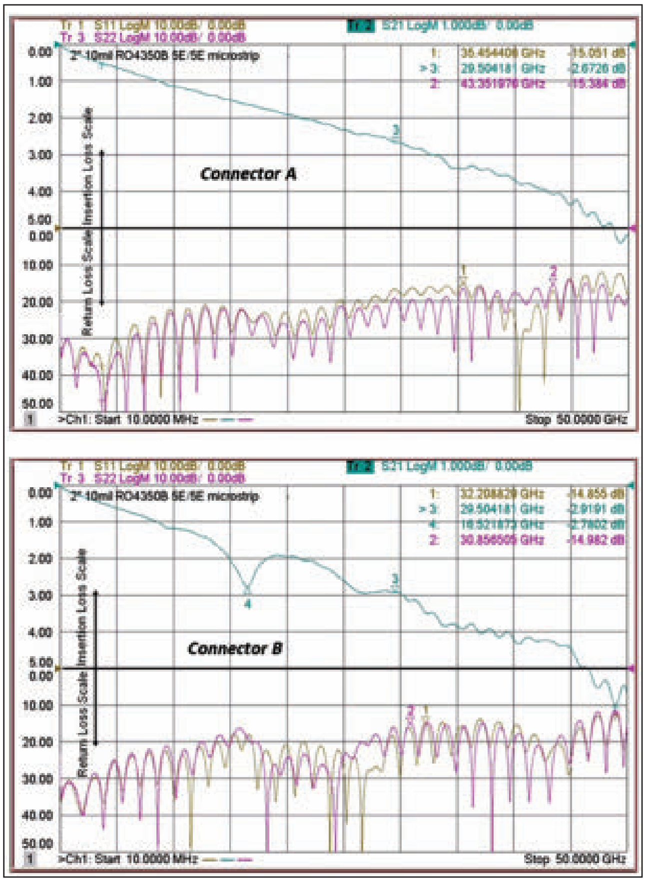


Fig. 3 Coplanar launch microstrip circuit tested with similar end launch coaxial connectors having different ground separations.

Figure 2b represents a coplanar launched microstrip circuit, where the body of the circuit is microstrip but the signal launch area is a grounded coplanar-waveguide (GCPW). Coplanar launched microstrip is advantageous because it minimizes the ground return path and has other beneficial properties. When using a connector with ground pins on both sides of the signal conductor, the ground pin separation distance can have a significant impact on performance. It has been demonstrated that this distance impacts the frequency response.[1]

In an experiment with a coplanar launched microstrip on 10-mil-thick RO4350B™ laminate from Rogers Corp., similar connectors are used, but with different ground spacings at their coplanar launch interfaces (see ***Figure 3***). Connector A has a ground separation of approximately 0.030", while Connector B has a ground separation of 0.064". The connectors launch onto the circuit the same in both cases.

The x-axis shows frequency, with each division representing 5 GHz. Performance is comparable at lower microwave frequencies (< 5 GHz), but above 15 GHz, performance of the circuit with wider ground separation degrades. The connectors are similar, although there is a slight difference in pin diameters between the two models, Connector B has a larger pin diameter and is designed for use with a thicker PCB material. This may also have contributed to the performance differences.

A simple and effective method for optimizing signal launch is to mini-

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Amplitude Stability vs. Flexure	⩽ ± 0.2 dB @ 18 GHz		
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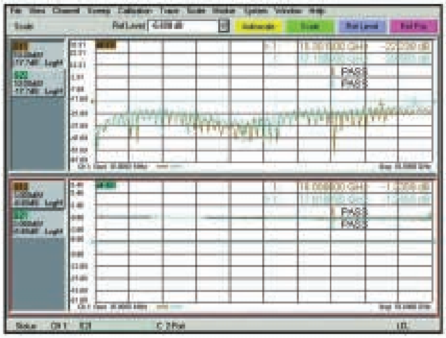
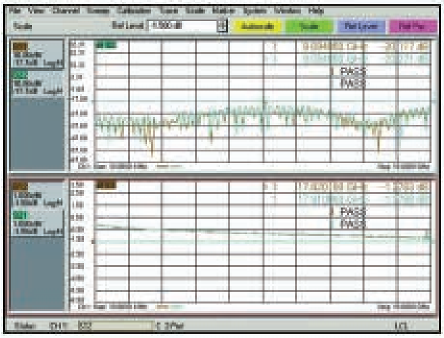
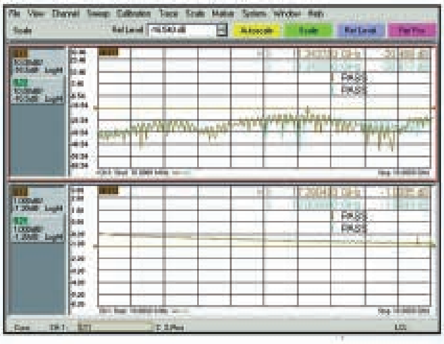


Insertion Loss and Return Loss for LL235, SMA M-SMA M, 18GHz (Typ.)



Insertion Loss and Return Loss for LL335i, SMA M-SMA M, 18GHz (Typ.)



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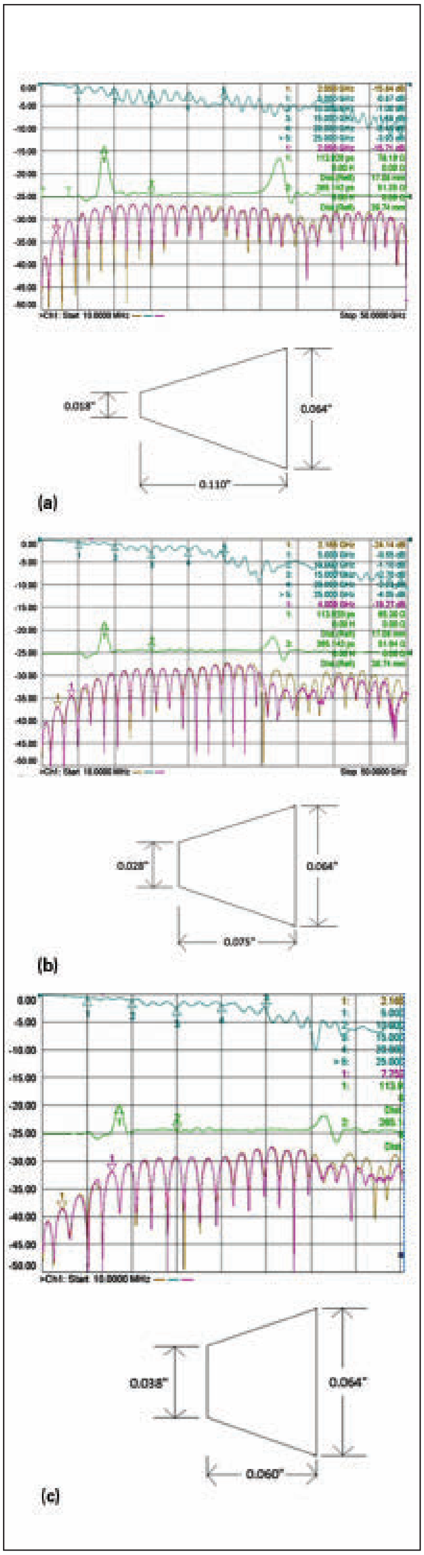

Fig. 4 *Performance of three microstrip circuits with different tapers; the original design having a long narrow taper (a), the taper length reduced (b), and the taper length reduced still further (c).*

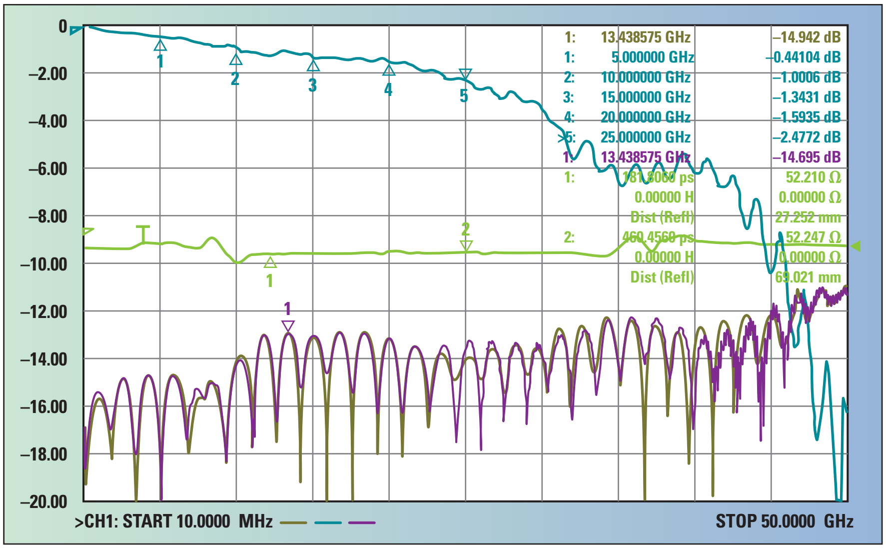

Fig. 5 *Performance that is further optimized.*

mize impedance mismatches in the signal launch area. A rise in the impedance curve is basically due to an increase in inductance while a dip in the impedance curve is due to an increase in capacitance. For the thick microstrip transmission line shown in Figure 2a (assuming a PCB material with a relatively low dielectric constant of about 3.6), the conductor is relatively wide – much wider than the connector's center conductor. With a large dimensional difference between the circuit's conductor and the connector's conductor, there is a strong capacitive spike at the transition. This can often be reduced by tapering the circuit's conductor to form a more narrow transition where it joins with the coaxial connector pin. Narrowing the PCB conductor makes it more inductive (or less capacitive), offsetting the capacitive spike in the impedance curve.

Frequency-dependent effects must be considered. A taper occurring over a long distance provides a greater inductive effect at lower frequencies than a shorter taper. For example, in the case of a signal launch with poor return loss at lower frequencies and having a capacitive impedance spike, a longer taper may be suitable. Conversely, a short taper has a greater effect on higher frequencies.

For a coplanar-launched geometry, the adjacent ground planes can increase the capacitance when they are close to the signal conductor. Frequency-dependent adjustments are often made through the combinations of signal taper and ground plane spacing to modify the inductance and capacitance of the signal launch as required. In some cases, the coplanar spacing is wide over a certain distance of the taper, correlating to some band of lower frequencies. The spacing then narrows at a wider portion of the taper and over a short distance to affect higher frequencies. In general, narrowing the conductor taper adds inductance. The length of the taper affects the frequency response. Altering the adjacent coplanar ground spacing changes the capacitance and the distance of the adjacent spacing influences the frequency band over which the change in capacitance is most effective.

