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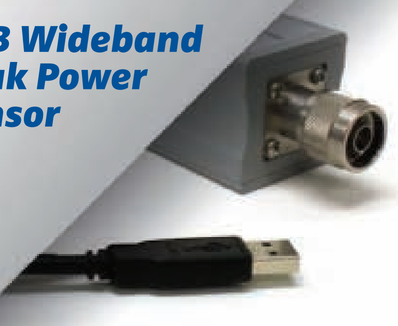

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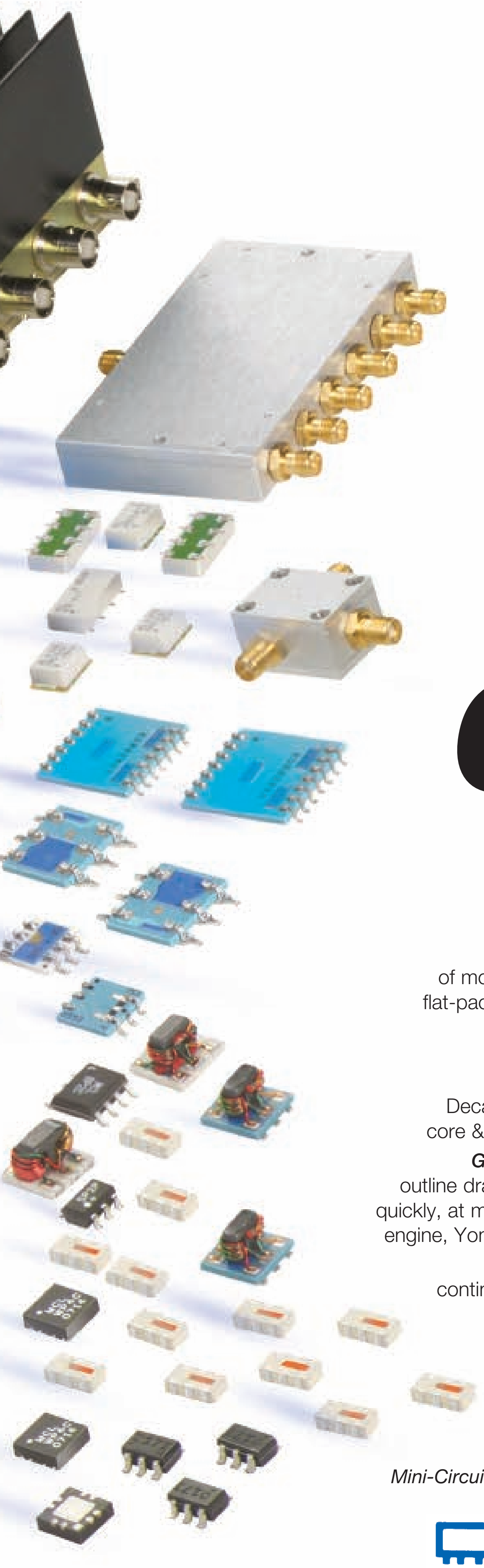

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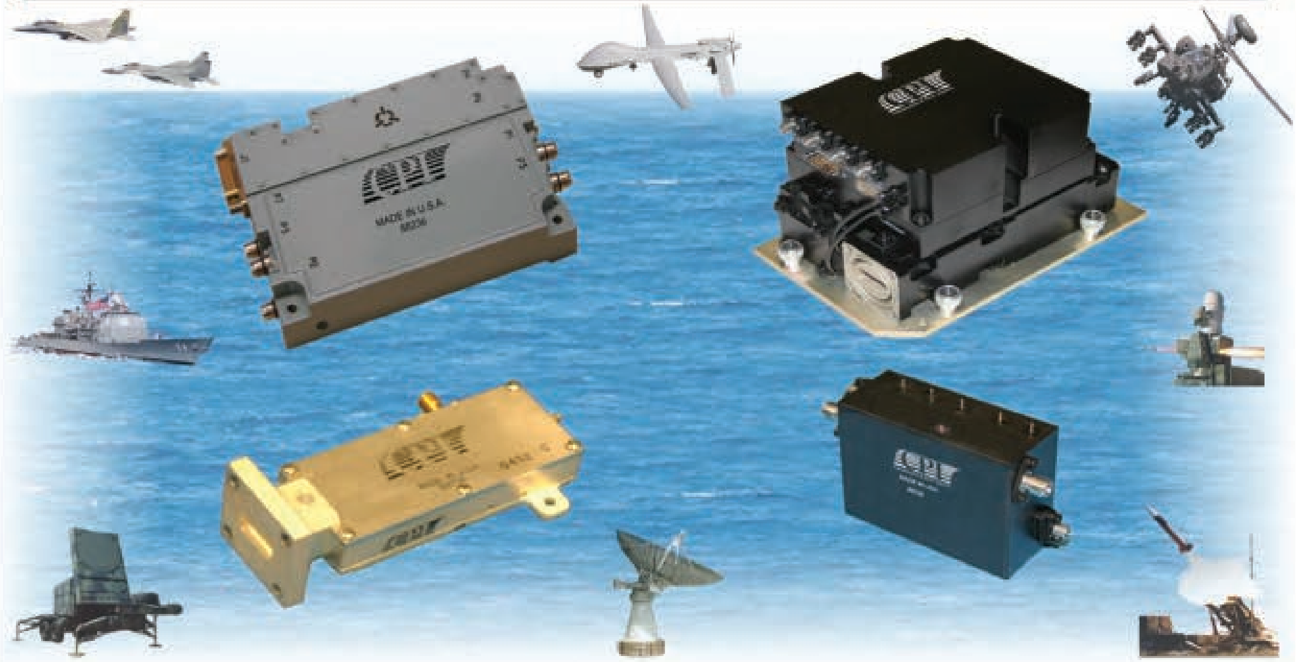

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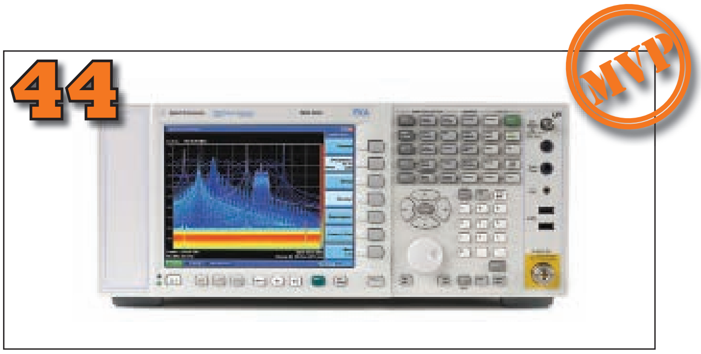
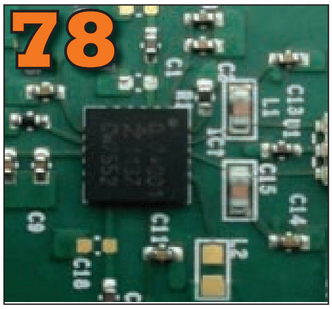
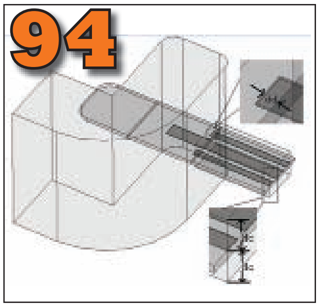
CONTENTS







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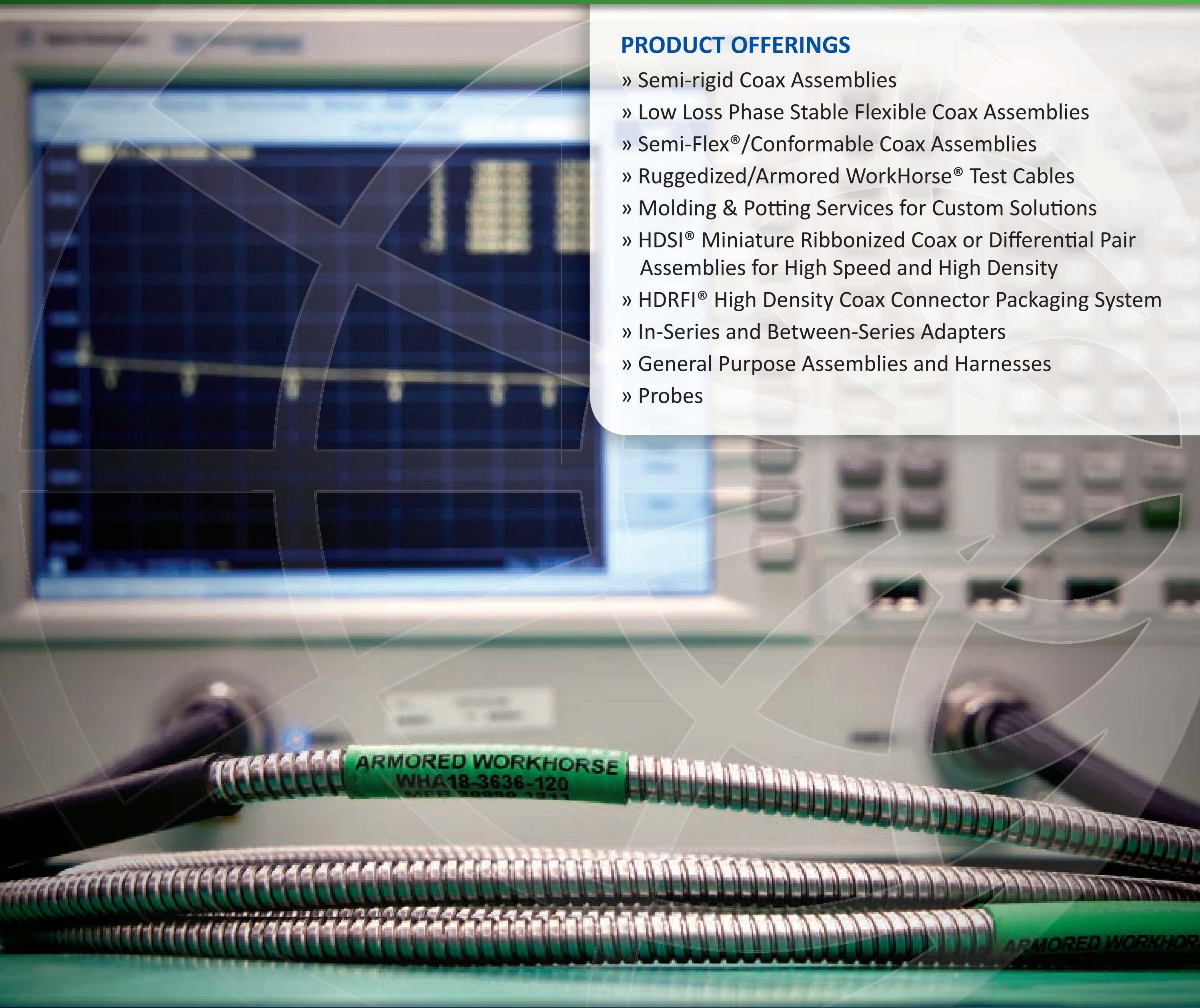

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LTE and the Evolution to LTE-Advanced Fundamentals: Part 1	3/26
Techniques for Precise Power Measurements in the Field	3/27
LTE and the Evolution to LTE-Advanced Fundamentals: Part 2	3/28
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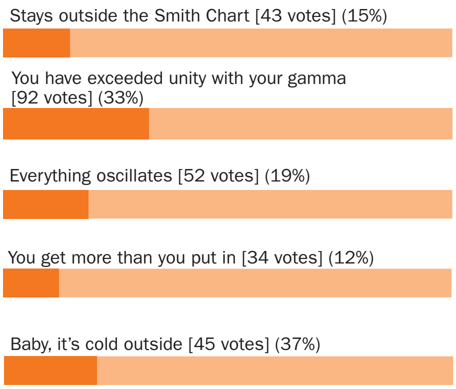

Executive Interview

John Croteau, CEO of **M/A-COM Technology Solutions**, recently moved from NXP Semiconductors to take over the reins at M/A-COM Tech. Croteau discusses carrying on the M/A-COM legacy, growth opportunities and the company's growing portfolio of GaN devices and modules.