EXAMPLES

Figure 4 provides a simple example. Figure 4a is a thick microstrip transmission line with a long and narrow taper. The taper is 0.018" (0.46 mm) wide starting at the edge of the circuit and over a length of 0.110" (2.794 mm), it transitions to the width of a 50 Ω conductor, 0.064" (1.626 mm). The taper is reduced to shorter lengths in Figures 4b and c. Field-serviceable, pressure-contact, end-launch connectors are used and

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not soldered, so the same connector is used in each case. The microstrip transmission line is 2" (50.8 mm) in length and fabricated on a 30 mil (0.76 mm) thick RO4350B™ microwave circuit laminate, with a dielectric constant of 3.66. In Figure 4a, the blue curve represents insertion loss (S_{21}), with many ripples in the response. In contrast, S_{21} in Figure 4c has the least number of ripples. As these curves reveal, the trend is for improved performance with shorter taper.

Perhaps the most telling curves in Figure 4 show the impedance of the cables, connectors and circuit (the green curves). The large positive peak in Figure 4a represents the connector on the circuit attached to a cable at port 1. The peak on that same curve to the right is the connector at the other end of the circuit. The large impedance peak is reduced with a reduction in taper length. The improvement of the impedance match in the signal launch areas is due to the taper becoming wider as it is shortened, the increase in taper width correlating with a reduced inductance.

An excellent reference on signal launch,[2] which uses this same material and material thickness in its examples, offers some further insight into circuit dimensions in the signal launch area. A coplanar launched microstrip built with its recommendations (see ***Figure 5***) yields performance superior to that of Figure 4. The most obvious improvement is elimination of the inductive spike in the impedance curve, which is actually a mix of a slight inductive spike and a slight capacitive dip. Having the correct taper minimizes the inductive spike, while additional capacitance is provided by the coupling of the coplanar line adjacent grounds in the launch area. The insertion loss curve for Figure 5 is smoother than shown in Figure 4c and the return loss curve is also improved. The example in Figure 4 will have a different outcome for a microstrip circuit on a PCB material with higher dielectric constant, or different thickness, or using a different connector style.

Signal launch is a complex issue and can be influenced by many different factors. This example and these guidelines are intended to assist designers in understanding some of the basic principles. ■

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1. Eric Holzman, *Essentials of RF and Microwave Grounding*, Artech House, Norwood, MA, 2006.
2. Bill Rosas, "The Design and Test of Broadband Launches up to 50 GHz on Thin and Thick Substrates," Southwest Microwave Inc., Tempe, AZ, 2011, www.southwestmicrowave.com.

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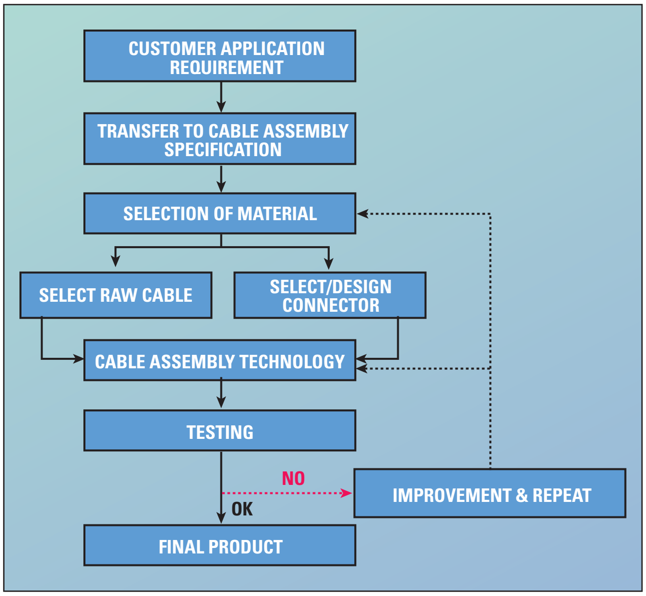
Optimizing Cable Assemblies per Application Requirement

Wei Liu and Da Wenpen
MICable Inc., Fuzhou, Fujian, China

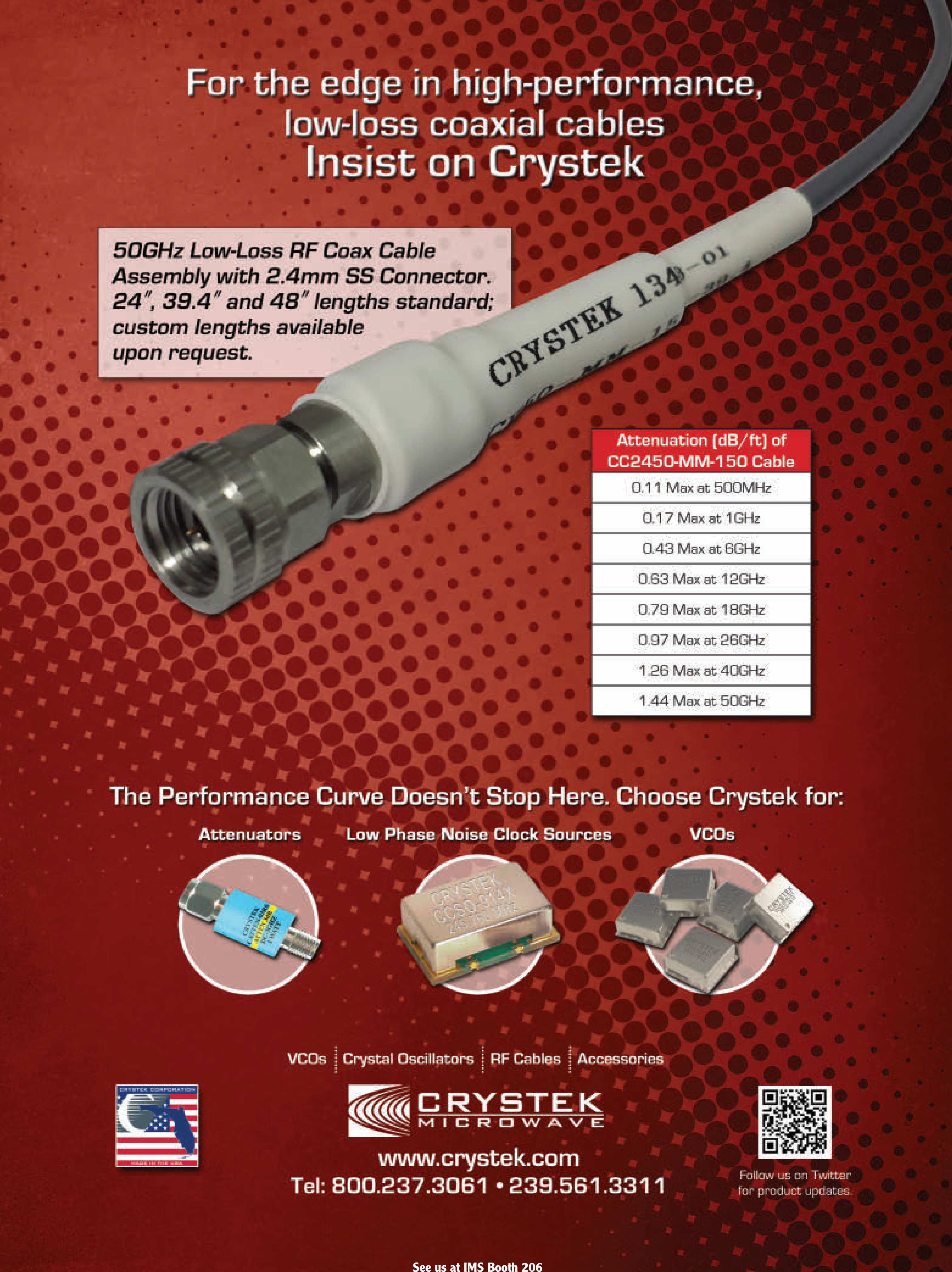
Cable assemblies are some of the most widely used components in military and commercial electronic systems. They are used as connections between components within racks, subsystems, antenna feeds and various test platforms, among many others. Although a cable assembly looks like a very simple component, consisting of just coaxial cable and connectors, in many situations it can be the critical factor determining system performance, reliability and cost. Developing the most suitable and effective cable assembly for a particular application with a reasonable cost can be a challenge to the system or subsystem designer. Good communication between customer and vendor is necessary for the proper choice of cable, connector and assembly technique.



▲ *Fig. 1 Flowchart of cable assembly development.*

The designer/customer must first be able to transfer the requirement and specification for a cable assembly to the vendor/manufacturer. Cable and connector selections are the next steps, possibly with assistance from the manufacturer, to ensure that all requirements are met within cost and delivery constraints. In some situations, existing cable and connectors are not suitable, and custom design may be necessary to meet the specifications. Assembly techniques must also be examined as they may dictate the use of alternative cable or connectors, due to manufacturing issues such as availability, time, cost or quality. Finally, testing must be done at all stages to ensure that the assemblies meet electrical, environmental and reliability requirements. ***Figure 1*** shows a typical development cycle for cable assemblies.

Customers often ask why some vendors make better cable assemblies than others, even though they use identical cable and connectors. Experience and knowledge of proper assembly techniques can be the answer. Modern electronic systems are expensive and complex and need to be dependable so cables should not be a source of any problems with proper selection of components and manufacturers.



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Below are two successful examples showing how cable assemblies were developed for a commercial and military application.

DC TO 26.5 GHz TEST CABLE ASSEMBLIES

Test cable assemblies are among the most difficult to make of all cable assembly demands. In many production situations, test cable assemblies are used multiple times daily and their performance and reliability will directly affect the customers' product performance and cost.

Performance requirements that customers expect for test cable assemblies:

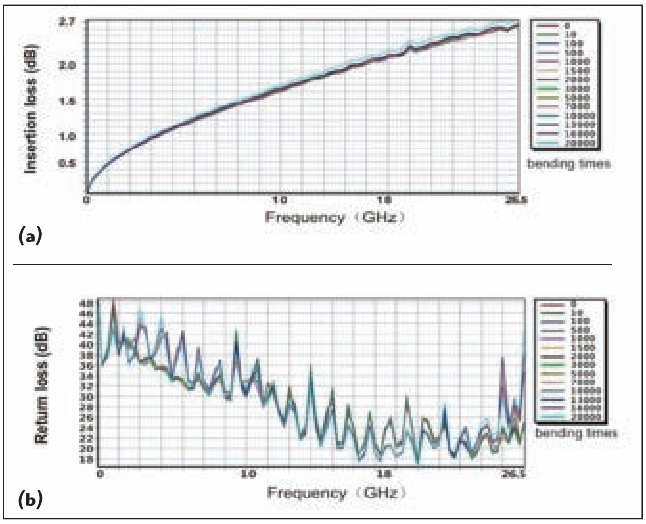
1. Very flexible with small bending radius for convenient use
2. Very small phase change versus flexure
3. Low amplitude/insertion loss change with movement and bending
4. Consistent good performance over time and frequent use
5. Low cost

A good test cable assembly, therefore, needs to be ultra flexible and amplitude/phase stable with a long life and low cost.

The first step in developing a new product is making the decision about product requirements and specifications. For test cable assemblies, the most important specification is phase and amplitude stability with flexure. ***Table 1*** lists the market specifications found in various published materials for test cables.