White Papers

Modern VNA Test Solutions Improve On-Wafer Measurement Efficiency
White Paper, Anritsu

"S" Series Amplifiers Produce Higher Power, Higher Linearity Signals for Testing Wireless Devices and Systems
White Paper, AR RF/Microwave Instrumentation

Tuning Doherty Combiners
Application Note, Anaren   Presented by: Richardson RFPD

Overview of Tests on Radar Systems and Components
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7 WAMICON **IEEE Wireless and Microwave Technology Conference** Orlando, FL	8	9	10 Microwave & RF **2013** Paris, France **Webinar: GPS Interference & Spoofing** Sponsored by ROHDE & SCHWARZ	11	12	13
14 IWS INTERNATIONAL WIRELESS SYMPOSIUM IEEE MTT-S 14-18 April 2013 Beijing, China	15	16	17 **Webinar: Linearizing GaN Power Amplifiers** Sponsored by Scintera, SUMITOMO ELECTRIC	18 **Webinar: Radar: Trends, Test Challenges and Solutions** Sponsored by Agilent Technologies	19	20
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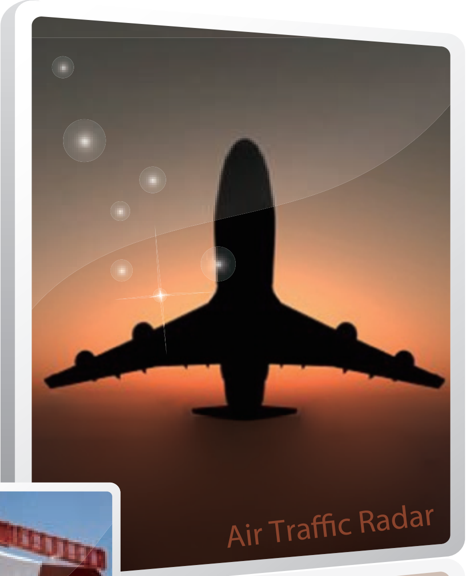

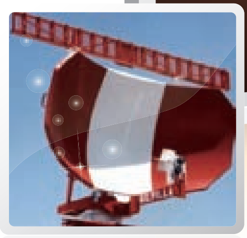

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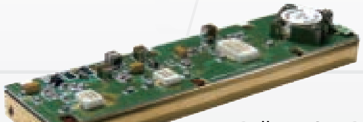

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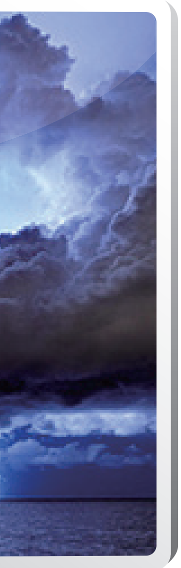

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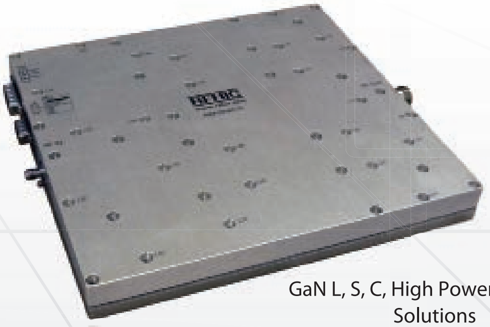

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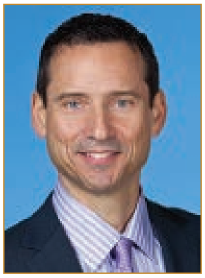
Cover Feature
Invited Paper

Synthetic Instrumentation: The Future of Test

The editors of Microwave Journal *asked three of the leading test and measurement companies that are heavily involved in software defined instruments to weigh in on the future of RF/microwave test and measurement instrumentation. Experts from National Instruments, Agilent Technologies and Aeroflex contributed their views on this subject.*

Redefining the Way We Solve Test Challenges



Mike Santori
National Instruments, Austin, TX

The role of software in test and measurement systems has changed dramatically over the past few decades. Today, software is the most critical core technology in modern, high performance measurement systems because it is the only thing that can abstract the fundamentally growing complexity of those systems. However, simply running software on computer processors is not enough. The most challenging applications are not possible without engineers that can use software to specify and design the behavior of their own instrumentation. This ability to create software designed instruments is at the heart of a revolution that is taking place in RF instrumentation and, more broadly, in the general test and measurement industry.

In the Beginning – Automating Measurements

The role of software in test and measurement systems has advanced steadily since the 1970s when IEEE-488, also known as GPIB, standardized the interface for programmable instrumentation. Up to that time, taking measurements was largely accomplished with benchtop instruments, a pencil and a notebook. There were a variety of different proprietary instrument controllers and interfaces available, but their capabilities were rudimentary and used more by advanced users.

The role of software in test and measurement took a huge leap forward in the 1980s, with the introduction of the original IBM PC and the first National Instruments (NI) GPIB interface board. With the use of PC software,

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engineers could use general-purpose PCs to create automated test systems that reliably and repeatedly acquired measurements, analyzed those measurements and presented results that could be shared widely.

From Instrument Control to Measurement Platform

In the later 1980s and into the 90s, a new concept of "virtual instrumentation" began to take hold in the test and measurement world. This concept revolutionized the role of computers and especially software in test and measurement systems. Rather than viewing a PC as simply a computer for automating measurements with GPIB, virtual instrumentation used the computer itself as a measurement platform. Moore's Law ensured that the processing power of a PC quickly outstripped the technology used in standalone instruments. Further, computer memory, storage capacity and graphics display capabilities far outpaced that of traditional instruments. Thus, a general-purpose PC quickly became a better computing platform than a traditional instrument.

Two critical elements were required to enable a virtual instrumentation system to meet and ultimately exceed the capabilities of traditional instruments: modular measurement hardware and software. On the hardware side, early computer plug-in boards offered fairly low-quality measurement capabilities compared to benchtop instruments, which relied on proprietary data converters. Demands of broad markets, such as consumer audio and wireless infrastructure, drove the development of off-the-shelf data converters that could perform high quality measurements when used on computer plug-in boards. Computer-based measurements took a big leap forward with the development of measurement-specific computing platforms, especially PXI (PCI eXtensions for Instrumentation), which was developed in the 1990s. PXI combines PCI computer technology with instrumentation-specific timing and synchronization capabilities. Soon, PXI virtual instruments were solving some of the most challenging measurement challenges, including high-performance RF measurements.

Yet, it was software that really made virtual instrumentation possible. Not only was software required to acquire, analyze and present measurements in a PC environment, but it had to do so in a sufficiently abstracted manner. In essence, abstraction software was required to enable engineers and scientists to efficiently solve their test and measurement challenges, without having to be experts in computer science and architecture. First released in the mid-1980s, NI LabVIEW software was one of the leading solutions for virtual instrumentation software and started the trend toward software playing a central role in modern test and measurement systems.

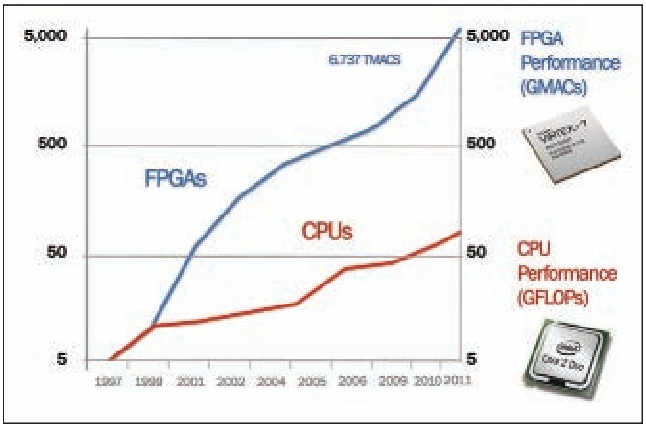


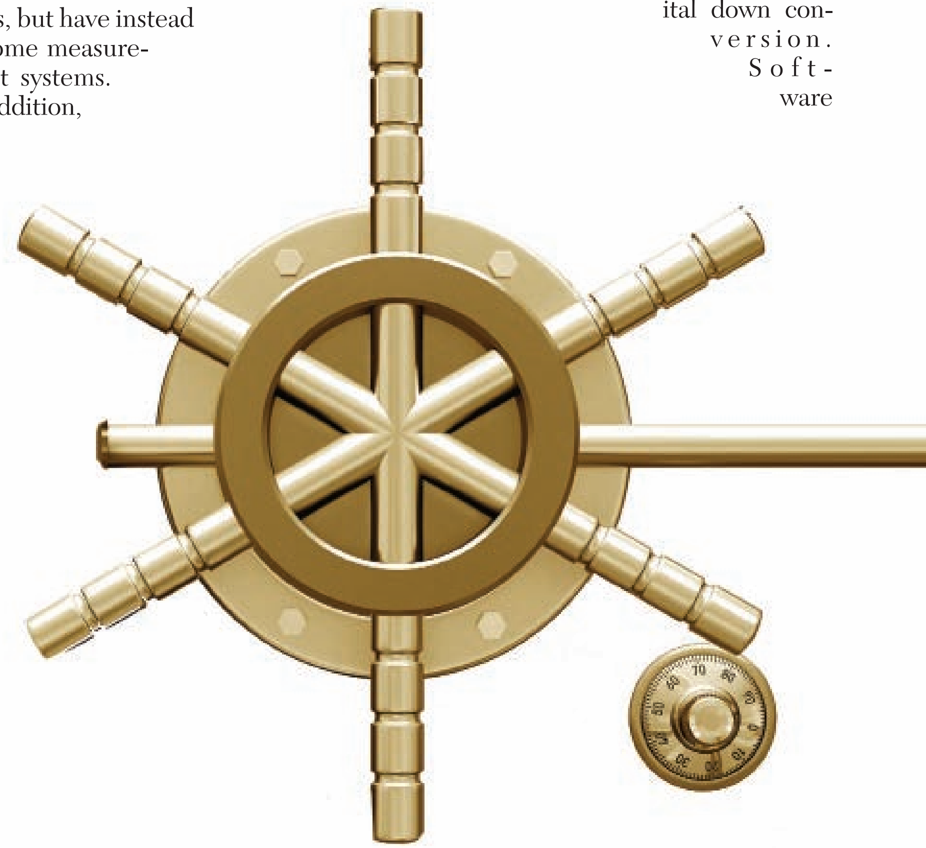
Fig. 1 FPGA is growing at a rate that exceed CPUs.

Enabling Software Designed Instrumentation with FPGAs

The next major step in measurement capabilities is being enabled with the inclusion of FPGA-based measurement hardware. Looking forward to the future, it is important to consider that "instruments" in the traditional sense are no longer single-function measurement devices, but have instead become measurement systems. In addition, engineers are looking to instruments not only to test devices, but also to design and prototype much larger systems.

Field Programmable Gate Array (FPGA) is a key technology that is bringing new levels of performance to next-generation instrumentation. FPGAs offer substantial processing power (see ***Figure 1***). With the inclusion of FPGAs, there is now a software-based capability to push measurement functions deep into the hardware itself.

Many of today's RF instruments already benefit from fixed-functionality FPGAs to execute tasks such as flatness correction, ADC linearization, IQ calibration and digital down conversion. Software



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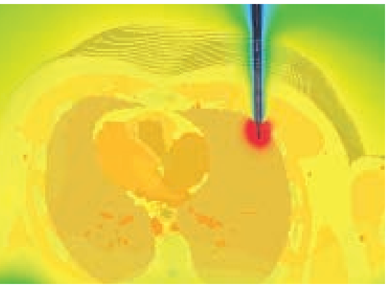

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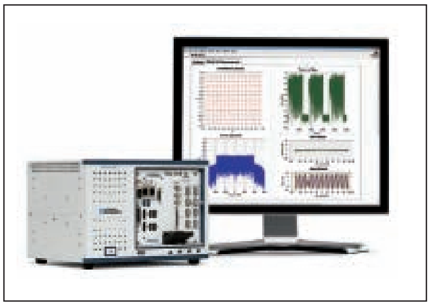
CST of America®, Inc. | To request literature (508) 665 4400 | www.cst.com designed instruments, such as the vector signal transceiver shown in ***Figure 2***, benefit from FPGA technology in an entirely new way because the FPGA is available to the user for customization. For example, moving the instrument control and decision making from a PC to an FPGA can dramatically reduce measurement time in complex measurement systems. Also, this capability combined with advanced FPGA-based signal processing will enable instruments to function in a wider range of embedded applications as well.

System Design Software – The Key to Software Designed Instrumentation

The right system design software tool is essential to pull together the computing and measurement technologies in today's modular hardware. From its beginning as instrument con-



▲ *Fig. 2 The NI PXIe vector signal transceiver benefits from FPGA.*

trol software, LabVIEW, for example, has evolved to be a comprehensive system design platform that allows engineers to create complex, high performance measurement systems. Engineers can use a common set of tools and languages to target applications on both processors and FPGAs, alleviating the need to know different languages and tools. It provides a higher-level abstraction to work at the system level, while also enabling engineers to create lower-level optimizations to address very high performance or complex requirements.

Multi-Mode RF Device Characterization

Faced with testing a new 802.11ac product, Qualcomm Atheros had to test its device under more operating conditions than ever before, resulting in more than an order of magnitude increase in measurement complexity. Using an FPGA-based vector signal transceiver and software, the company was able to design a test system that synchronizes digital DUT control with RF measurements. The resulting test system reduces overall test time by more than order of magnitude and enables engineers to observe device behavior in multiple operating modes.

As seen in ***Figure 3***, the traditional test instrumentation was used to obtain an iterative set of measurements. Because the measurement time was very high, the test engineers had to choose a subset of operating points to characterize, resulting in essentially a "guesstimate" over the device's operating characteristics. With traditional instrumentation, approximately 40 points of meaningful WLAN transceiver data were collected per iteration.

However, by switching to an FPGA-based instrument approach, the company improved measurement performance by 200 times, enabling the engineers to acquire all 300,000 oper-

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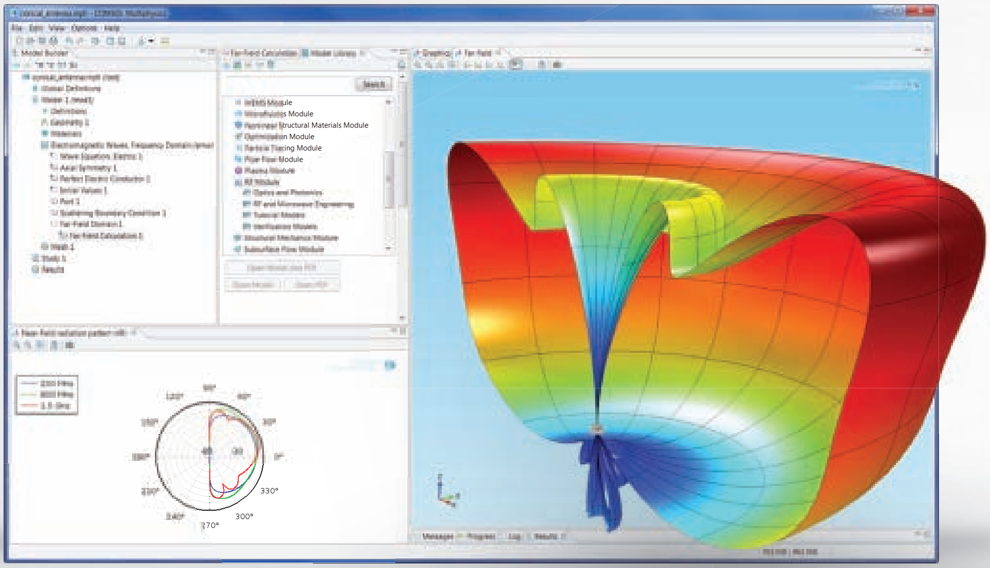

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ating modes in a single test sweep. The resulting characteristic curves, shown in the bottom of the figure, showed much more detailed information about the device. The speed increase of the sytem triggered full gain table sweeps to acquire all 300,000 points.

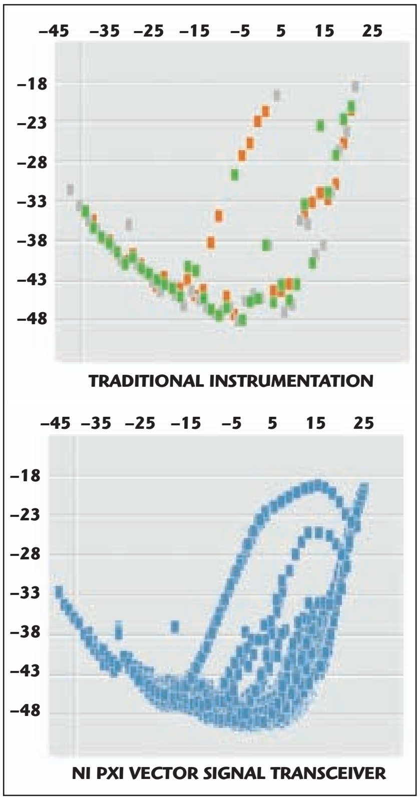
Instrumentation in Embedded Applications

A second class of applications for software designed instrumentation is embedded communications and signal processing. While measurement devices have traditionally been thought of as instruments, modular, software designed instrumentation allows engineers to use RF instrumentation in embedded applications as well. Today, a growing number of engineers are using modular PXI instruments for embedded applications, like spectrum monitoring, passive RADAR systems (see ***Figure 4***) and even communications system prototyping and software defined radio.

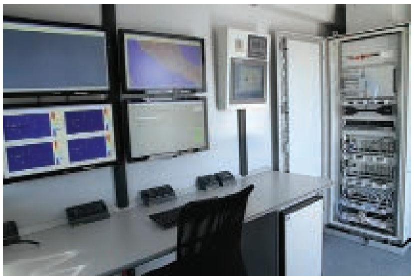
For more information, please read our January 2013 article on a new passive radar system developed by SELEX at www.mwjournal.com/aulos. These applications require instrumentation to be increasingly smaller, modular and have better access to deterministic signal processing targets. Communications system design software must be able to abstract increasingly complex systems, enabling engineers to implement existing and new communications algorithms and deploy those algorithms on processors and FPGAs.

Looking Toward a Future of Converged RF Design and Test

Software designed instrumentation blurs the line between design and test



▲ *Fig. 3 The NI PXIe vector signal transceiver using FPGA improved the measurement performance 200 times.*



▲ *Fig. 4 Complex systems, such as a passive radar system, are designed and deployed with NI LabVIEW software and NI PXI hardware embedded in the final system.*

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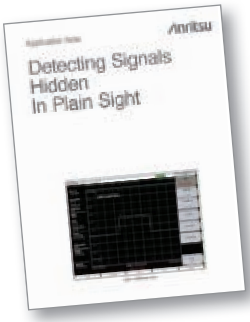

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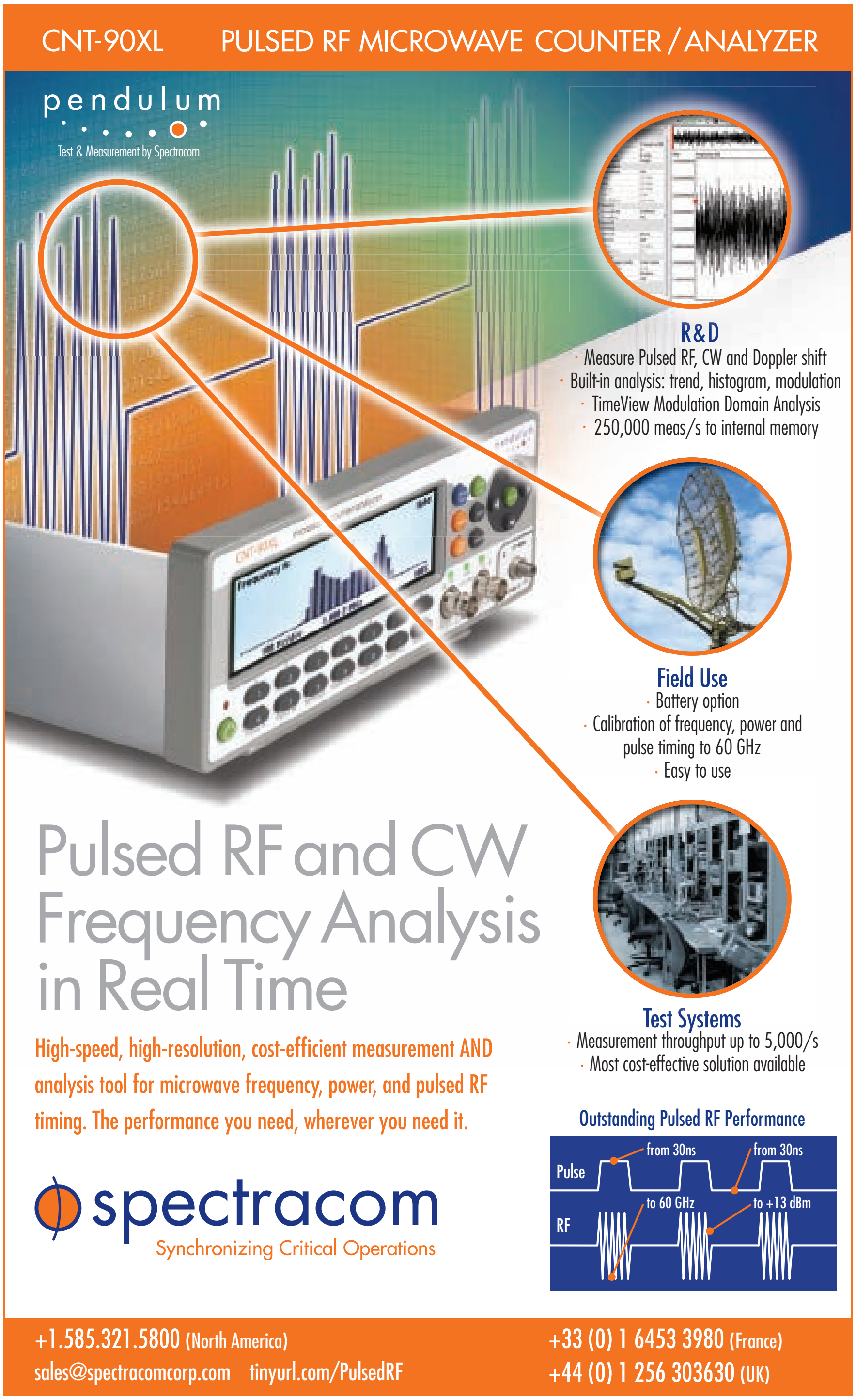
like never before. One of the more intriguing opportunities will be the ability to share IP between design and test, whether that IP runs on a processor or an embedded FPGA. Using system design software, engineers will be able to use the same tools to create a new communication protocol and move that protocol to FPGA-based hardware for prototyping. Today, this is very challenging because of the disparity between the mathematics software used to create the algorithms and the design tools used to implement those algorithms. Advances in higher level synthesis and integration of multiple design models of computation will be required to fully enable engineers to achieve this seamless transition between design, implementation and test.

As a final thought, it is interesting to note that software in test and measurement has come a long way from its beginnings as simply a vehicle to automate a set of stand-alone instruments. Instead, software has become the heart of the instrumentation itself, enabling instruments to solve more difficult problems in both measurement and system design. In effect, automation is now an embedded capability of the system that is required to meet the complex measurement requirements that engineers face. Today's software designed measurement systems are just the first generation to deliver what are sure to be game-changing RF design and measurement capabilities for a long time in the future.



The Future of Software Defined Instrumentation


Jean Dassonville and Phil Lorch
Agilent Technologies, Santa Clara, CA

Today's RF wireless and microwave design/manufacturing engineers face emerging test challenges driven by increasingly complex modulation schemes, an ever growing number of communication standards, wider information bandwidths and new frequency bands and applications. Complicating matters, they often need to build integrated radios or other subsystems that work across analog (RF and IF) and digital (for baseband data processing) domains.

The ultimate goal for these engineers is to turn their ideas into validated products as quickly and reliably as possible. In order to achieve this goal, they expect their test equipment to provide enough flexibility to accelerate measurement insight into new and complex design problems and support the evolution of communications standards, while also maintaining a high level of measurement integrity (accuracy and traceability). Using this type of equipment, engineers can be assured their measurements will be

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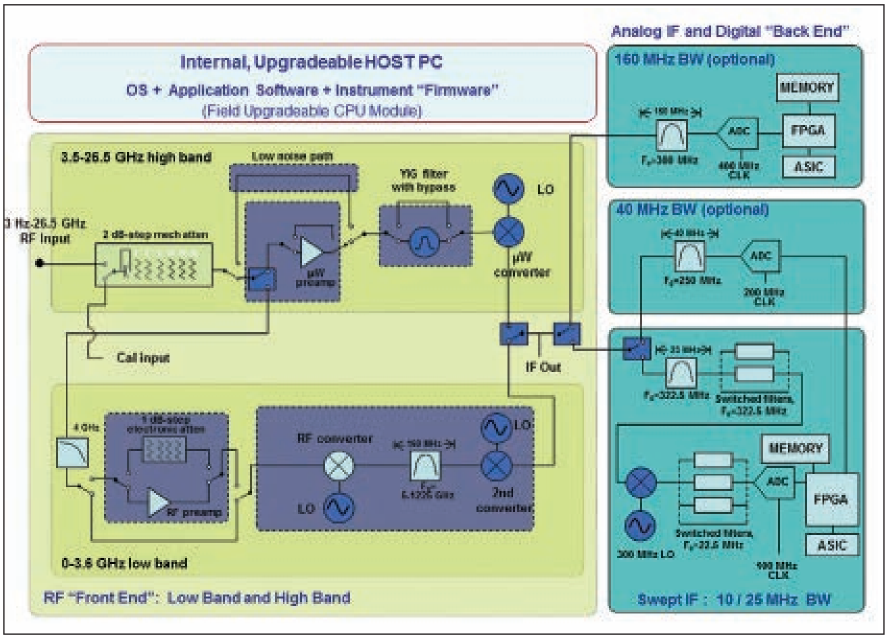
Flexibility, Performance and Measurement Integrity

When it comes to RF and microwave instrumentation, test and measurement (T&M) equipment architectures usually combine physical hardware circuitry for high-quality RF signal generation and analysis, with ASICs and reconfigurable logic (FPGAs) that perform necessary digital signal processing (DSP), embedded firmware and application software. ***Figure 5*** shows a simplified block diagram of a vector signal analyzer, highlighting its key hardware and software elements. Together, these hardware and software elements define the instrument's capabilities and functionality. Each element of the instrument's block diagram contributes to its overall measurement accuracy, performance, speed, flexibility and ultimately, its level of application insight. As a result, instrument designers and system architects often spend a great deal of effort leveraging decades of measurement experience to fine-tune the interoperation of these elements. By doing so, they are able to optimize a given instrument's flexibility and performance over a wide range of conditions, while maintaining measurement integrity (see the sidebar below, "Defining Measurement Integrity").

The combination of hardware, reconfigurable logic, DSP and firmware enables new levels of measurement performance. With accurate models of an instrument's analog, RF and IF paths for example, embedded digital signal processing engines can perform real-time corrections and compensate for signal degradation, improving the measurement accuracy and flatness of wideband, digitally modulated communications or radar signals. Because of this, T&M manufacturers are now marrying these hardware and software elements to improve performance, while at the same time ensuring the instrument's internal complexity is hidden, allowing RF design and test engineers to focus on their own design tasks and applications. Some RF instruments now include internal, field-upgradeable PC modules that enable



▲ *Fig. 5 Simplified block diagram of Agilent's PXA vector signal analyzer.*

connectivity to the design environment and are flexible enough to support evolving standards, new CPUs and additional memory in support of new, more demanding applications.

New Levels of Flexibility and Connectivity

In some cases, design and test engineers want to access an instrument's internal reconfigurable hardware resources and embedded firmware so they can customize it to their own needs. They like the idea of flexibility and want to benefit from it, but they do not typically want to deal with the added complexity, time or effort required to build new measurements from the ground up. They may also have some of their own functional measurement intellectual property (IP) that they wish to incorporate for testing purposes.

To address this emerging demand for more flexibility, instrument manufacturers have two distinct strategic options. The first option maximizes instrument flexibility through access to its internal resources by exposing and shifting the complexity of the instrument's design toward the test engineer. Without a lot of validation and further testing against known reference standards however, this sort of "instrument disaggregation" can negatively impact overall measurement integrity. It lacks traceability to standards, guaranteed specifications and a well-defined metrology process to back up the measurements. Consequently, the test engineer is forced to spend more time developing basic instrumentation, as well as the test, and then needs to verify it before any actual testing work can take place.

Moreover, as the engineer's test application becomes more hardware specific, any newly-developed measurement IP becomes difficult to reuse on other new test platforms with different reconfigurable logic or electronic modules. This problem is similar to one that occurs with software programming. For example, on one hand, program-

DEFINING MEASUREMENT INTEGRITY

As unique as any RF and microwave test situation may be, measurement integrity is crucial. What is measurement integrity? Quite simply, measurement integrity focuses on producing consistent results, test-to-test, day-to-day, with respect to the metrology and traceability standards and delivering the right level of performance (that is accuracy and measurement range), given speed requirements, to help design and test engineers understand the device's real behavior and make better decisions.