Considering that the new product should be competitive in the market, the cable assembly should have the following specifications:

1. Equal or better than the best electric performance in the market, better than the specifications listed in Table 1.
2. The cable should have a small bending radius and be very flexible. For this example, it was decided to select 0.195" as the outer diameter of the cable and 1.95" radius mandrel instead of the Table 1 2.25" radius as the test condition for phase and amplitude stability.
3. The assembly should have better reliability and longer life compared to presen- products in the market.
4. The assembly should have a competitive cost compared to present products in the market.



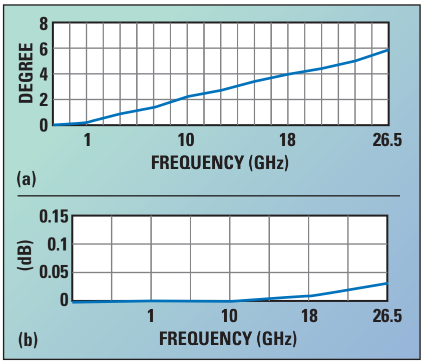
▲ *Fig. 2 Insertion loss change (a) and return loss (b) measured over 20,000 flex cycles (C041 cable, 1 m).*

TABLE I IDEAL SPECIFICATIONS FOR TEST CABLE ASSEMBLIES				
Specifications	**Typical @ 18 GHz**	**Max @ 18 GHz**	**Typical @ 26.5 GHz**	**Max @ 26.5 GHz**
Phase stability with flexure (degrees)	±2	±4.7	±3	±6.6
Amplitude stability with flexure (dB)	±0.05	±0.15	±0.05	±0.15
Note: the above assemblies are 36" long with the cable wrapped 360 degrees around a 2.25" radius mandrel.				

In the process of developing the example test cable assembly, the following steps were taken:

1. Work with the cable manufacturer for special custom designed cables according to the requirements.
2. Improve connector design to a more rugged and easily assembled configuration, so the cable is well protected.
3. Use a stronger connector strain release design so the life of the cable assembly can be extended and the assembly can have a shorter bend radius.
4. Improve assembly techniques to counteract the differential expansion coefficient of the dielectric and center conductor, for better mechanical reliability and electric performance.
5. Develop a complete test method to check the performance as well as the long term reliability.

The example DC to 26.5 GHz test cable assembly uses a custom designed cable with 0.195" outer diameter, soft and flexible PVC jacket, solid PTFE dielectric and improved braid layer design. The rugged connectors, special strain release design and improved assembly technique were used in the new cable assembly. This process of cable assembly design and manufacturing produced a new cable that meets all of the requirements. Listed in ***Table 2*** is the test data of the new cable assembly and ***Figure 2*** is a plot of the change in insertion loss and return loss over 20,000 bend cycles showing little change over the entire frequency range to 26.5 GHz.



▲ *Fig. 3 Phase stability (a) and amplitude stability (b) versus flexure.*

TABLE II DATA FOR C041-01-01-1M CABLE ASSEMBLY DURING BENDING UP TO 24,000 TIMES				
# of Bending Times	S11/S22	S12/S21	Insertion Loss Change*	Phase Change*
0	18.56/19.13	2.63/2.65	0.04	4.63°
1500	18.38/19.97	2.61/2.61	0.03	4.89°
3000	18.43/18.57	2.58/2.63	0.03	4.45°
4500	17.92/18.78	2.58/2.63	0.03	4.51°
6000	19.13/17.85	2.64/2.68	0.04	4.77°
7500	18.91/17.66	2.67/2.69	0.04	4.58°
9000	17.72/19.12	2.61/2.63	0.03	4.64°
10500	18.83/17.74	2.69/2.69	0.05	4.95°
12000	18.83/17.67	2.68/2.67	0.04	4.44°
13500	19.00/17.20	2.64/2.66	0.05	4.85°
15000	19.21/17.24	2.69/2.69	0.03	4.72°
16500	19.18/17.66	2.61/2.62	0.04	4.77°
18000	18.93/17.71	2.70/2.68	0.05	4.46°
19500	19.20/17.57	2.67/2.75	0.05	4.81°
21000	19.21/17.49	2.75/2.71	0.04	4.50°
22500	19.22/17.57	2.73/2.75	0.03	4.39°
24000	18.93/17.67	2.67/2.73	0.05	4.75°

* The above data is from a 36" long assembly with the cable wrapped 360° around a 1.95" radius mandrel.

TABLE III PERFORMANCE OF C04I-01-01-1M AFTER TEMPERATURE CYCLES (-55° TO +85°C, DC TO 26 GHz)				
	No. 1 Cable Assembly		No. 2 Cable Assembly	
Number of Cycles	Insertion Loss (dB)	Return Loss (dB)	Insertion Loss (dB)	Return Loss (dB)
0	2.67	18.9	2.78	19.6
25	3.11	18.5	3.18	19.60

Phase and amplitude stability plotted in ***Figure 3*** show that a 36" long cable has phase stability less than 4° and 6° with the cable wrapped around a 1.95" radius mandrel at 18 and 26.5 GHz, respectively, with amplitude stability of 0.03 dB max. The data shows that after up to 20,000 bending cycles, the return and insertion loss plus the phase and amplitude stability exhibit little change. The cable also shows good electrical performance with the same tests after 25 temperature cycles between -55° and +85°C (see ***Table 3***). The bending machine used for exercising the cables is shown in ***Figure 4***.

PHASED ARRAY RADAR APPLICATION

Phased array radar has become an important product around the world but has inherent problems for cable assembly manufacturers. Large numbers of assemblies are needed with close phase matching, making the specifications difficult to consistently reproduce.

When system engineers select cable assemblies for phased array systems, the following requirements are needed:

1. The cable needs to have low loss, high power capability and close tolerances.
2. The cable must meet excellent phase matching specifications, with little phase change while bending, during vibration, and with temperature fluctuation.
3. Phase matching requirements are needed for large quantities.

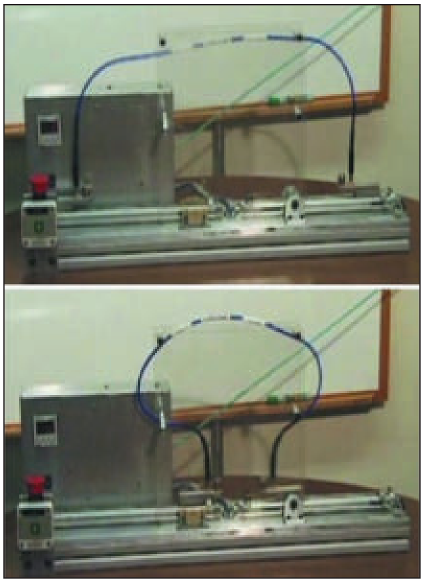
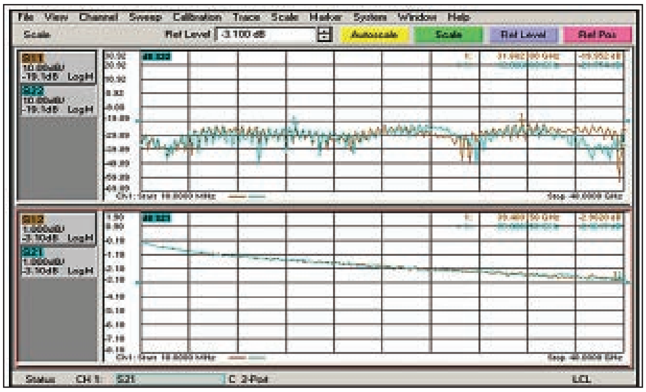


Fig. 4 Bending machine for performing cable flexure.

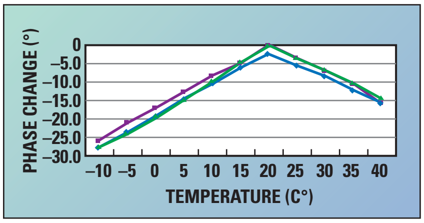
Airborne phased array system manufacturers state that their biggest problem is phase mismatching during rapid altitude change. Calibration will not correct this issue and cable assembly manufacturers have had a hard time correcting this problem. In addition, phase tracking over temperature is an equally important specification that the system engineers should require for the product. Many system engineers incorrectly emphasize the cable's phase stability over temperature instead of phase tracking. A tight phase tracking specification is the correct goal to achieve good phase matching over wide altitude and temperature variations. Making good phase tracking cable assemblies is a big challenge, requiring strict consistency in materials and manufacturing techniques.

Cable assembly manufacturers should have the following capabilities to properly address the problems in phased array systems:

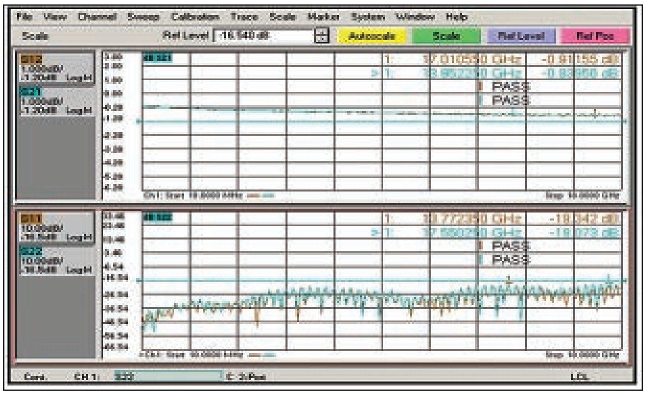
1. Helping the customer select the cable that is most suitable to the application.



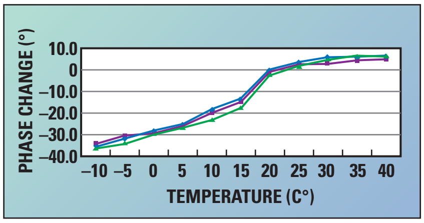
▲ *Fig. 5 B01-40-40-1M test data from DC to 40 GHz.*



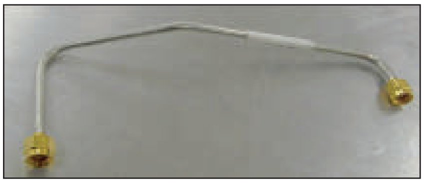
▲ *Fig. 6 B01-40-40-1M phase tracking versus temperature.*



▲ *Fig. 7 A04I-01-01-1M test data from DC to 18 GHz.*



▲ *Fig. 8 A04I-07-07-1.5M phase tracking versus temperature at 18 GHz.*



▲ *Fig. 9 Semi-rigid phase matching and tracking cable assembly.*

2. Producing high performnce phase matching and tracking cable assemblies, with the ability to produce large numbers of consistent assemblies.
3. Strictly controlling the consistency of the materials and manufacturing techniques so that the specifications of phase and amplitude can be met during variations in environmental conditions.