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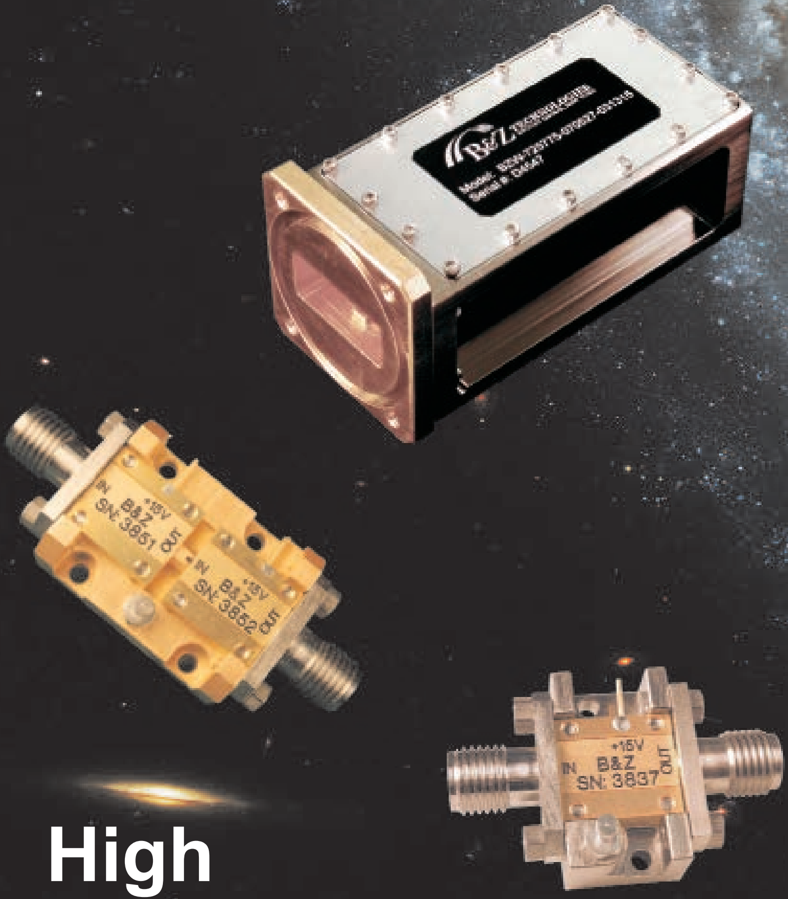

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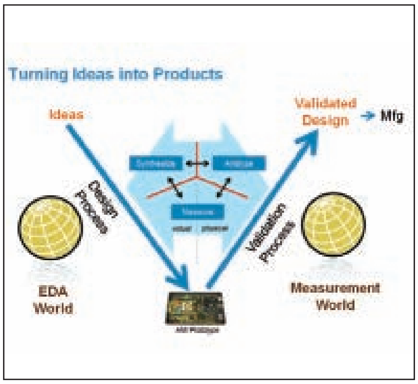
ming in high-level languages, such as C and C++, enables code reuse across multiple platforms. On the other hand, programming in Assembly Language enables more flexibility and faster execution, but is usually more complex and the resulting design becomes very dependent on both the hardware and system architecture.

The second strategic option that instrument manufacturers may employ couples flexibility with a clear focus on accelerating measurement insight and maintaining measurement integrity. Unlike the first option, this approach keeps the complexity hidden from end-users, leaving them free to focus on their own design tasks and overall workflow.

This approach is best achieved through an integrated portfolio of design and measurement building blocks. Agilent Technologies' strategy, for example, provides users with an integrated design and measurement environment that includes both hardware (such as benchtop and modular form-factor instruments) and software building blocks. The latter encompasses external software like the 89600 VSA for signal analysis or Signal Studio for signal creation, as well as embedded instrument firmware such as the X-Series advanced measurement applications. These hardware and software elements interoperate seamlessly with Agilent's electronic design automation (EDA) tools such as Advanced Design System (ADS), GoldenGate and SystemVue and also work with third-party software, like Visual Studio and MATLAB, to enable construction of new application-specific measurement solutions.

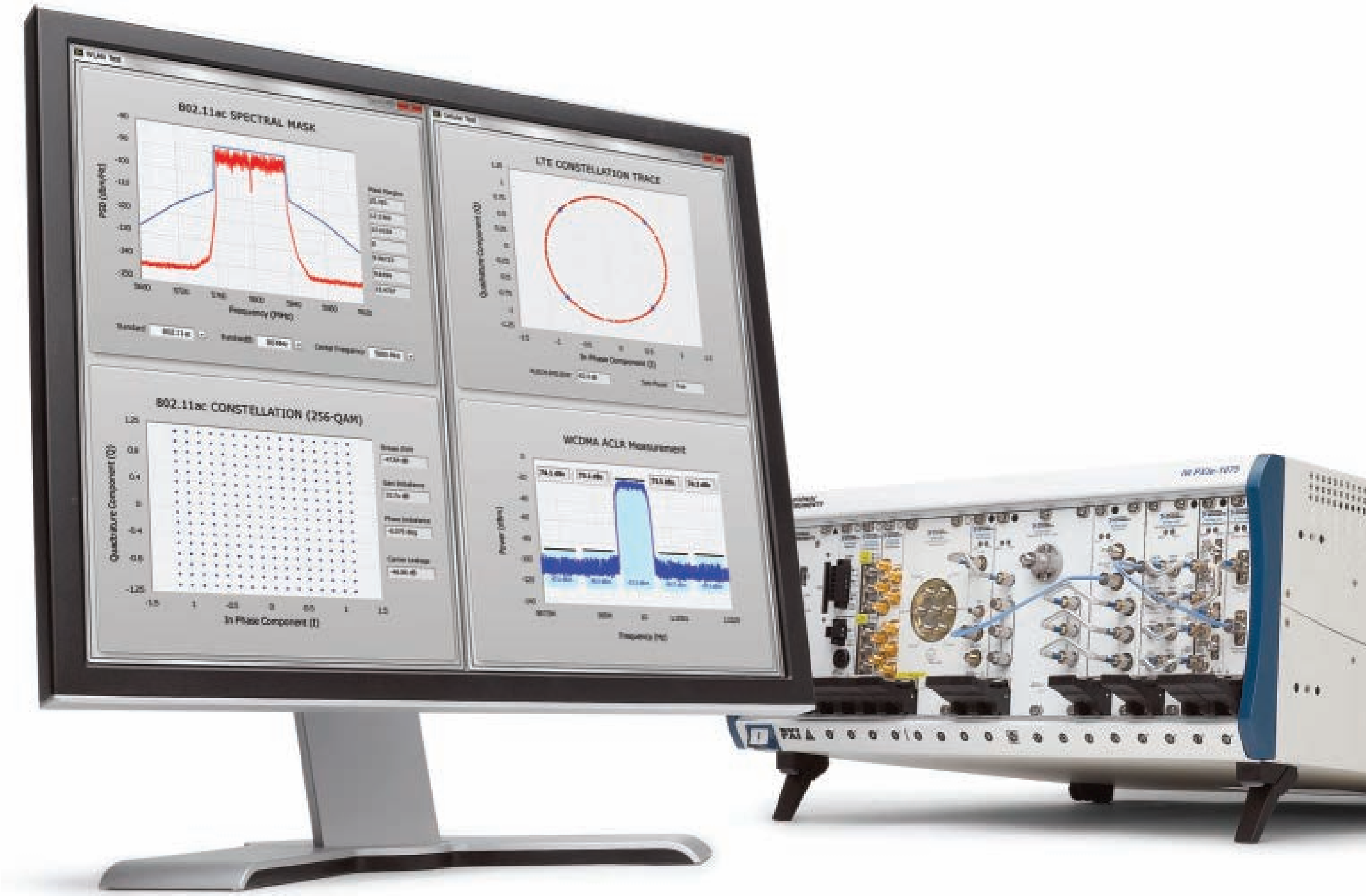


▲ *Fig. 6 Bringing the EDA and measurement worlds together.*

Quickly turning an idea into a shipping product requires a true closing of the traditional gaps between design, validation and final manufacturing test and can be accomplished by tightly integrating solutions for design automation with test instruments for performing highly accurate measurement and test. ***Figure 6*** illustrates how bringing the EDA and measurement worlds closer together allows engineers to more quickly turn their ideas into validated, shippable products. To better understand this concept, consider an analogous situation that has occurred in the PC industry. In the early days of this industry, open PC architectures and operating systems enabled individuals to build customized PCs by selecting from a variety of CPUs, hard drives, graphics accelerators, operating systems and finally, custom application software. However, this customization came at the expense of added complexity and forced the user to test his or her custom-built PC after putting all these components together.

Redefining RF and Microwave Instrumentation

with open software and modular hardware



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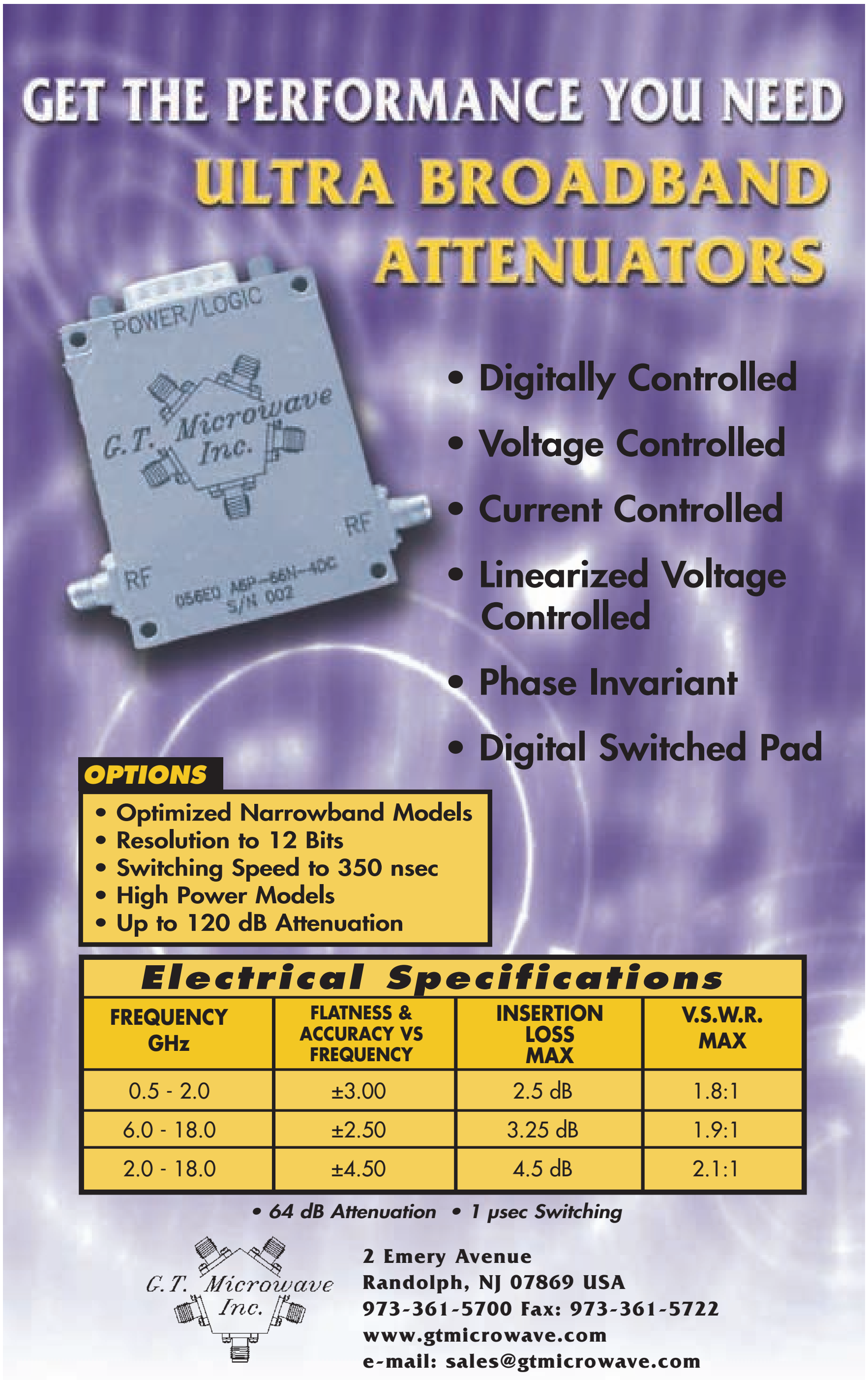
In contrast, a more integrated strategy, focused on key T&M applications, enables an easier user experience. In the PC realm, using pre-built computers, smart mobile and entertainment devices and cloud storage, individuals can easily customize their own user experience and then seamlessly share data between each one of their devices with little to no worry or hassle. In the RF and microwave design realm, an integrated "pre-built" measurement environment yields a similar benefit. The building blocks of the design and measurement world "just work." They interoperate seamlessly, leaving the engineer to focus on his or her design and testing tasks, rather than having to build and verify measurement software or hardware.

Evolving Instrumentation

Market and technology forces will keep driving engineers and designers to demand faster measurement insight through flexible and scalable design and measurement solutions that span RF, analog and digital domains, regardless of the instrument form factor. One of the main drivers for this trend is the increasing integration of RF, microwave, analog and high-speed digital technologies inside today's newly designed devices. As an example of this cross-domain integration, consider modulation quality measurements, which often need to be performed on digitized IQ data captured with a logic or protocol analyzer. As most wireless communication designs include analog and digital paths, modulation measurements can be performed with a combination of RF signal analyzers and logic analyzers integrated with software (see ***Figure 7***).

Solutions, which consist of integrated design and measurement building blocks, can address these challenges by bridging the virtual and real world to integrate the product development workflow from simulation to prototyping and validation. Initially, only a small portion of the overall block diagram will actually be available. Software provides modeling analysis and measurement integration that enable engineers to quickly move ideas to proven, real-world hardware. Here, design and integration with FPGAs and RF is shown for a software defined radio development workflow. Agilent's RF workflow environment extends and builds on the hardware and software building blocks with an integrated design and measurement approach to address emerging test challenges (see ***Figure 8***). In the early stages of a new design project, more of the system elements will need to be simulated before the projected system performance can be ascertained. Engineers may even have some of their own IP that they want to exercise, but with no complete radio available (that is with RF up or down conversion), they will be unable to test it unless an integrated approach that involves simulation of the missing pieces is available. As more of the entire system design is realized in the form of prototypes, more physical measurements can be performed and compared with simulated results and vice versa.

Going forward, the vast majority of designers will expect the same measurement integrity that exists in today's instruments, but with the

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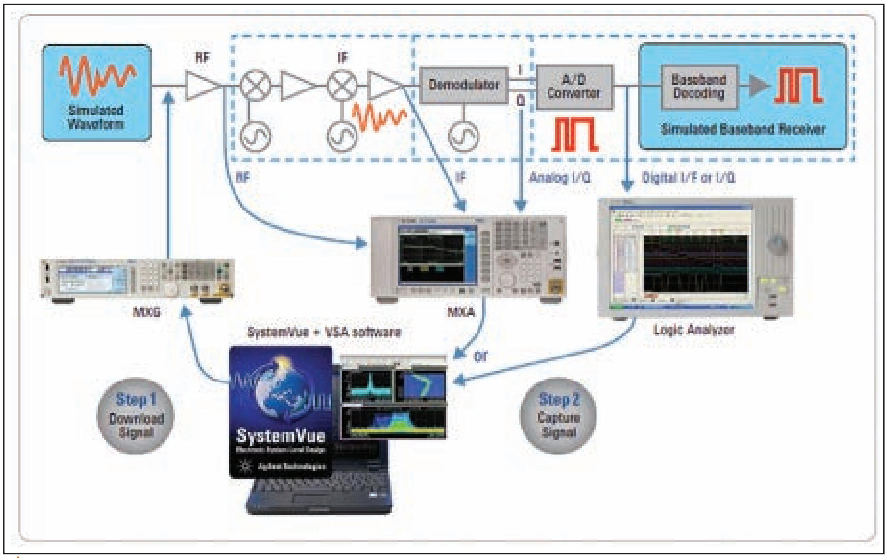
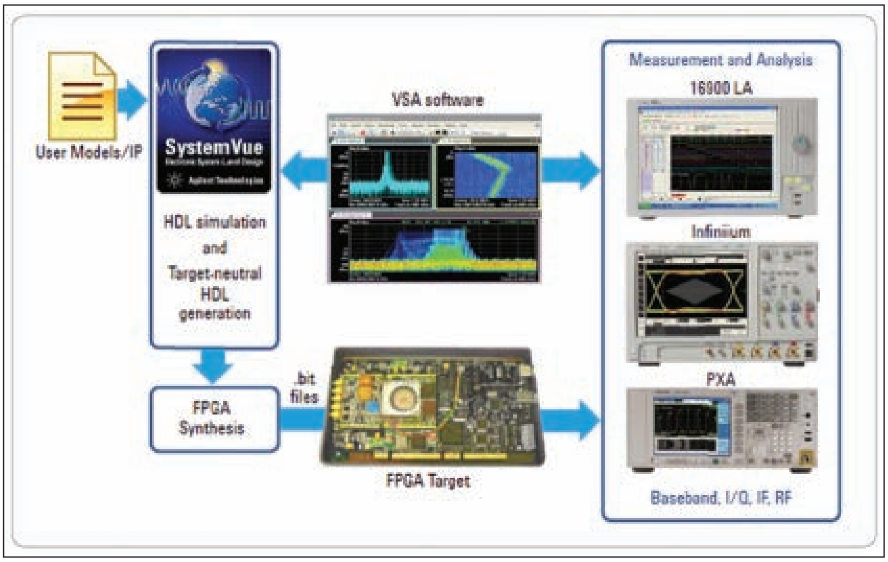


▲ *Fig. 7 Modulation measurements can be performed with RF signal analyzers and logic analyzers.*



▲ *Fig. 8 Software such as SystemVue provides modeling analysis and measurement integration.*

flexibility to support new communication standards, wider modulation bandwidths and possibly even higher frequencies. An approach that integrates design and measurement building blocks provides an ideal means of answering this need. Realizing this vision, however, will require instrument vendors to continue developing engineer-centric integrated measurement solutions that combine the key building blocks previously described: instruments (in a variety of form factors), instrument firmware and application software, as well as EDA tools. The benefit of bringing these building blocks together is two-fold: enabling higher efficiency and ultimately, faster time-to-market for today's RF and microwave system designers.

Maximizing Return on Test Equipment Investment

Dave Hutton
Aeroflex, Plainview, NY

The market for RF and wireless test and measurement is a particularly demanding one, requiring instruments to be flexible and to provide both a long term return on investment and low overall cost of ownership. The almost ubiquitous use of software-defined radio (SDR) technology in LTE and 3G test systems has proved crucial in meeting these demands, enabling the rapid addition of support for new 3GPP features and new radio technologies, while providing the capability to test new telecommunications technologies and enhancements when required by the market. PXI modules are often used in wireless and RF test products to allow a common hardware and software platform approach, which includes hardware modules and reusable software building blocks. The functionality and applications of these test instruments, whether stand-alone or modular instrumentation, are determined and defined entirely by PC-based software.

Flexibility

"The SDR approach meets the test needs in both R&D and manufacturing for network infrastructure manufacturers, network operators and handset manufacturers," said Evan Gray, product and marketing director at Aeroflex. "Customers want the same test equipment to support multiple technologies, new radio technologies and enhancements to existing ones — for example from HSPA to DC-HSPA, from LTE to LTE-A, or a combination of LTE and W-CDMA technologies — and they do not want to change hardware platforms to achieve this."

For R&D applications, SDR enables a single investment in a platform to keep up with rapid changes in the standards. For manufacturing customers, it enables straightforward upgrades to new radio standards and protects the investment in test infrastructure. The ability to upgrade in situ and to convert between testing different technologies on the same platform are significant advantages for a manufacturing line.

Customer-specific modifications to modular test equipment are relatively easy to make, by providing the capability to access the APIs at different levels and thus to integrate the system to an appropriate level of functionality to suit their particular requirements. The software defined approach also

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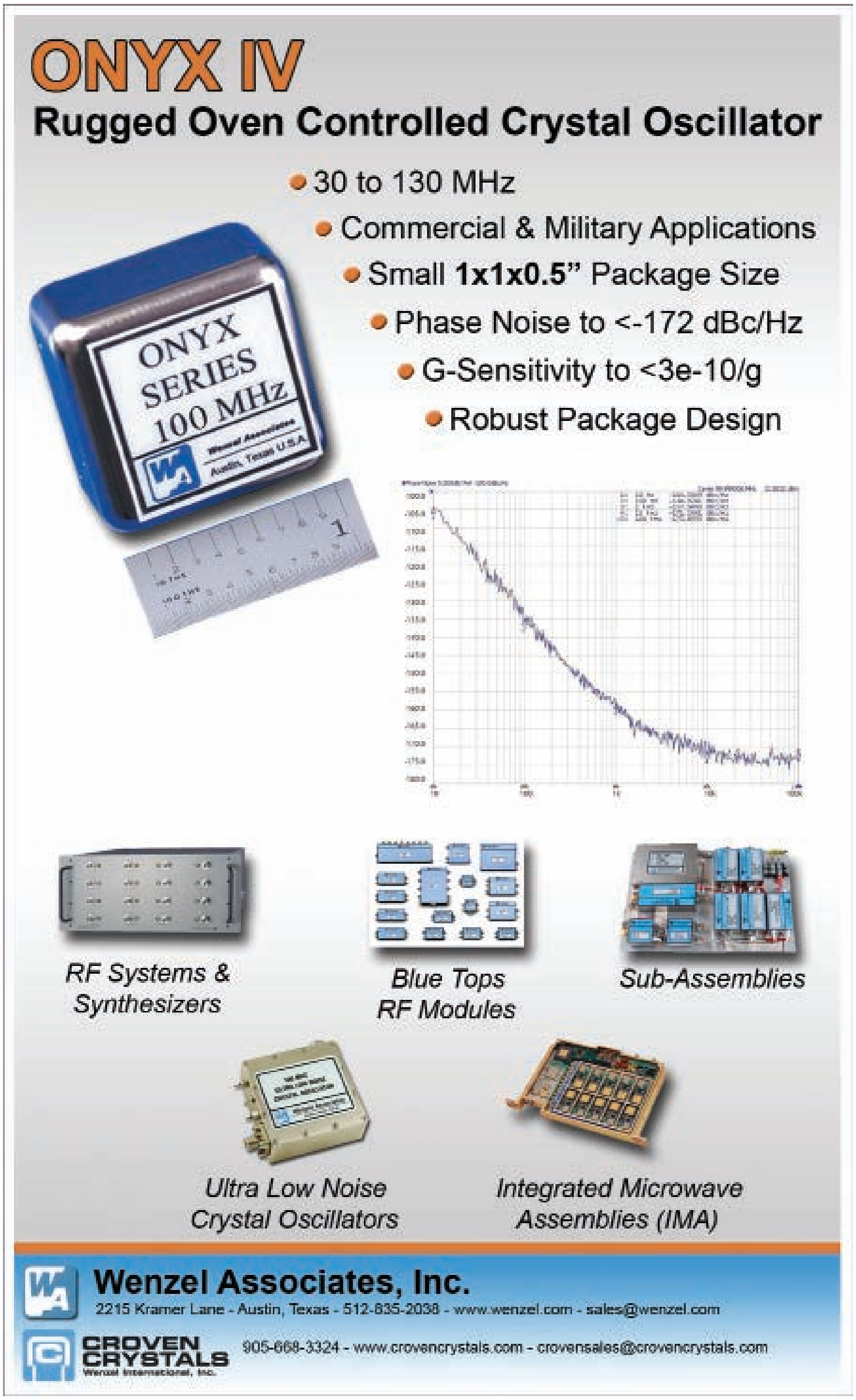
allows the customers to write their own analysis and generation tools, by enabling the digitizers and generators to produce or load IQ data directly.

The software defined approach means that the lifetime of the instruments is extended and the costs of upgrading for future radio technologies are reduced, so that the customer has the benefit of a low total cost of ownership as well as a future-proof test system. Without SDR, the cost of supporting multiple technologies would be much higher, as additional hardware platforms would be required for each technology. In many software defined instruments, the measurement software can run on commercial PCs, enabling users to benefit from continuing improvements in low-cost PC processing power and data storage technology and test software can be upgraded as easily as conventional software updates.



Enabling Technologies

The use of digital signal processors, microprocessors, standardized PXI modules and FPGAs, underpins both general purpose RF test equipment and application-specific wireless test instruments. PXI modular equipment forms the backbone of much of today's software defined instrumentation. Whether it is sold in modular form to OEMs developing their own test systems, or used in-house by test and measurement vendors who may be producing either one-box solutions for R&D test or sophisticated production ATE systems, almost all test equipment on the market today is essentially modular. The user benefits from the assurance that the performance will be the same, whether represented as a module or as part of an instrument. The PXI modules generally use FPGAs for local control, sequencing and generic DSP, along with high bandwidth DAC and ADC, allowing the majority of the control, analysis and flexibility to be defined by software running on the controlling PC.

Figure 9 shows the basic architecture of a PXI software suite that allows mix-and-match modules to be used and readily updated to cover all the latest communications standards and device types. This modular approach to the software enables a single integrated user interface (UI) across all of the compatible PXI modules. It is a flexible application that provides a single UI to whatever arrangement of source/analysis modules are connected to the PC bus, either to one or to a number of vector signal analyzers, vector signal generators or both. Although it may not be possible to provide software for every test scenario, the test cases that are most in demand and especially those

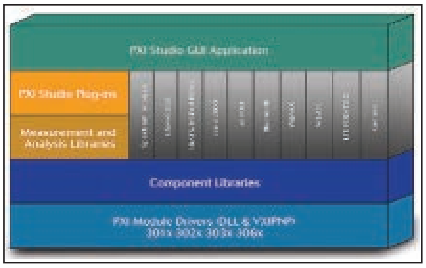


Fig. 9 PXI software suite featuring modules for a wide range of communication standards that can be readily added or upgraded.