A set of comprehensive methods was developed, including cable evaluation, connector design, manufacturing and assembling techniques, and inspection and testing procedures, in order to produce products that met this type of application's requirements. Cable was chosen from a well known supplier, QPL approved, that previous experience had shown high standards. Connectors were designed and tested thoroughly. To control quality and consistency, inspection after every process was emphasized and workers trained to IPC J-STD-001 and IPC/WHMA-A-620 standards. Rapid phase correcting techniques were developed and computerized semi-rigid bending machines, fast and precise stripping equipment and PNA vector network analyzers were utilized. Quality management systems according to MIL-I-45208 and MIL-STD-2219 were used, along with ISO 9001 and China GJB-9001B-2009 standards.

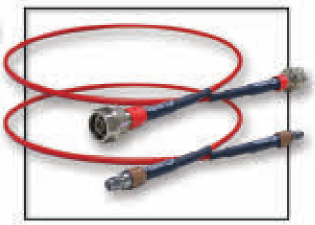
Figure 5 shows the test data for three phased array cable assemblies (B01-40-40-1M) from DC to 40 GHz with insertion loss of 2.97 dB max., VSWR of 1.23:1, phase stability vs. flexure of ±8° at 40 GHz (bend radius: 51 mm), and phase stability vs. temperature of 500 ppm max. @ -40° to ~+85°C. ***Figure 6*** shows the measured phase tracking plots for these cables' phase tracking with a max. phase change inconsistency of 1.6° for every 5°C from -10° to 40°C for three different cable assemblies.

Figure 7 shows the test data for 3 DC to 18 GHz cable assemblies (A04I-01-01-1M) with insertion loss of 0.91 dB max., VSWR of 1.25:1, phase stability vs. flexure: ±5.4° at 18 GHz (bend radius of 76 mm), phase stability vs. temperature 250 ppm max. @ +22° ~+100°C, and power handling of 600 W at 10 GHz. ***Figure 8*** shows the phase tracking data for (A04I-07-07-1.5M) at 18 GHz with a max. phase change of 3.8° for every 5°C from -10° to 40° for three different cable assemblies.

Finally, bent phase matching and tracking semi-rigid cable assemblies were manufactured with a minimum bending radius of 6 mm with phase match ≤1° at 2.3 GHz, phase tracking ≤1° at 2.3 GHz. Manufacturing was able to deliver 1400 pieces in two weeks (see ***Figure 9***). As the data shows, the temperature tracking performance of the cable assemblies was tightly controlled. The cable assemblies have good consistency, proving the capability to offer good temperature tracking performance over volume production.

CONCLUSION

As the commercial and military markets demand higher performance and more reliable cable assemblies, a good combination of cable design and assembly techniques are more important than ever before. The cable assembly designer/engineer must understand the customer's application and know how to transfer the application demand to the requirement of the cable assembly. The cable assembly manufacturer must then be able to source the proper components, assemble them with advanced techniques and equipment and be alert for changes to meet the specifications and requirements of the project. Good communication between all is absolutely necessary – good teamwork is a must. ■



Reliable Cable Assembly Performance Over Time

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W. L. Gore & Associates Inc., Landenberg, PA

In today's competitive electronics industries, reliability is essential for applications that use microwave/RF cable assemblies to ensure consistent, repeatable measurements and to maintain electrical performance over time. Therefore, cable assemblies must be durable enough to withstand continuous movement, flexing and exposure to environmental conditions while still maintaining reliable electrical performance.

A recent study[1] showed that globally more than 75 percent of microwave/RF cable assemblies are replaced frequently (see ***Figure 1***). These assemblies were replaced for a variety of reasons, including damage during installation or use, poor quality construction, connector termination issues or failure when exposed to outdoor environmental conditions. However, the most common reason by far was damage during installation or use. The study found that overall, 36 percent were replaced once a year and 20 percent were replaced at least twice a year. As a result, equipment manufacturers are experiencing delays in production schedules, increased troubleshooting and maintenance, more frequent calibration, additional retesting, compromised system performance, and higher overall costs to purchase replacement assemblies.

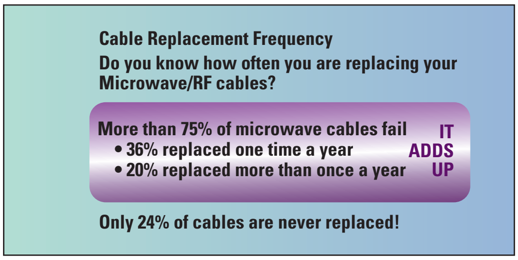


Fig. 1 Summary of cable replacement study.[1]

In addition, the impact of replacing cable assemblies varied in different regions. The study showed that in the United States, 70 percent of equipment manufacturers are replacing their cables frequently, with 35 percent being replaced at least once a year and 12 percent being replaced once a quarter. In Europe, 49 percent of equipment manufacturers had to replace their cables once a year. However, the most significant impact was in Asia Pacific with 32 percent of cables replaced once a year, 21 percent replaced once a quarter, and 11 percent replaced at least monthly. The study further indicated that the industry expects

microwave/RF cable assemblies to last a very long time — years rather than months, even lasting longer than the life of their system.

DURABILITY TESTING

W. L. Gore & Associates (Gore) evaluated the durability and performance over time of several microwave/RF cable assemblies typically used in the industry. The cable assemblies selected were described as having a ruggedized construction (including GORE® PHASEFLEX® Microwave/RF Test Assemblies). While many cable assemblies perform well out-of-the-box (see ***Figure 2***), the study wanted to evaluate how cables with similar specifications performed after repeated use, and whether their performance changed or remained stable.

When tested under the same criteria, the results[2] showed that the failure rate of cables across the industry varied significantly. For example, in an accelerated life test simulating real-world conditions such as flexure and handling, some cables failed in less than 25 days, but others continued to perform after seven years. The testing also showed that the internal construction of some cable assemblies physically changed (i.e., stretched and distorted) after repeated use, which compromised their electrical performance. However, others performed significantly better over time without any physical changes, which means that these cable assemblies maintained electrical integrity in environments where the others failed (see ***Figures 3*** and ***4***).

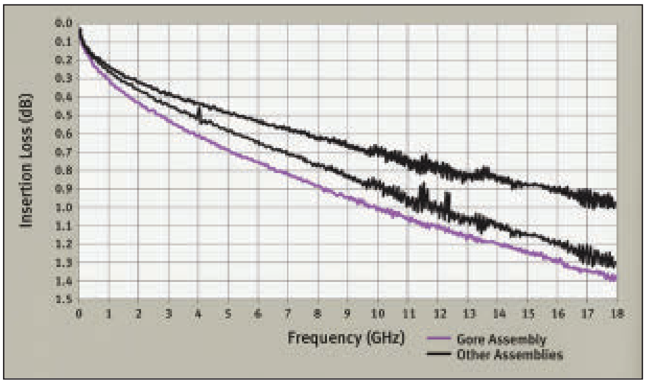


Fig. 2 Out-of-the-box cable assembly performance comparison at 18 GHz.

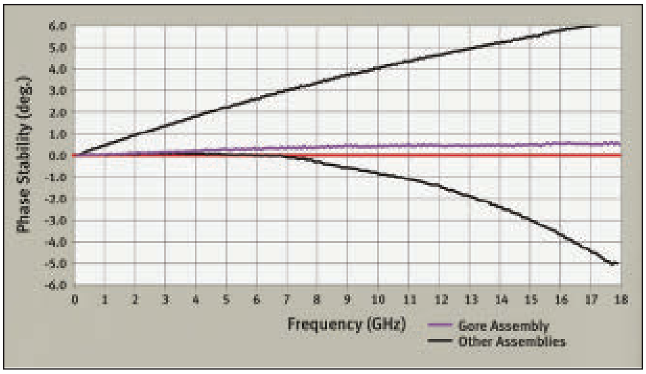


Fig. 3 Cable assembly phase stability with flexure comparison at 18 GHz.

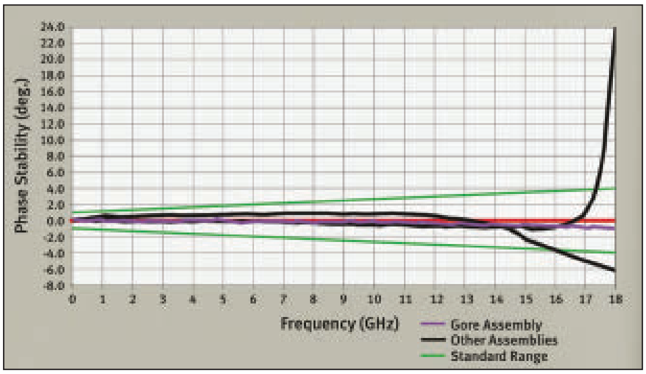


Fig. 4 Cable assembly phase stability over time comparison.

TOTAL COSTS OVER TIME

It is important to consider the cost implications when selecting the right cable, as the consequences of cable failure and replacement can be quite high. The total cost of ownership should include installation, maintenance, manufacturing downtime and replacement cables. So, how much money can you really save by making purchasing decisions based solely on the initial price of a microwave/RF cable assembly?

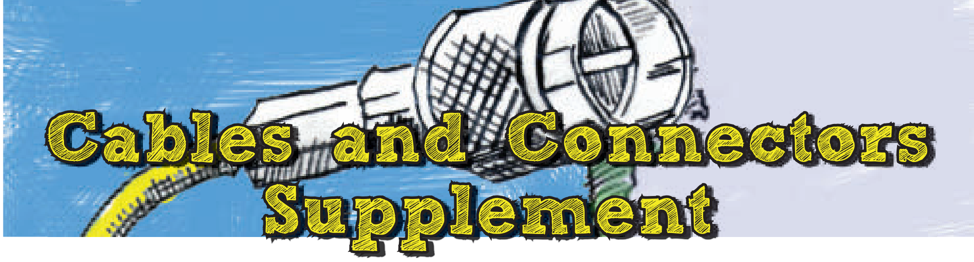
Based on this testing, one could spend more money and resources in replacing lower-cost cables that do not survive the test of time. Using a real-world example, assume a system requires four cables, and you are using cables that are replaced every 25 days. Over the ten-year life of the system, you will be purchasing approximately 600 new cables. If the average cost of a cable is between \$200 and \$400, it will cost between \$120,000 and \$240,000 to replace the cables over 10 years. However, if the cables used last more than seven years, then they would only need to be replaced once.

And these totals do not include the additional costs due to downtime, maintenance, recalibration and retesting. In some industries, these additional costs can far exceed the direct purchase cost. For example, a chip manufacturer has estimated that its downtime costs can exceed \$50,000 per hour. Therefore, one should complete a similar cost analysis to consider the full impact of cable failure and replacement before selecting microwave/RF cable assemblies.

SELECTING THE RIGHT CABLE

It is critical to select a cable manufacturer that understands the challenges of the application, because demanding environments can easily compromise a cable assembly's signal integrity, reliability and performance over time. Therefore, it is important to evaluate the electrical, mechanical, and environmental challenges that will affect an assembly's performance in the specific application. Some key things to consider when selecting microwave/RF cable assemblies include:

- **Reliable Performance** — The user should consider electrical performance first because various factors can compromise signal integrity, such as electromagnetic interference, crosstalk, attenuation and conductor resistance. Mechanical



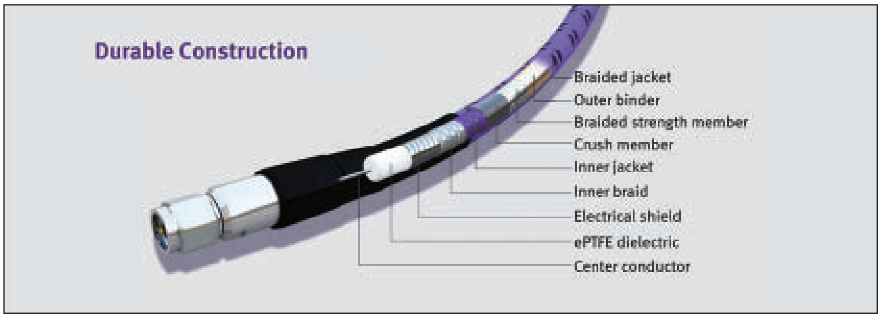


Fig. 5 Example of durable cable construction.

stress is also important to consider; factors such as vibration, frequent flexing and potential damage during installation and maintenance can physically change the cable and affect electrical integrity. The cables must also maintain reliable performance in environments in which they will operate, such as extreme temperatures, radiation, exposure to harsh chemicals, and even rapid altitude changes encountered during take-off and landing of an aircraft. The most important consideration is having the cable manufacturer evaluate electrical performance while simulating mechanical and environmental stress similar to that in your application.

- **Durable Construction** — To reduce cable replacements, be sure to choose cables that withstand installation and handling, provide low insertion loss, ensure phase and amplitude stability, and maintain electrical and mechanical integrity during use. Materials used in microwave/RF cable assemblies are key to their electrical and mechanical performance. For example, internally ruggedized cables that have a small bend radius and enhanced tensile strength are more flexible and easier to route without damage. In addition, engineered fluoropolymers can enhance the durability of microwave/RF cable assemblies in a variety of challenging environments as shown in ***Figure 5***.
- **Application Specific Constraints** — Cable assemblies should also be evaluated for the constraints within your specific application, such as the need for small, lightweight cables that reduce mass and increase fuel efficiency in the aerospace industry. In the test and measurement market, portable analyzers are increasingly being used to facilitate testing out in the field. These analyzers need microwave/RF cable assemblies that can withstand extreme environmental conditions, as well as frequent handling during use. Cables that have a longer service life can reduce the need for maintenance and equipment downtime, resulting in lower costs for testing in laboratory, production and field test environments.

Having to replace cable assemblies frequently is costly. Not only does the overall purchasing cost increase, but companies can often experience a much greater impact from delayed production schedules, compromised system performance and additional retesting and calibration. The out-of-the-box performance of microwave/RF cable assemblies does not necessarily ensure reliable performance over the lifetime of a system. Choosing a cable assembly with a durable construction that has been tested to survive real-world conditions is the key to reducing replacement costs and the only way to ensure reliability over time. ■

References

1. This study was compiled and published by the Penton Design Engineering & Sourcing Group.
2. For more information, visit www.gore.com/test to download a white paper describing the test methods and results.

Passive Intermodulation Characteristics

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The art and science of radio hardware design has been to some degree about minimizing, avoiding and, if possible, altogether eliminating unwanted spurious signals that find their way into the receive path of a radio. Typical sources of such signals are usually the multitude of two or more terminal devices that contain active semiconductor junctions such as diodes, transistors and ICs made up of them. These junctions with their nonlinear current voltage characteristics can be a rich source of harmonics and various intermodulation products, especially if more than one signal is present across them. Though magnetic materials commonly encountered in electronic circuits of most kinds are also a potential source of such nonlinearities, these components are usually used in blocking low level, low frequency ripples and occasional spikes in voltage or current and rarely interfere with communication signals unless poorly designed and selected.

One exception is the RF ferrites in the form of isolators and circulators. Such components, usually preceded by amplifiers, will generate and contribute to the harmonic and intermodulation content present in the outputs of such circuits. In a typical telecommunication system, such unwanted spurious signals will be eliminated and blocked before they have a chance to leak back into the receiver. Voluminous standards exist to ensure that such interferers are always well controlled and contained. Most RF engineers are usually well aware of these issues. These effects can be modeled and the theory behind them is well understood, so such nonlinear signal products can be analyzed and managed relatively easily.

There is another type of signal distortion that has become a great concern in wireless applications recently and that is passive intermodulation (PIM). This is the kind of intermodulation that is generated by passive components and interfaces. It is counterintuitive for most engineers and designers that totally passive components can produce intermodulation products, but they do and can degrade operation of advanced wire-

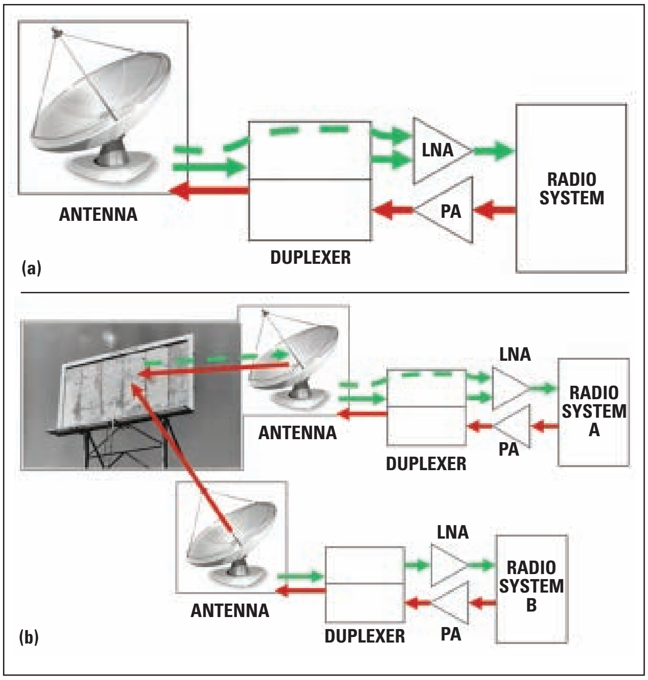


Fig. 1 *Shared apertures with multiple carriers can cause PIM to appear in the receiver of a duplex system (a) and external PIM generated beyond the antenna, either in combination with another transmitter or by reflection of the mixed transmit signal of the same transmitter by a nearby PIM generating object/obstacle (b).*

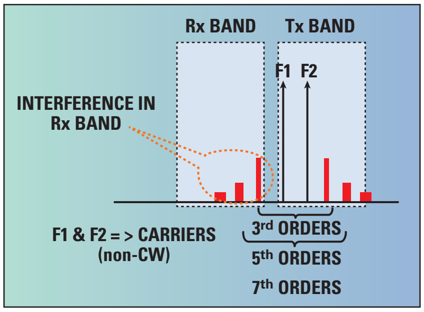


Fig. 2 *Odd-order IM products fall near the carriers themselves, sometimes within the Rx band of the same or another operator and cannot be filtered (note that IM bandwidth is n times the bandwidth of the fundamental tones for non-CW signals).*

less services and even block radio links altogether if not controlled and managed properly.

WHAT CAUSES PIM?

It is important to understand that typically there is no single and unique source of PIM and this is a general term for a whole category of intermodulation phenomena caused by passive elements in the path of an RF signal. It is also true that at the microscopic level, the actual process of PIM generation is still poorly understood. We know, for example, that poor contacts are the most common source of PIM. Poor contact may mean connectors not torqued to proper limits or poor quality of mating surfaces which may be the result of poor surface finish as well as presence of any contaminants such as flux, oxidation or loose particles. These result in mildly nonlinear contacts as opposed to clean ohmic ones. Dissimilar metals in contact may create diode-like effects also. Ferromagnetic material or coatings as well as certain types of PCB designs, metallization schemes and certain dielectric materials and coatings can generate PIM too.

Electro-thermal effects can cause PIM as well. Electro-thermal conductivity modulation in resonant structures like filters and antennas is very different in nature than other types of PIM since there are no dissimilar metals or even junctions or contacts involved.

When the antennas are also part of the consideration, then "external" PIM that is produced and introduced beyond the transmit antenna when single or multiple antennas reflect strong signals from nearby metallic structures is also a possibility. This is true for both indoor and outdoor installations.

As can be surmised from above, there are a wide variety of causes for PIM, from basic component design to quality of assembly and installation, and all will exist and contribute to total PIM at some level. It is important to realize that it may be unnecessary or even impossible to eliminate

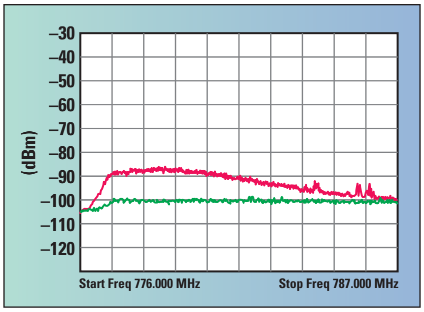


Fig. 3 *Rise in the noise floor of an LTE receiver due to PIM when the transmitter is turned on.*

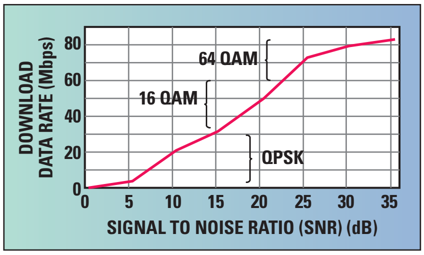


Fig. 4 *Downlink data rate in modern wireless systems is dependent on the signal to noise ratio at the receiver.*

PIM altogether but it is critical that it stays below a certain level at locations where it may impact the receiver sensitivity.

WHAT IS THE PROBLEM?

The detrimental nature of PIM to radio reception has been well known for a long time by radar and satellite earth station engineers due to the shared antenna apertures for very strong transmit and very weak receive signals (see ***Figure 1***). This also explains why PIM is typically a concern for infrastructure equipment and not for the user equipment.

At the point or points of PIM generation along a transmit chain, the generated intermodulation products and energy will travel in both forward and reverse directions. If there is a path back to the receiver and if PIM has components in the passband of the receive chain (see ***Figure 2***), then some of this energy will be mixed in with the actual receive signal as excess noise, as shown in ***Figure 3***. In essence, PIM is always present in any RF system but the degree of it and where it ends up is the concern for good radio operation.

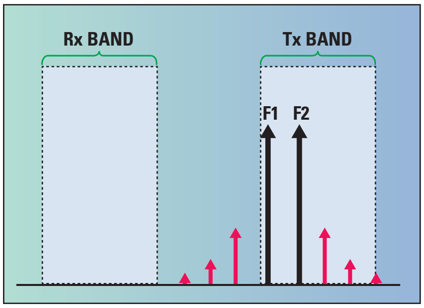


Fig. 5 Many times the IM products generated will not fall into the Rx band, or those that do will have very high orders and negligible power.