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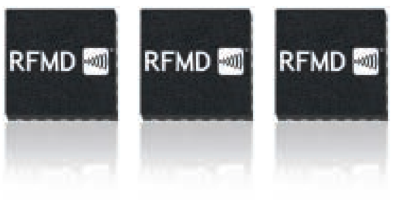

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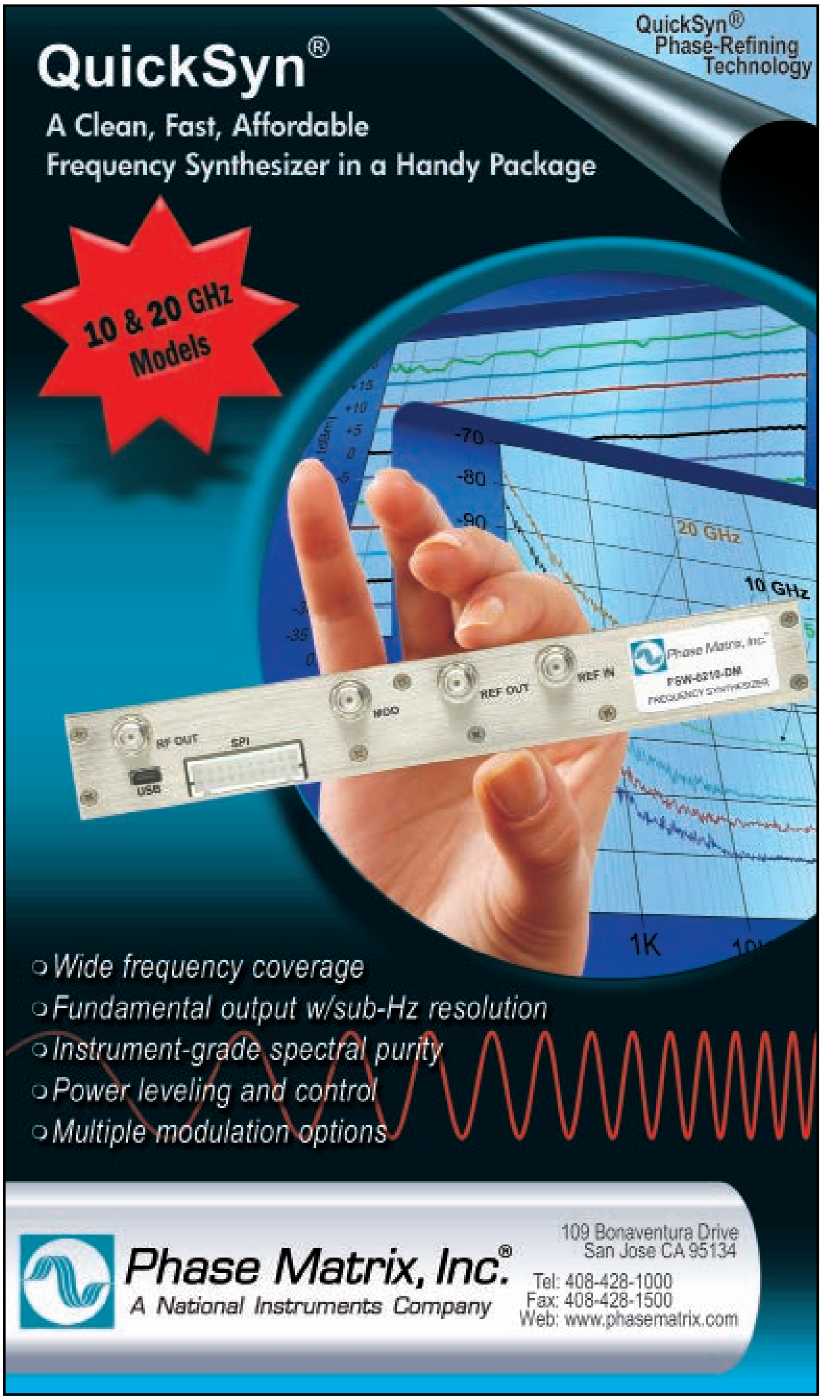
that require coordination of stimulation and response, can largely be covered.

The flexibility of RF hardware is the real key to allowing an instrument to be fully software defined and it is in this area that the real advances over the next few years are likely to take place. The hardware modules need to include flexible wide-tuning, wide-bandwidth transmitter and receiver blocks, coupled to flexible baseband processing hardware. It is important that the bandwidth of the radio hardware is adequate to cover all the frequency bands to be tested, in order that the other parameters can be selected entirely by the software. After several years of development, RF MEMS technology is maturing and, in the near future, Aeroflex expects low insertion loss MEMS switches to make it easier to switch seamlessly between different bands. Active duplexers will provide the frequency agility that is needed to deal with fragmented spectrum. The development of programmable RF will bring programmable bandpass filters and will allow wideband LNAs and power amplifiers to be deployed in future software defined instrument platforms.

Transmitters and receivers in signal generators and analyzers need to be able to cope with a wide range of crest factors for the different communications standards, as well as the broad operating frequency range and signal bandwidth. This requires tightly defined RF leveling capability, the ability to closely control I/Q modulation bandwidth and orthogonality and the integrity of the arbitrary waveform generator, which needs a high sampling rate to produce all the required waveforms. Also crucial is the ability to calibrate the instrument to achieve a good EVM by achieving tight control of amplitude and phase balance and DC offsets.

Market Trends

Among the important trends in the market are the new communication standards in development or in the early stages of deployment, such as WLAN 802.11ac and LTE-A, which require increased bandwidth. Equally, the trend over the last few years has been for products such as phones, tablets and routers to incorporate multiple radio technologies. Test instruments need flexibility and scalability to meet these requirements and the ability to upgrade and keep pace with standards will keep software defined test instrumentation at the leading edge of the market's demands. Customers also continue to demand shorter times to market for new technologies, which increasingly favors a software defined approach, since it can be too time-consuming and expensive to design specific hardware solutions. ■



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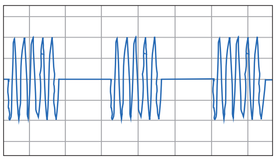
* See data sheets for an extensive list of compatible hardware and software.



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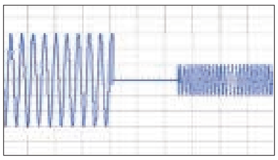
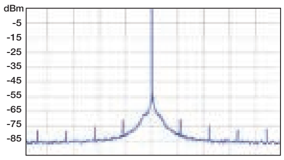


Frequency and power hopping.



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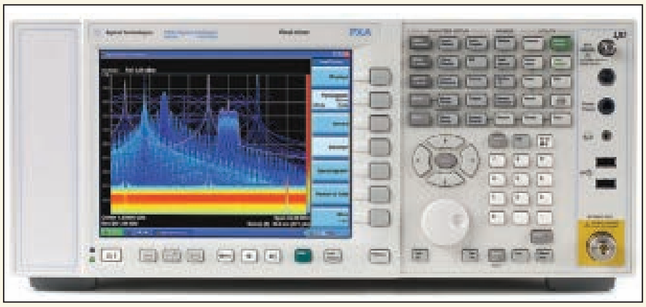
As signals continue to become increasingly complex and agile, gap-free measurement techniques such as real-time spectrum analysis and time capture are gaining acceptance in mainstream applications. Instruments such as Agilent's PXA signal analyzer are taking this a step farther into the mainstream by making these capabilities available within a traditional signal analyzer rather than a dedicated or single-purpose instrument (see ***Figure 1***).

Agilent's real-time spectrum analyzer (RTSA) capability is an upgrade option for new and existing PXAs, making the PXA the first traditional signal analyzer to offer the opportunity to add real-time analysis after the purchase. This makes real-time capability available for about one-tenth the cost of purchasing a new real-time analyzer.



▲ *Fig. 1 A real-time PXA is a cost effective solution that can identify spurious signals and then observe pulsed spurs using the real-time mode.*

Adding RTSA lets the user see, capture and understand highly elusive signals on the lab bench or in the field. For deeper analysis, a user can combine a real-time PXA with the Agilent 89600 VSA software to create a solution that enables thorough characterization of complex and modulated signals.

DEFINING REAL-TIME ANALYSIS

Although the phrase "real-time analysis" can mean different things to different people, a consistent core concept can be defined as follows: In a spectrum or signal analyzer with a digital intermediate frequency (IF) section, real-time operation is a state in which all signal samples are processed for some sort of measurement result or triggering operation (see ***Figure 2***). In most cases the measurement results are scalar (e.g., power or magnitude), corresponding to traditional spectrum measurements. In this case, each CALC operation includes the computation of a fast Fourier transform (FFT) or power spectrum as well as averaging, display updates, and so on. In addition to gap-free analysis, a real-time RF analyzer may be defined as having four more key attributes: high-speed measurements, consistent measurement speed, advanced composite displays and frequency-mask triggering (FMT).

In general, the stream of spectra from real-time processing can be used in one of two ways: The spectra can be combined into a composite spectrum display or successively compared to a limit mask to implement FMT. Both of these capabilities are present in a real-time PXA equipped with the RTSA option.

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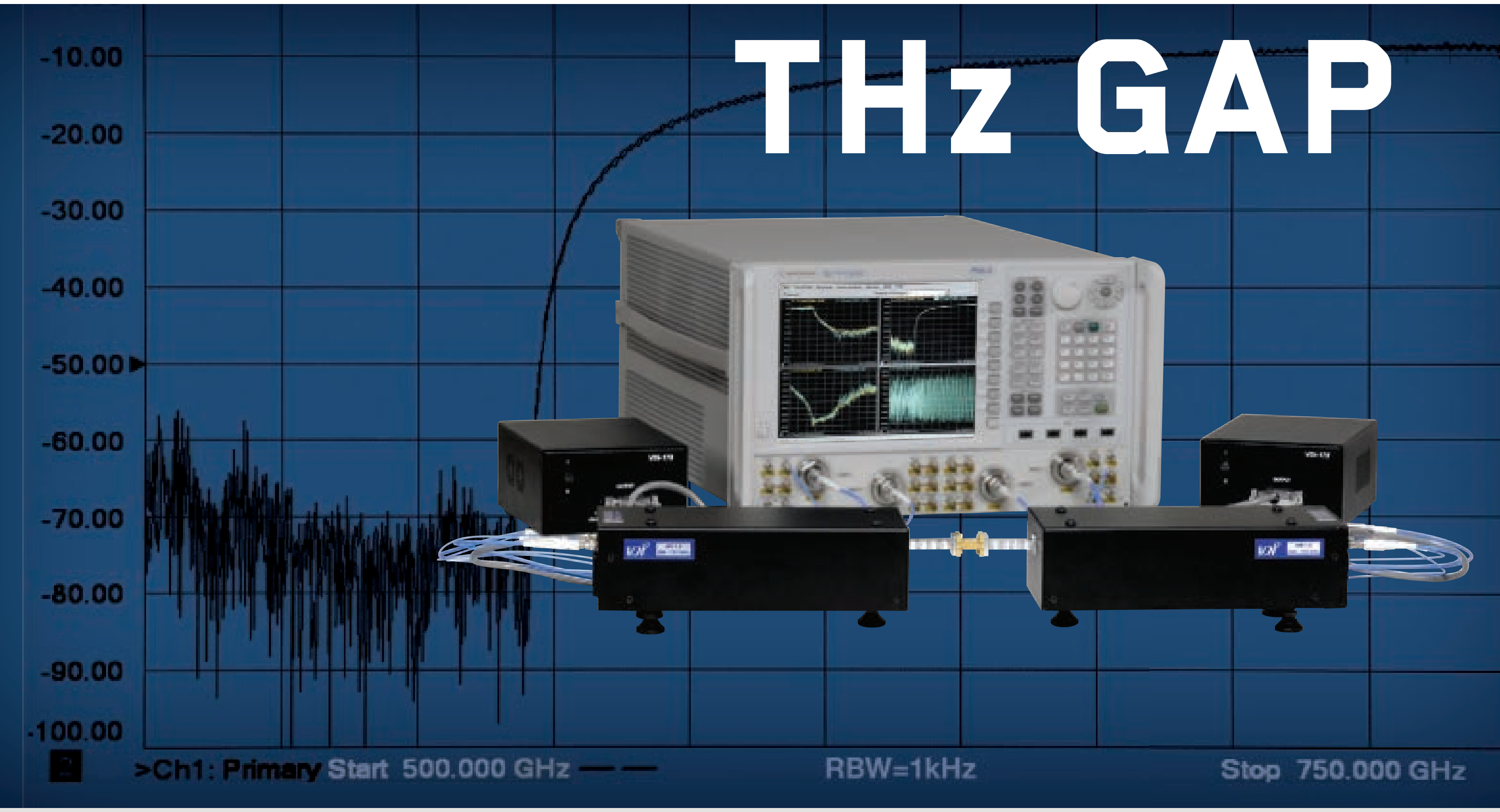

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Dynamic Range (BW=10Hz,dB,typ)	120	120	120	120	120	120	115	115	100	100	**100**	60
Dynamic Range (BW=10Hz,dB,min)	100	100	100	100	100	100	100	100	80	80	**80**	40
Magnitude Stability (±dB)	0.15	0.15	0.15	0.15	0.25	0.25	0.3	0.3	0.5	0.5	**0.8**	1
Phase Stability (±deg)	2	2	2	2	4	4	6	6	8	8	**10**	15
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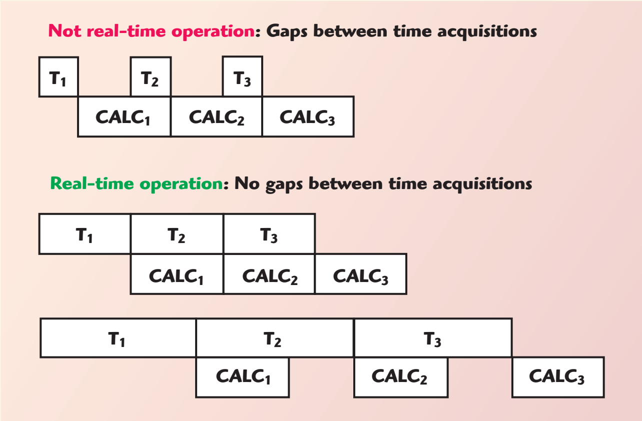
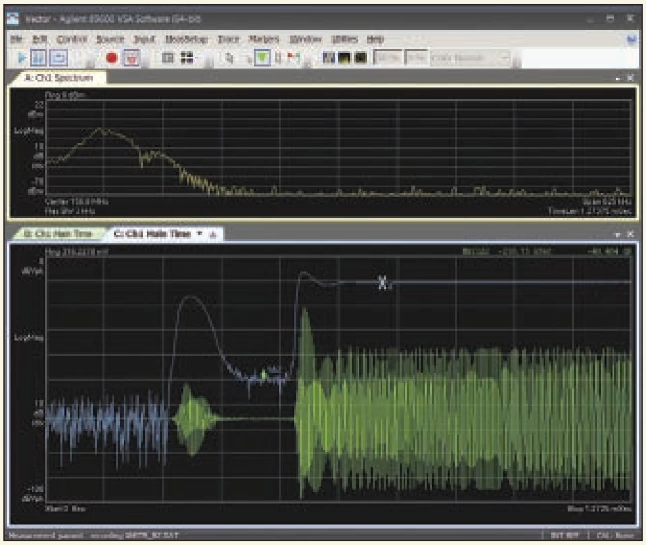


▲ *Fig. 2 Real-time operation occurs when the calculation speed is fast enough to ensure gap-free analysis of sampled data.*



▲ *Fig. 3 Vector signal analysis can show detail such as time-gated spectrum (top) and simultaneous views of the signal such as power envelope (blue) and time waveform (green).*

IMPLEMENTING REAL-TIME SPECTRUM ANALYSIS IN THE PXA

As with a dedicated real-time spectrum analyzer, the real-time PXA uses ASICs and FPGAs to convert sampled signal data into signal spectra at nearly 300,000 spectra per second. Spectrum data is combined to create information-rich displays such as density or histograms. Alternatively, the stream of spectra can be sequentially tested against limits and logical criteria to produce a spectrum- and behavior-specific frequency-mask trigger.