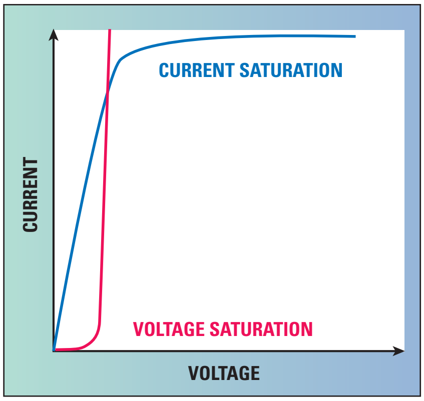


Fig. 7 Unlike an amplifier where the source of nonlinearity is the current saturation, most of the nonlinearities that generate PIM are caused by voltage saturation due to imperfect contacts.

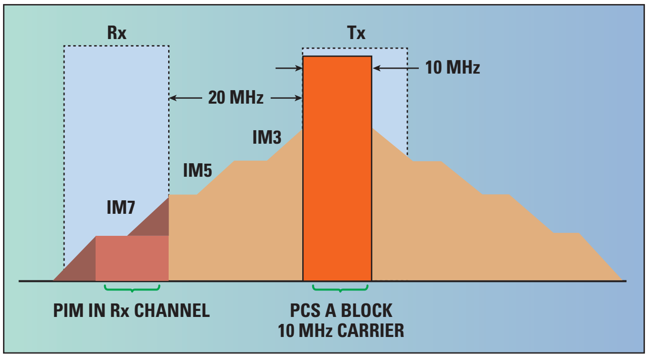


Fig. 6 When broadband signals are involved, it does not take two carriers to generate PIM. A single broadband carrier will generate its own PIM also.

Use of an increasing variety of wireless bands and the need to share antennas to minimize non-recurring as well as recurring cost of wireless antenna installations, not to mention esthetic concerns, have exasperated PIM-related problems in recent years. In addition to shared antenna and other infrastructures, proliferating in-building wireless (IBW) systems, mainly distributed antenna systems (DAS), which also combine and consolidate high power macro base stations, small cells or repeaters create more opportunities for PIM problems. Also contributing to the problem are the higher data rates and the complex modulation schemes that enable them. High data rates are achieved only under good SNR conditions, where either the desired signal is strong with respect to all other noise and interference, or such noise is very small (see ***Figure 4***). So while coverage is critical, good signal quality is just as critical now.

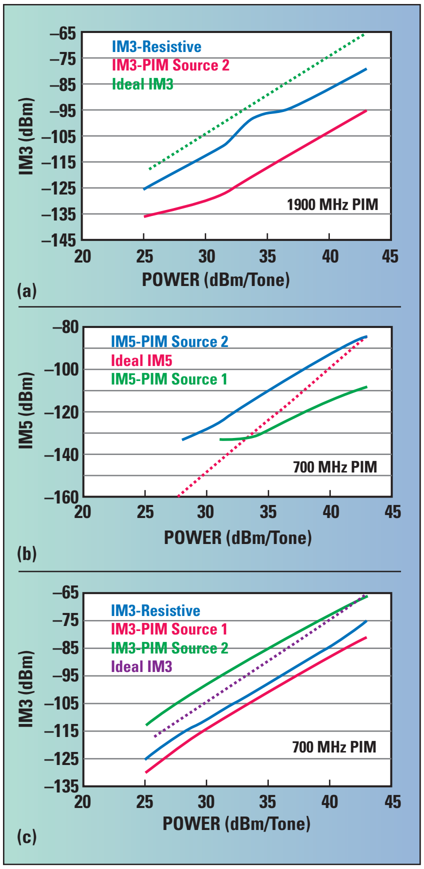
Consequently, any PIM in the receive band that will raise the noise floor, especially in a 4G receiver, and will be detrimental to receiver operation and achievable data rates. Note that not all PIM, even high levels, presents a problem for the receiver if it is blocked or out of the band of operation, as shown in ***Figure 5***. It is also possible for a single broadband carrier to generate its own PIM due to self-mixing without a second carrier present (see ***Figure 6***).

PIM CHARACTERISTICS

The very presence of PIM points to a nonlinearity in the signal path, of course. Thus we have to reach in our tool box of nonlinear analysis to understand, quantify and, most importantly, specify acceptable PIM levels in a system and for individual components used. Similarities to other types of nonlinearities, that we are all so familiar with in the RF world, can be misleading if relied on beyond the basics. Where the nonlinear theory is very precise and helpful is identifying where to expect the PIM signals to appear given the presence of the interacting high power signals/carriers. Regardless of the type and source of nonlinearity present, there will be odd- and even-order intermodulation products when anything other than a single CW tone is forced into the system. Thus we can precisely determine where the PIM will appear given a knowledge of the carrier frequencies. In a typical telecommunication application, it would be the third and other odd-order products that would be of interest.

The problem is our trusted nonlinear analysis and methods would be of little use in predicting typical PIM amplitudes. The sources of nonlinearities that cause PIM are not the semiconductor junction types we are more familiar with as previously discussed. Sources of nonlinearity may be a poor interface and ohmic contact. Current flow through such surfaces may involve tunneling type conduction. This is a very mild type of nonlinearity, closer to ohmic than a usual semiconductor junction (see ***Figure 7***). There may be millions of such contacts in parallel with true ohmic contact points present in two contacting surfaces, thus creating a collective nonlinearity that is highly dependent on pressure, temperature, signal amplitude itself and maybe even time. It would be hard to expect such a system to follow a single power law. Note that the mechanism is not one of saturation either. To make matters worse, while some PIM sources are point sources, well localized, some are distributed. Various orders also add and cancel as a function of frequency and tone/carrier separation. Consequently, one cannot and should not make extrapolations that are typically made with better behaved nonlinearities, such as quantifying the nonlinearity and PIM by an IP3 of the system. Due to combined effects described above, it is not very unusual to observe 5th or 7th order PIM to have a higher observed power level than 3rd for example.

Data clearly indicates that PIM rarely follows the typical odd-order power law. For each dB increase in incident RF (tone) power, one rarely observes a 3 dB increase, or a 3:1 slope for IMD3, which nominally would be the strongest component (see ***Figure 8***). More commonly, the observed slope lies somewhere between 1.5:1 to 2.7:1. It is also likely to be very frequency dependent. So, IP3 turns out



▲ *Fig. 8 IM3 vs. power for two different devices compared with ideal at 1900 MHz (a), IM5s do not follow 5:1 slope either (b) and typical PIM IM3 rises 1.5-2.5:1 (c) (most setups are limited to near –140 dBm measurement by noise floor).*

to be a rather meaningless parameter in quantifying and specifying PIM. Similarly, one should not expect PIM to decrease by 30 dB (IMD3 component) because the RF excitation is 10 dB lower and vice versa. It rarely works that way in practice. The same applies to higher orders too, as seen in Figure 8b.

AVOIDING PIM

The best method of assuring good PIM performance is to obviously start with guaranteed low-PIM components in the first place. Second, try to specify PIM as close to working conditions and power as possible to avoid needlessly expensive solutions. Given the infinite variety of conditions these components, subsystems and systems are used in, it is difficult to make up an all-encompassing standard. The closest we have to a standard is the IEC 62037-1 and -4 that specify the conditions for testing PIM and specifically in cables and connectors. These documents "recommend" the use of 2 × 20 W CW tones leaving the choice of frequencies and separation to the user per the needs of the system in use. These standards make no mention of the allowed maximum PIM level either. Again this is left to the discretion of the system designer or maintenance engineering since depending on the application and location, the requirements may vastly vary.

Meanwhile industry has developed ad hoc specifications for PIM, mostly based on field tests and trial and error. A maximum PIM level of –110 dBm in the receive band is usually what is desirable in many cases, especially when BTS interfaces are involved. Many component vendors aim for –118 dBm or better depending on the type of component. Given the standard test level of 43 dBm per tone (CW), this corresponds to a –153 dBc of PIM level. Note that it may be hard to relate this analytically to an ideal state-of-the-art receive sensitivity of around –120 dBm since these are defined for specific bandwidths and for CDMA/OFDM type signals that resemble anything but CW.

One of the drawbacks of a fixed power testing per IEC is its unsuitability to lower power applications. Designing and manufacturing a passive component or assembly for a 2 × 20 W test when, let's say, the application is only 2 W, results in a costly and heavier solution than required. In the absence of a standard and accepted guideline, some users are inclined to stick with the 2 × 20 W test requirement which results in significant cost increase for the product. Even when the test requirement is pulled back to 2 × 2 W for example, the false expectation is for the PIM performance to be 30 dB better, around –140 dBm based on traditional IP3 analysis. This level is about –173 dBc from the test tone, the reliable measurement limit of many of the state of the art test instruments. It gets even worse if the PIM of specific interest is 5^{th} or 7^{th} order and one tries to apply textbook power laws. Then the requirement exceeds what is physically measurable. In Figure 8b, when reducing power down to 1 W per tone for example, the actual IM5 measured is about 25 dB higher than what a simple 5:1 extrapolation would predict. It is possible to lower PIM for a component to such low levels by careful design, numerous iterations and very well controlled manufacturing process, but it is unlikely to obtain a reasonable yield for commercial applications, in addition to being unnecessary for proper system operation. So there is an obvious need to rethink the PIM specifications as the base stations get smaller and power outputs get lower.

Some of the confusion can directly be traced to the convention of specifying PIM as a relative measure in dBc rather than an absolute. This has become a defacto standard method of PIM measure. In reality and practice, a radio receiver responds to power, not dBc. Sensitivity of the radio does not typically change with PIM or other low-level interference. Since in practice, power levels impinging on an aperture may vary from system to system or for different installations, one could, in theory, adjust the required dBc value based on 2 × 20 W measurement and establish the requirement appropriate for the actual power levels. This would be straightforward only if PIM behaved according to a known power law. It does not, as shown in Figure 8. So while higher power level components and systems are tested with a standard level of 20 W tones, which is likely to be a good figure of merit, lower power system specs still remain open to interpretation and requires better knowledge of specific operating conditions and receiver sensitivity requirements. Otherwise, trying to extrapolate from 2 × 20 W tests to lower power levels, without considering the actual absolute power levels involved and required, will result in unrealistic component and subsystem requirements which will drive the costs up and yields down. ■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Compact and Reliable 4.3-10 Connector

HUBER+SUHNER AG
Herisau, Switzerland

The choice between classical interfaces such as 7/16, N or 4.1/9.5 connectors and the new 4.3-10 interface can make a significant impact on how a particular network will perform. There are several considerations to make when choosing a connector, including the network design and the choice of the mobile telecommunications system used.

Because Long Term Evolution (LTE) networks feature an increased mobile data rate of 100 Mb/s, this higher transmission rate will expose PIM vulnerabilities in today's networks with frequency division duplexing. 4G networks require superior network transmission fidelity, higher than previous generations. Network operators also face the challenge of maintaining customer loyalty in an unforgiving competitive arena. As such, good network PIM performance and PIM testing are now imperative. Indeed, the 4.3-10 connector satisfies the requirement of very low PIM performance and compactness, fitting into a 1" (25.4 mm) flange and being up to 60 percent lighter than some RF interfaces.

FEATURES AND BENEFITS

A key feature of this connector is the separation of the electrical from the mechanical plane. This implies another way of contacting the outer contact. The front contact force that is needed for interfaces like 7/16, N or 4.1/9.5 is not needed for the 4.3-10. That is because the contact is realized radially, which requires a lower force for the maximization of the contact points.

The decoupling of the electrical from the mechanical plane means there is no need for a high torque value to achieve high electrical performances. Besides the screw version, the design can offer a hand-screw solution or a push pull design because of this feature. The coupling mechanism does not influence the PIM or return loss performance and all the three configurations – screw, hand-screw or push pull connectors (shown in ***Figure 1***) perform the same. For better handling during installation, the hand-screw or push pull versions make it possible to rotate the cable and still have a secure connection.

The 4.3-10 connector interface is characterized by protected contact surfaces, thus making the connector more robust and even if not handled with the greatest care, it is possible to have optimal PIM performance. All three coupling mechanisms can meet the same universal jack (female), giving absolute flexibility to the end user to install the plugs (male) in the most convenient way. For those customers who prefer tool-less solutions, the hand-screw or push pull connectors are the best choice. The installation is very simple and intuitive and is espe-

Fig. 1 The 4.3-10 connector is available in hand-screw, screw and push pull versions.

cially suitable for multiple installations in very tight spaces.

As mentioned, the dimensions of the 4.3-10 connector enable the coupling to fit in a 1" flange, thus offering the opportunity to design high density modules. Also, the fact that the hand-screw and push pull type require no torque wrench renders possible the option to reduce the pitch itself to 1". Since only low or no torque is required, the board panel can be designed to be lighter and thinner.

APPLICATIONS

Due to its properties, the 4.3-10 connector is suitable for numerous applications. For instance, in new base stations, the 4.3-10 can be used for interconnections in the remote radio head as well as an interface on the antenna and on the jumpers. The connectors can be used in multi-operator, multiband distributed antenna systems (DAS) where RF signals have to be combined, terminated or distributed to the antenna, as well as in small cell applications where it is particularly suitable for meeting the challenging space restrictions and electrical performance requirements.

With wireless data use increasing rapidly, network infrastructure, both in-building and outdoors, must support good coverage and bandwidth in order to handle and transport such large amounts of data. Also, signals of different wireless operators with different frequencies have to be accommodated and re-distributed to provide the best coverage without mutual interference. Therefore, signal quality and reliability is becoming a feature of differentiation for operators.

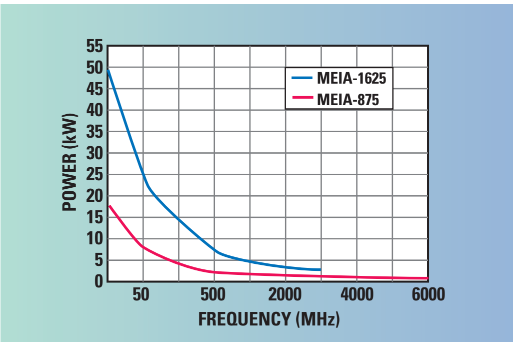
With today's requirements for RF connectors such as compactness, robustness, easy installation and very reliable electrical performance, the 4.3-10 connector, with its excellent electrical performance independent of the torque applied, innovative and multiple coupling mechanism and compactness, provides significant customer benefits and therefore competitive advantages in communication systems.

HUBER+SUHNER AG, Herisau, Switzerland, +41 71 353-4111, www.hubersuhner.com.

The Next Generation in High Power RF Transmission

TRU Corp.
Peabody, MA

TRU Corp. has introduced the latest innovation in high power connector design with the MEIA™ series interface. MEIA connectors and cable assemblies provide an innovative solution to common issues experienced in coaxial high power RF transmission. Higher power applications exceeding 5 kW begin to eliminate practical use of standard 7-16 and LC connector interfaces that do not have the required power handling or design margin in frequencies above 100 to 200 MHz. MEIA-1625 will handle approximately three times more power than a 7-16 interface and two times greater than an LC, up to an operating frequency of 3 GHz (see ***Figure 1***). Traditionally, engineers have turned to EIA 7/8 or EIA 1-5/8 connectors to handle these high power requirements but were faced with a set of different challenges regarding size, weight and the difficulty of hand fastening the flanged interface with bolts and nuts.



▲ *Fig. 1 Power handling of MEIA-1625 (blue) and MEIA-875 (red) connectors (interface only, 25°C, sea level, matched load).*

The MEIA interface provides equivalent kW power handling compared to similar EIA connector line sizes but provides a 30 percent smaller and 40 percent lighter form factor with a high efficiency, threaded coupling mechanism as shown in ***Figure 2***. This threaded cou-

pling eliminates the issues inherently found in mechanically aligning and fastening a flanged EIA interface with individual bolts. MEIA offers greater ease of installation and coupling while providing superior power handling characteristics.

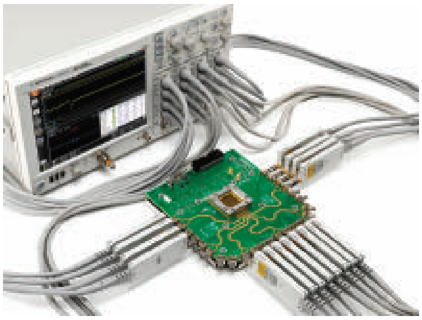
Operating over the frequency of DC to 3 GHz, the MEIA connectors have a voltage rating of 5100 V rms and dielectric withstanding voltage of 10400 V rms. The connectors offer a durability of 500 cycles minimum and meet various environmental testing standards.

The MEIA series is available with TRU Corp.'s flexible TRU-560 and TRU-500 coax cables to create an unmatched combination of high power and flexibility to suit your challenging applications. MEIA series high power panel mount receptacles can be designed with a variety of back-end launch geometries to optimize your equipment for performance and safety. MEIA to EIA adapters are available to allow transformation of existing EIA connections to the more efficient MEIA interface coupling.

▲ *Fig. 2 MEIA-1625 is 30% smaller and 40% lighter than the comparable EIA 1-5/8 (a) and has a shorter form factor and more efficient threaded coupling than the EIA 1-5/8 (b).*

TRU Corp.'s long heritage in high power design has made it a premier supplier in high power markets including critical safety applications in the industrial equipment segment. The company's experienced technical staff is available to personally answer application questions.

TRU Corp.,
Peabody, MA,
sales@trucorporation.com,
www.trucorporation.com.



TDR/TDT Solution with Electronic Calibration

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Agilent Technologies Inc. has introduced the Agilent N1055A 35/50 GHz (8 ps) time-domain reflectometry and transmission module for the Agilent 86100D DCA-X platform. The 86100D DCA-X oscilloscope mainframe can be configured with one to four N1055A TDR/TDT plug-in modules to provide a 2- to 16-channel TDR/TDT measurement system that is both economical and accurate.

The 2/4 port TDR/TDT remote heads can be configured with a sampler bandwidth of 35 or 50 GHz, providing single-ended and differential measurement capability, including True-Mode stimulus functionality. With TDR step edge speeds as fast as 8 ps and receiver bandwidths of 50 GHz, the DCA-TDR solution resolves the magnitude and location of impedance discontinuities with unmatched performance.

With Agilent 86100D Option 202 enhanced impedance and S-parameter analysis software, scattering parameters (S-parameters) are generated in real time within the oscilloscope and simultaneously displayed with time domain results. The N1055A's fast rise time enables calibrated S-parameter measurements to 50 GHz and above. The high-channel-count capability of the DCA-TDR solution also helps to minimize cable reconnections and facilitate more efficient near-end crosstalk and far-end crosstalk measurements in both R&D and high-volume test applications.

The DCA-TDR solution achieves a significant breakthrough for accuracy and ease-of-use with its support for electronic calibration (ECal) modules, leveraging an advanced calibration technique originally developed for vector network analyzers and recognized as the "gold standard" in S-parameter measurements. A special Agilent N4694A DC-67 GHz ECal module was developed for the DCA-TDR to let users calibrate and de-skew channels and TDR modules quickly.

VENDORVIEW

Agilent Technologies Inc.,
Santa Clara, CA,
www.agilent.com/find/N1055A.

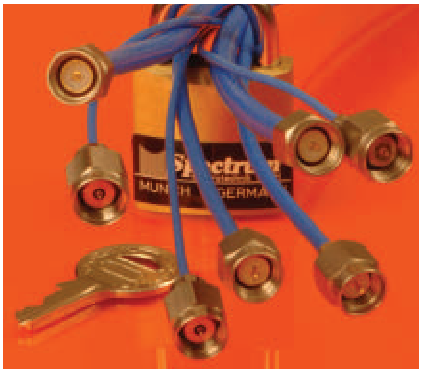
Spaceflight Cable Assemblies and Connectors

W. L. Gore & Associates has introduced a line of GORE® Spaceflight Microwave/RF Assemblies that have been optimized for Ka-Band uplink and downlink satellite applications. The durable construction of the Type 5G Series provides good shielding effectiveness and ensures reliable signal integrity with good insertion loss and return loss performance up to 32 GHz. They have been qualified for spaceflight applications in three separate phases – integration, launch and in-orbit – to ensure consistently reliable performance for the duration of the mission.

The assemblies can be terminated with either 2.92 mm straight-pin connectors (ZMQ) or 2.92 mm right-angle pin connectors (ZQA). These connectors withstand the harsh environment experienced during satellite launch and orbit without compromising signal performance. Additionally, the low-profile of these connectors will increase flexibility during the layout process of satellite design.

The ZQA connector features a non-bifurcated swept contact design for use with low-loss microwave coaxial cable qualified for 32 GHz spaceflight applications. Traditional box right-angle connectors are often associated with poor VSWR performance, particularly at frequencies approaching 18 GHz. This is because many box right-angle designs employ a bifurcated (two-part) internal contact. While the bifurcated configuration allows for easy assembly and low cost, its shape does not lend itself to good internal impedance control or to a robust solder connection.

W. L. Gore & Associates Inc.,
Landenberg, PA,
www.gore.com/zqaconnector.



Flexible Cables Offer Replacement for Semi-Rigid

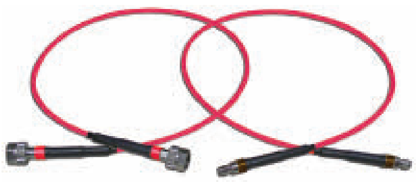
SpectrumFlex is a flexible cable that can be terminated with any standard semi-rigid cable connector. There are three versions available: Series 47F, which is a replacement for 0.047" semi-rigid cable, Series 89F that can replace 0.085" semi-rigid cable, and Series 169F, which is a replacement for 0.141" semi-rigid cable.