To make worthwhile contributions in real-time spectrum analysis, the Agilent design team focused on four key areas: bandwidth, dynamic range, probability of intercept (POI) and integrated analysis capabilities.

BANDWIDTH

As the signal bandwidths and frequency spans to be analyzed increase, greater bandwidth is necessary. With maximum analysis bandwidth of 160 MHz for real-time measurements, a PXA equipped with RTSA can address today's wideband signals and signal environments. This gap-free bandwidth applies not only to real-time spectrum analysis but also to FMT, gap-free time capture and real-time magnitude calculations for IF triggering.

Another key point: unlike some similar analyzers, a real-time PXA always gathers gap-free data for bandwidths up to 160 MHz. The user can be confident that real-time mode is consistently capturing detailed information about intermittent or rapidly changing signals.

DYNAMIC RANGE

The real-time PXA enables detection of small, fleeting and infrequent signals in the presence of large ones by providing spurious-free dynamic range of up to –75 dB across the full 160 MHz bandwidth. Dynamic range is enhanced by the low noise floor of the PXA itself and, when dealing with very small signals, this can be further enhanced with a "low noise path" option that improves sensitivity while simultaneously handling high-level signals. In all cases, the PXA's low noise floor increases the separation between small signals and noise.

PROBABILITY OF INTERCEPT (POI)

POI is the key benchmark for real-time analysis and the real-time PXA can detect signals as short as 5.0 ns, measuring down to 3.57 μs with 100 percent POI and full amplitude accuracy. Gap-free analysis is just one element of POI. Within an instrument, the other contributing factors include analyzer and processor dynamic range (including sensitivity), sampling bandwidth, processing continuity and FFT processing overlap (which compensates for the shape of windowing functions).

INTEGRATED ANALYSIS CAPABILITIES

In some cases, simply finding an elusive signal is sufficient: the mere presence of a signal — and perhaps its overall spectral shape — may be all that's needed to answer a question, confirm a problem or suggest a solution. In other situations, finding the signal is just the first step toward a solution to a problem in a system or signal environment.

Using VSA software with a real-time PXA enables thorough analysis and demodulation of signals acquired in real-time mode. In addition, real-time FMT can be used to focus all VSA measurement functions — including demodulation and time capture — on highly elusive signals (see ***Figure 3***). These capabilities are especially effective when measuring modulated transients, frequency-hopping signals, frequency settling, and undesired transients in signal sources such as voltage-controlled oscillators (VCO).

FULLY UTILIZING SIGNALS ACQUIRED IN REAL-TIME

Two additional capabilities are worth a closer look: histogram or density displays and frequency-mask triggering.

Histogram or Density Displays

To capture the dynamics of agile or fleeting signals, real-time spectrum analyzers generate thousands of spectra every second. Because this is more than the human eye can discern, it is necessary to represent large amounts of measurement data in a single display trace. As an example, the real-time PXA can produce nearly 300,000 spectra per second but most people can see only 30 per second. Thus, to present real-time results in a meaningful way, each display update needs to represent about 10,000 results.

In a real-time analyzer, informative displays are created by compiling statistics and displaying how often a particular measurement value occurs (e.g., specific amplitude at a specific frequency). This histogram of measurement results is a spectrum measurement enhanced to show frequency of occurrence, and win SEMICONDUCTORS

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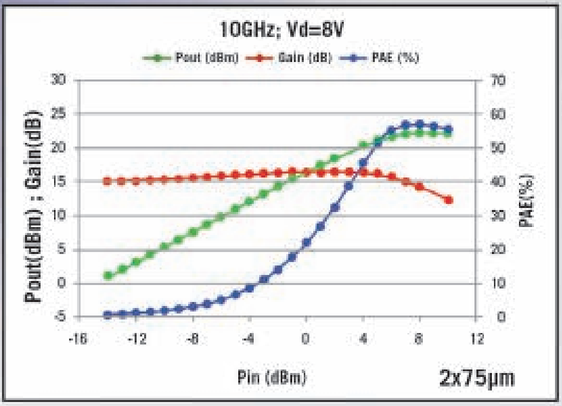

Gain (dB)	P1dB (dBm)	P1dB (mW/mm)	Psat (dBm)	Psat (mW/mm)	PAE Max(%)
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Idmax (Vg=0.5V)	490 mA/mm	620 mA/mm	525 mA/mm	760 mA/mm
Peak Gm	410 mS/mm	460 mS/mm	580 mS/mm	725 mS/mm
Vto	-1.15 V	-1.3 V	-0.7 V	-0.95 V
BVGD	20V(18V min)	16V(14V min)	9V(8V min)	10V(8V min)
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f_{max}	190 GHz	185 GHz	150 GHz	180 GHz
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some may consider this to be a backward-looking version of probability.

These displays are coded using color or intensity, and a persistence function can be added to focus attention on more recent events as older data fades away. Trace data such as the most recent single display update, or an average, can also be overlaid as a trace that looks similar to a traditional spectrum measurement.

This approach allows engineers to see and focus on infrequent events or transients, then separate them from other behavior. By changing persistence and color-weighting values or schemes, specific behaviors can be highlighted. The real-time PXA enables interpretation and analysis of results providing complete trace-marker capabilities with persistence displays.

FMT Technology

When looking for a specific signal, FMT compares the high-speed data stream to a user-defined spectrum mask. A trigger is generated when the mask is exceeded or when the signal enters the mask region. This capability is made more useful with conditional triggering on actions such as a signal exiting or re-entering the mask.

In the real-time PXA, masks can be a combination of upper and lower limits, and can be entered numerically or graphically. As a time-saving feature, the analyzer can use the measured signal environment to automatically generate a mask, which the user can modify as needed. To simplify this process, the mask is shown along with the live measured trace.

FMT may be used to generate successive triggers on a relatively frequent basis. In contrast, one of its most powerful uses is those situations in which the behavior to be measured is very rare, with gaps of minutes or hours between events. If the VSA software is included, pre- and post-trigger delays can be used to capture the beginning or end of an event, or anything in between.

ENHANCING UTILITY

In most organizations, today's economic climate increases the pressure to fully utilize existing equipment such as traditional signal analyzers. On the flip side, tight spending controls make it harder to justify single-purpose tools such as dedicated real-time analyzers.

This is one of the key reasons Agilent decided to create RTSA as an upgrade option that can be added to new or existing PXA signal analyzers. It is also one of the reasons why the PXA was designed from day 1 with an architecture that enables the addition of new capabilities such as RTSA. The result is an analyzer that provides both traditional and real-time capabilities in one unit — and delivers consistent performance when using either mode at a cost that is much less than purchasing a new hardware.

VENDORVIEW

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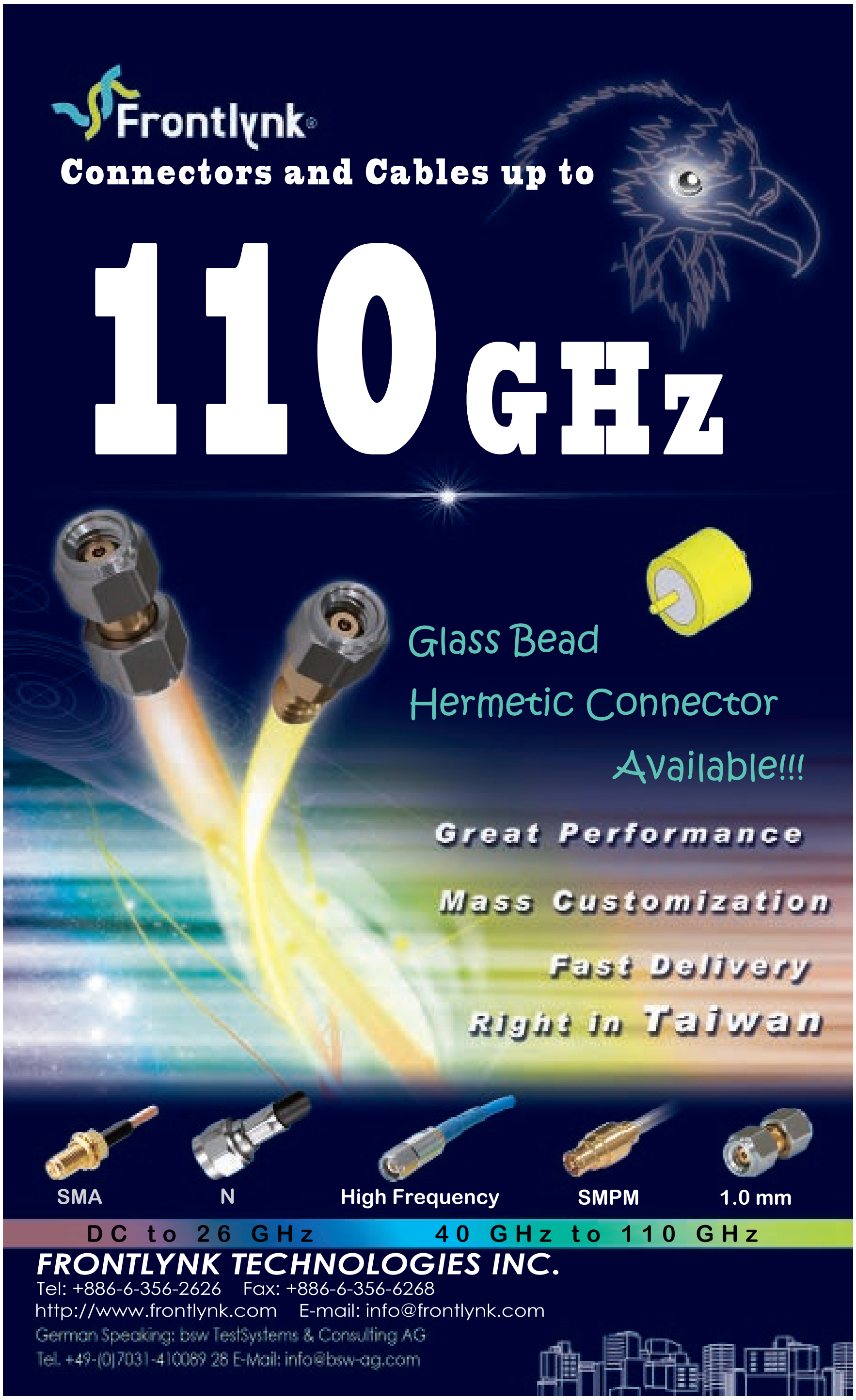

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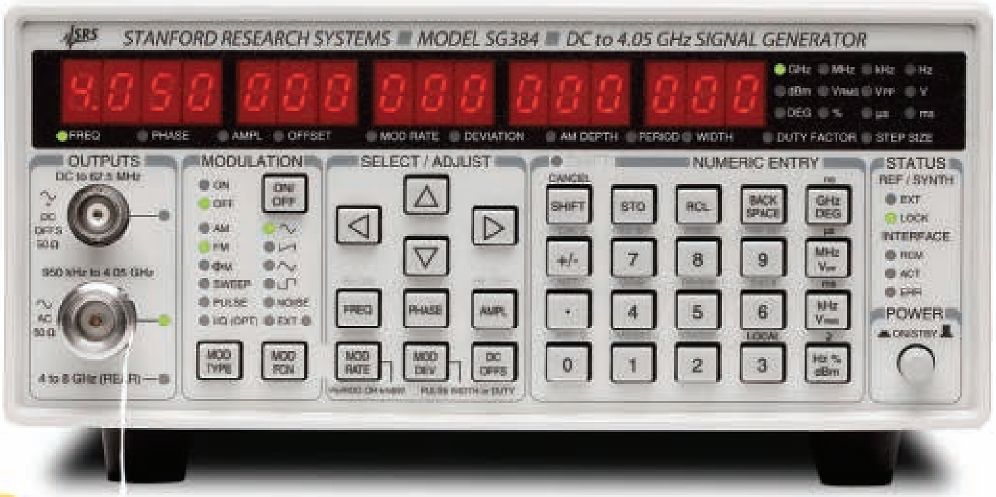

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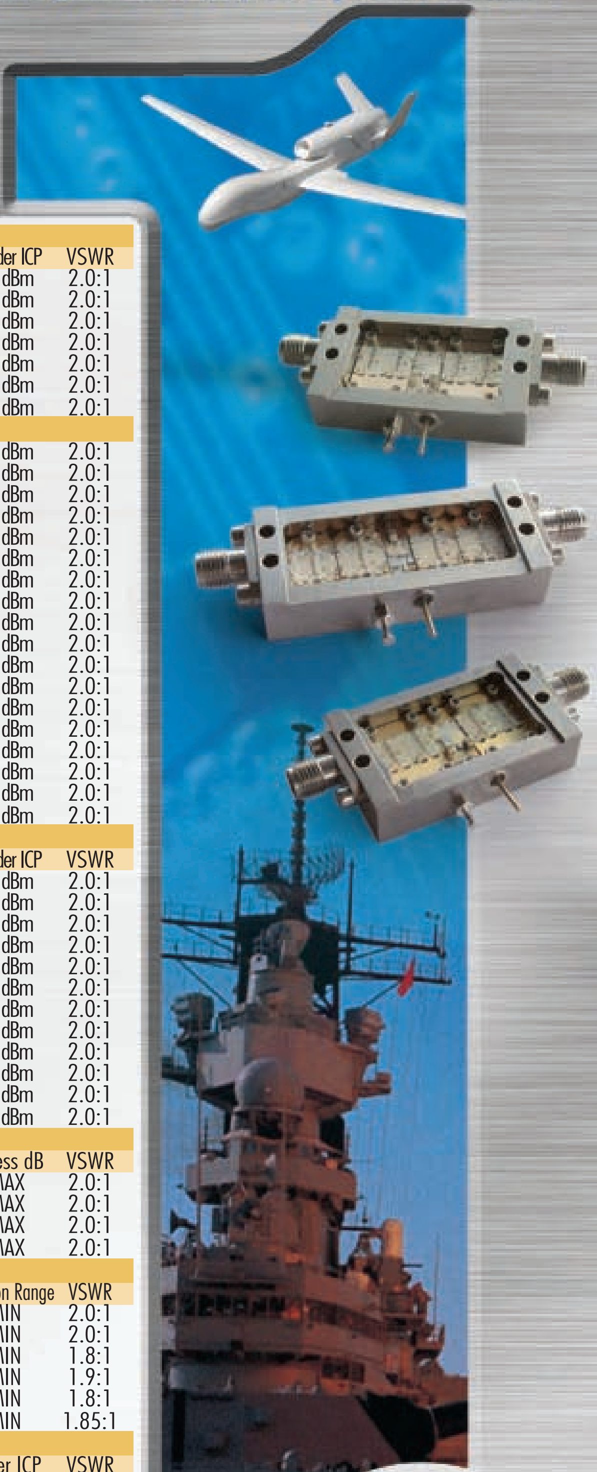

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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Northrop Grumman's Fire Control Products Play Key Role in Successful Missile Defense Test

Northrop Grumman Corp.'s command launch equipment (CLE) software effectively launched the ground-based interceptor in a flight test of the U.S. Missile Defense Agency's (MDA) Ground-Based Midcourse Defense (GMD) system.