SpectrumFlex 47F and 89F are miniature assemblies with 0.055" (1.40 mm) and 0.096" (2.44 mm) diameters, durable construction and low profiles in SMA configuration. They offer excellent electrical performance in a trouble-free, compact assembly. They are especially suitable for situations where: the development of complicated semi-rigid cable drawings is prohibitive from a time or cost perspective; the installation of other miniature cable assemblies has caused expensive or hard-to-find failures; high density devices require stable, miniature cable assemblies for connection during test; and the cost of SMA right-angle connectors may be prohibitive.

Combining flexibility and durability with a larger diameter – 0.160" (4.06 mm) SpectrumFlex 169F maintains excellent electrical characteristics and performance through multiple flexures and offers a high strength replacement for RG 402 semi-rigid cable.

The SpectrumFlex 47F comprises a solid silver-plated copper-clad steel center conductor, solid PTFE dielectric, high coverage, silver-plated copper ribbon braid, high coverage, silver-plated stainless steel braid and extruded FEP jacket. Both the SpectrumFlex 89F and the 169F are made up of the same center conductor and dielectric, helically wrapped silver-plated copper foil shield, high coverage, silver-plated high strength alloy braid and extruded FEP jacket. The robust construction of all three versions ensures high compression resistance and durability and eliminates cable breakage associated with repeated bending and handling.

Spectrum Elektrotechnik GmbH,
Munich, Germany
+49 89 3548040,
www.spectrum-et.org.



All-Purpose Test & Measurement Cables

Maury Microwave's Utility™ series sets a new standard for high-end all-purpose test and measurement cable assemblies. Designed for general testing applications, Utility offers excellent value with its low cost, low insertion loss, excellent return loss, flexibility, and amplitude and phase stability. Typical insertion loss is 0.64 dB/ft (cable only), VSWR maximum of 1.30 (up to 18 GHz, Type N connector) and 1.25 (up to 20 GHz, SMA connector), typical phase stability versus bending of ±3.0° and typical amplitude stability versus bending of ±0.015 dB. Utility is the ideal interconnection for reliable and repeatable measurements when mated with test instruments, including bench-top testing, on-wafer characterization and ATE systems.

Utility cable assemblies are now part of the ColorConnect™ family. Following the proposed IEEE high frequency connector/adapter color convention, Utility cable assemblies are among the first commercially available assemblies to offer clear indications of compatibility and intermatability. ColorConnect makes it a simple matter to avoid and eliminate damaged equipment, degraded equipment reliability, degraded performance and lengthy maintenance times due to improper mating (and attempted mating) of incompatible interconnects. Utility RF/microwave cable assemblies are available with N-Type connectors to 18 GHz and SMA connectors to 20 GHz in 24", 36", 48" and 60" lengths (custom lengths are available).

Maury Microwave,
Ontario, CA
(909) 987-4715,
www.maurymw.com.

Cables and Connectors Supplement

LITERATURE SHOWCASE

Test Cable Assemblies Catalog

VENDORVIEW

Florida RF Labs has a new catalog detailing an extensive selection of test cable assemblies for precision measurements. The assemblies include Lab-Flex®, Titan-Flex™, ASR and ASR-F. Florida RF Labs has provided assemblies delivering consistent performance and robust interfaces that can be used in static and dynamic conditions for many years.

Florida RF Labs,
www.emc-rflabs.com.

4.3-10 Connector Brochure

HUBER+SUHNER, a leading global supplier of RF product, is an active partner of a developing group designated to provide an innovative solution for the telecom market. The new 4.3-10 connector system is designed to meet the rising performance needs of mobile network equipment and at the same time reducing its size supporting the ongoing space reduction requirements. This brochure details the full connector and adapter range of HUBER+SUHNER for the 4.3-10 connector system.

HUBER+SUHNER,
www.hubersuhner.com/4310.

Cable Assemblies

Maury Microwave is a worldwide leader in interconnect solutions with three families of cable assemblies to meet your every need. Test Port cable assemblies offer the highest accuracy for VNA measurements. Stability™ cable assemblies consistently deliver high performance for phase-stable applications. Utility™ cable assemblies have been designed for price/performance and everyday lab use. Stability and Utility cable assemblies are available in stock in standard.

Maury Microwave Corp.,
www.maurymw.com.

Connectors and Cables

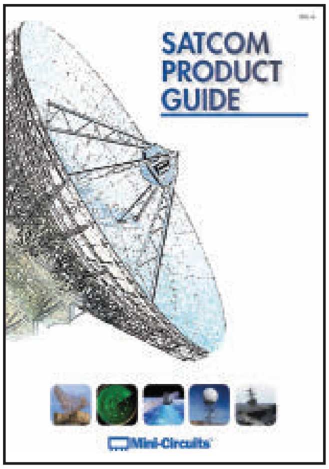
Offering DC to 110 GHz connectors and cables: 1 mm, K, 2.92, SMA, N, BNC and TNC. Offering power dividers, couplers, amplifiers, isolators, circulators, switches DC to 40 GHz. Contact: sales@mesamicrowave.com or (480) 890-1612.

Mesa Microwave,
www.mesamicrowave.com.

Coaxial Cable Assemblies

MIcable Inc. is a leading designer and manufacturer of high performance microwave coaxial cable assemblies for a variety of applications, including DC to 50 GHz flexible cable assemblies, hand-flex cable assemblies, semi-rigid cable assemblies and VNA test cable assemblies. MIcable also designs and produces various precise coaxial stainless steel and copper connectors and adapters. Custom designed cable assemblies are also available. Please email sales@micable.cn for more information.

MIcable Inc.,
www.micable.cn.



SATCOM Product Guide

VENDORVIEW

Mini-Circuits is pleased to release its new SATCOM Product Guide featuring a full survey of components and assemblies for satellite and earth station systems. With selected models 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. Request your copy from the literature section of Mini-Circuit's website or email apps@minicircuits.com.

Mini-Circuits,
www.minicircuits.com.

Cables and Connectors Supplement

LITERATURE SHOWCASE

PIC MicroMATES

PIC Wire & Cable's MicroMATES® line of cables and connectors was designed to advance interconnect technology for Ku- and X-Band assemblies. Learn more about these 50 Ω high frequency/microwave assemblies engineered with minimum 200°C rating on all materials plus superior components including: Inner flat braid or strip braid, high temp polyimide foil, dual braided shields and silver-plated copper throughout. Just two weeks lead time on most assemblies.

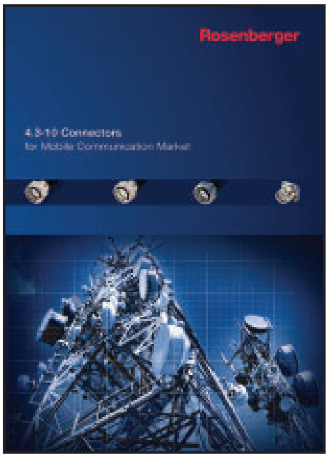
PIC Wire & Cable,
www.picwire.com.

T&M Instruments

VENDORVIEW

Whatever your job is, you are not always performing complex measurements and do not always need the ultimate high-end T&M equipment. What you need are precise, reliable, universal measuring instruments. That is exactly what you get with value instruments from Rohde & Schwarz: they combine practical features with excellent measurement characteristics; they are easy to use and easy on the budget. Find out more in the Value Instruments Catalog 2013 from Rohde & Schwarz.

Rohde & Schwarz GmbH & Co. KG,
www.rohde-schwarz.com.



4.3-10 Connectors

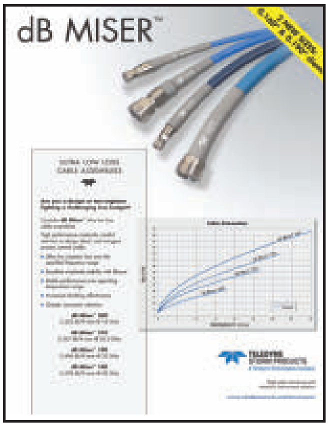
Rosenberger presents a new brochure for its 4.3-10 connector series. The new 4.3-10 connector series, developed together with the renowned RF suppliers Huber + Suhner, Spinner and Telegärtner, has been designed to meet the rising performance needs of mobile network equipment. Outstanding product features include best electrical performance and very low passive intermodulation, very small connector dimensions and easy installation. Plug types are available as screw-on, hand-screw and quick-lock types – installation failures are limited by torque independency.

Rosenberger Hochfrequenztechnik GmbH & Co. KG,
www.rosenberger.com.

MM-Wave Connector Assembly

Successfully launching an RF connector to a PCB at millimeter wave frequencies requires a carefully engineered plan for design, simulation and installation. SV Microwave is now offering the design services and assembly tools needed to optimize your high frequency connector launch.

SV Microwave,
www.svmicro.com.



dB Miser Brochure

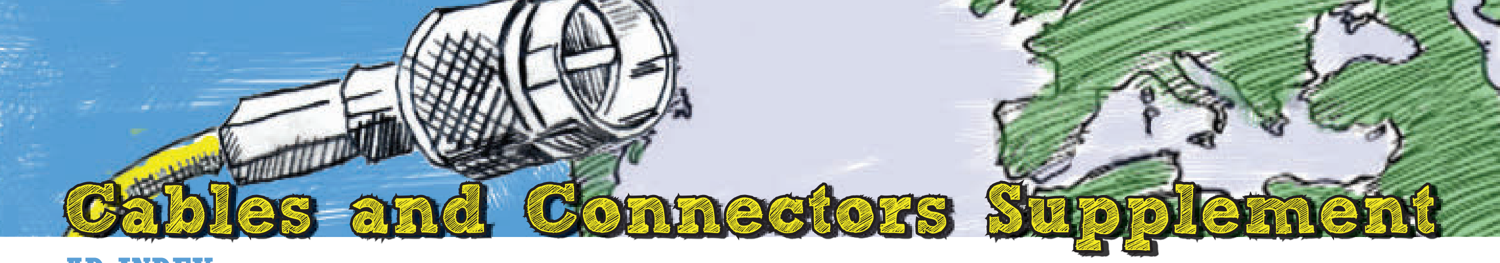
The clear choice for engineers facing challenging system gain or signal-to-noise requirements, dB Miser™ cables exhibit ultra low loss, excellent amplitude stability with flexure, stable performance over temperature and exceptional connector retention. This expanded brochure introduces two new cables in the dB Miser line of assemblies: a 0.160" diameter cable (0.678 dB/ft nom. at 40 GHz) and a 0.190" diameter cable (0.496 dB/ft nom. at 32 GHz), as well as new connector offerings.

Teledyne Storm Microwave,
www.teledynestorm.com.

GORE PHASEFLEX Microwave/RF Test Assemblies

For test applications that require precise, repeatable measurements, GORE® PHASEFLEX® Microwave/RF test assemblies provide excellent phase and amplitude stability with flexure. The rugged, lightweight construction of these assemblies delivers reliable performance with longer service life and reduced equipment downtime, which results in lower costs for testing in laboratory, production, and field test environments.

W. L. Gore & Associates,
www.gore.com/test.



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WHEN EVERY CONNECTION COUNTS...
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