"Our Northrop Grumman GMD team is committed to supporting MDA as they continue to enhance the integrated missile defense capability needed to defend our nation, its allies and deployed forces," said Kelley Zelickson, vice president of air and missile defense systems.

During the GMD flight test, known as CTV-01, a ground-based interceptor was launched from Vandenberg Air Force Base, CA to test changes that have been made to the exoatmospheric kill vehicle. The CLE software controls the interceptor while on the ground, computes the detailed intercept trajectory and provides it to the interceptor, and at the appropriate time commands the interceptor's ignition and launch.

"The effectiveness of our fire control products were proven again in this latest test, continuing our record of meeting all test objectives," said Steve Owens, GMD operating unit director for Northrop Grumman and deputy program director for the Boeing/Northrop Grumman GMD team.

Northrop Grumman is responsible for designing and deploying the GMD fire control products, which include the Fire Control System, In-Flight Interceptor Communications System Data Terminal, Communications Network Equipment, Network System Manager and CLE software. Northrop Grumman is a strategic partner, with The Boeing Co., of the GMD team.

Northrop Grumman also supported the test through its prime contractor role at the Missile Defense Integration and Operations Center in Colorado Springs. Company personnel provided engineering and communications expertise that helped the Mission Control Center Facility and the NORTHCOM Command and Control Battle Management and Communication system execute the mission. Northrop Grumman engineers also continuously monitored all test executions to assess the progress and success of the GMD flight test.

Enhanced Exoatmospheric Kill Vehicle Successful in Non-Intercept Flight Test

Raytheon Co.'s upgraded Exoatmospheric Kill Vehicle played a mission-critical role in a non-intercept flight test of Boeing's Ground-Based Midcourse Defense (GMD) program. The EKV is a vital component of the GMD's Ground-Based Interceptor. The EKV allows the GBI to lock on and eliminate high-speed ballistic missile warheads in space using nothing more than the force of impact.

"Rigorous non-intercept flight tests are important in proving the effectiveness and operational capability of ballistic missile defense weapons and their various components," said Wes Kremer, Raytheon Missile Systems' vice president of Air and Missile Defense Systems. "Today's test allowed us to challenge the EKV in a series of realistic outer-space environments, which gives us a broad range of data prior to moving toward an intercept scenario."

During the test, the EKV performed as planned, maneuvering the interceptor to the appropriate altitude and closing velocity required for an intercept.

"The sole purpose of the Ground-Based Midcourse Defense program is to defend the homeland from the threat of ballistic missile attack," said Kremer. "This test moves us one step closer to an intercept flight test in 2013."

Lockheed Martin Completes Work on U.S. Navy's Second MUOS Satellite

Lockheed Martin has successfully completed required system testing on the second satellite in the U.S. Navy's Mobile User Objective System (MUOS), designated MUOS-2. The satellite has been placed in storage to await its scheduled launch date in July 2013. The MUOS constellation will provide significantly improved and secure communications for mobile warfighters, including simultaneous voice, video and data services – similar to the capabilities experienced today with smartphones. The first MUOS satellite, launched February 24, and the associated ground system are currently providing legacy on orbit capability, followed by the launch of MUOS-2 in 2013. The five-satellite, global constellation is expected to achieve full operational capability in 2015.

"The joint U.S. Navy and Lockheed Martin MUOS team completed an efficient integration and test campaign of MUOS-2 and we look forward to delivering this critical satellite for launch," said Iris Bombelyn, vice president for the Lockheed Martin's Narrowband Communications mission area. "As we continue to produce MUOS satellites, we expect to drive even greater efficiency and affordability into our operations."

In the spring of 2013, Lockheed Martin will remove the satellite from storage, perform final spacecraft component installations and conduct a final factory confidence test in Sunnyvale, CA prior to shipping MUOS-2 to Cape Canaveral Air Force Station, FL, for its launch aboard an Atlas V rocket. MUOS satellites are equipped with a Wideband Code Division Multiple Access (WCDMA) payload that provides a 16-fold increase in transmission throughput over the current ultra high frequency (UHF) satellite system. Lockheed Martin announced completion and delivery of the waveform last week. Each MUOS satellite also

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includes a legacy UHF payload that is fully compatible with the current UHF follow-on system and legacy terminals. This dual-payload design ensures a smooth transition to the cutting-edge WCDMA technology while the UFO system is phased out.

Boeing-Led Missile Defense Team Completes GMD Flight Test

Boeing, working with the U.S. Missile Defense Agency and industry teammates, returned the Ground-Based Midcourse Defense (GMD) system to testing with a successful flight. GMD is the United States' only defense against long-range ballistic missile threats.

"Today's test signals the next step in GMD's future capability and is the culmination of successful partnerships among government, military leaders and industry," said Greg Hyslop, vice president and general manager for Boeing Strategic Missile and Defense Systems. "Throughout our team effort to solve one of the toughest challenges facing the aerospace industry, GMD remained on alert and continues to defend the United States."

GMD flight testing was halted in early 2011 after a guidance error resulted in a failed intercept in a December 2010 test.

"Returning to flight has been the top priority for the GMD program. We have used industry and government's combined expertise to solve a complex technical issue related to what the interceptor's exoatmospheric kill vehicle (EKV) experiences in space," said Norm Tew, Boeing vice president and GMD program director. "Today's success is an important step toward our next goal of a successful intercept test."

Today's success is an important step toward our next goal of a successful intercept test.

The test at Vandenberg Air Force Base began at 2 PM Pacific time with the launch of a GMD Ground-Based Interceptor (GBI) carrying a next-generation EKV. The test measured the EKV's performance as the vehicle operated under stressful space conditions. Data gathered during the test will be used to validate the EKV's design.

GMD is an integral element of the United States' layered ballistic missile defense architecture. With interceptors deployed at Vandenberg and at Fort Greely, Alaska, the program consists of command-and-control facilities, communications terminals and a 20,000-mile fiber-optic communications network that interface with ballistic missile defense radars and other sensors. Boeing has served as prime contractor since 2001 and works with industry partners Northrop Grumman, Orbital Sciences Corp. and Raytheon.

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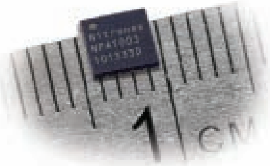

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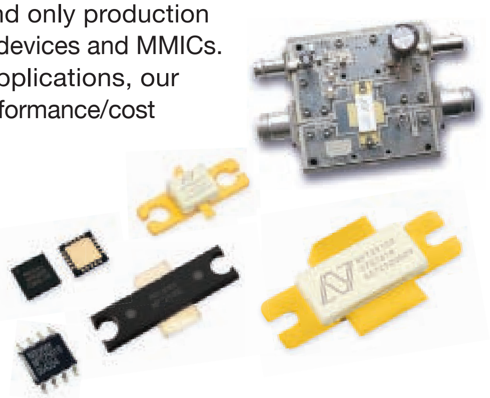

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Raytheon Opening New Silicon Carbide Foundry in Scotland

Raytheon has opened a new UK-leading silicon carbide manufacturing foundry facility, developed through several years' research into advanced manufacturing processes and materials science. The application of silicon carbide in electronic systems will place the UK in a leading position to develop next-generation, high-efficiency, smaller, low-weight power conversion products used in harsh environments across the automotive, aerospace, geothermal explorations, oil and gas, and clean energy sectors.

Raytheon's ability to process silicon carbide utilises high-temperature annealing and high-temperature/high-voltage ion implantation. The components provide unique properties in electronics: silicon carbide has the ability to operate at higher voltages and greater temperatures than pure silicon, and at a third of the weight and volume, thus improving operational performance and reducing system operating costs. Raytheon claims to be the first company to have successfully tested silicon carbide circuit devices at temperatures up to 400°C.

"What was previously unachievable is now possible with silicon carbide..."

The Secretary of State for Scotland, the Rt. Hon. Michael Moore, who opened the foundry, said, "Today marks an important demonstration of what we can achieve in the UK through collaboration. The silicon carbide foundry is the first of its kind in the UK and represents the fusion of Raytheon's investment in UK manufacturing technology with university expertise, backed by UK government funding from the Technology Strategy Board.

Bob Delorge, chief executive, Raytheon UK, said, "Raytheon's investment in the foundry coupled with support from the Technology Strategy Board exceeds £3.5 million to date. This places the company at the start of a journey to exploit new global markets for this cost-efficient material, which is estimated to bring significant new business to Raytheon in Scotland in the coming years."

"What was previously unachievable is now possible with silicon carbide," he added, "as it allows for smaller and lighter electronics to operate in harsh environments, and addresses a real customer need for significant energy efficiency savings in the manufacture of power switching and rectifying components (AC/DC converters)."

TSB Catapulting Innovation Forward in UK

The Technology Strategy Board (TSB) has made great progress in establishing a network of world-leading technology and innovation centres – Catapults – in the UK, according to its chief executive, Iain Gray. A Catapult is a technology and innovation centre where the very best of the UK's businesses, scientists and engineers can work side by side on research and development – transforming ideas into new products and services to generate economic growth.

...the BuNGee consortium's objective will be to increase the overall mobile network infrastructure capacity...

Each Catapult focuses on an area that the government has already identified as strategically important in global terms and where there is genuine potential for the UK to gain competitive advantage. The seven centres focus on: high value manufacturing, satellite applications, connected digital economy, transport systems, future cities, offshore renewable energy and cell therapies.

Catapult centres will help businesses to adopt, develop and exploit innovative products and technologies – the next stepping-stone on the journey to commercialisation. They offer concentrated expertise in areas vital for that journey – such as manufacturing processes, test facilities, type approval and accreditation or supply chain development.

Gray commented that with an investment of around £1 billion over the coming few years, Catapults represent one of the most important developments in UK innovation and technology and will make a major impact in the coming decades. This represents a significant investment by government and one that has been welcomed across the research and innovation spectrum. The potential global market that could be accessed by UK businesses through each of the Catapult centres is likely to be worth billions of pounds per annum.

SMEs Given Deadline to Apply for Eurostars Funding

The next deadline for the submission of an application for Eurostars funding has been set at 4 April 2013. Under the programme, participants are allowed funding for the development of new high-tech products: 75 percent of the funds come from national funds and 25 percent from the European Commission, bringing national agencies to cooperate and share public funds across countries.

Financed by the governments of 33 European countries, the Eurostars Programme is supporting innovators all over the continent. Within Eurostars, small businesses lead international research projects where they partner with other small companies, universities and big companies. The track record of a completed Eurostars project proves that a small company is able to manage a large international project, helping it to gain recognition from banks, private investors and blue chip companies.

Because Eurostars was designed for small companies, it is much easier to participate in this programme than it is with

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other similar European instruments, as the application and reporting processes are significantly simpler in comparison.

Eurostars funding is used for the development of new technological products and purely academic projects are not eligible for Eurostars funding. The aim is to create the new star company that will lead the European high-tech industry in the future.

ETSI Standards Group for Network Functions Virtualization Created

Seven of the world's leading telecoms network operators have initiated a new standards group for virtualization of network functions. AT&T, BT, Deutsche Telekom, Orange, Telecom Italia, Telefonica and Verizon have been joined by 52 other network operators, telecoms equipment vendors, IT vendors and technology providers to create the ETSI Industry Specification Group (ISG) for Network Functions Virtualization (NFV).

Telecoms networks contain an increasing variety of proprietary hardware appliances. To launch a new network service often requires yet another appliance and finding the space and power to accommodate these boxes is becoming increasingly difficult, in addition to the complexity of integrating and deploying these appliances in a network. Moreover, hardware-based appliances rapidly reach end of life: hardware lifecycles are becoming shorter as innovation accelerates, reducing the return on investment of deploying new services and constraining innovation in an increasingly network-centric world.

Virtualization of network functions aims to address these problems by evolving standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage. It involves implementing network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need to install new equipment.

...hardware lifecycles are becoming shorter as innovation accelerates...

The ETSI ISG NFV will develop requirements and architecture specifications for the hardware and software infrastructure required to support these virtualized functions, as well as guidelines for developing network functions. This effort will incorporate existing virtualization technologies and existing standards as appropriate and will co-ordinate with ongoing work in other standards committees. The first specifications are expected before the end of 2013.

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USB-3SPDT-A18	3	0.25	1.2	80	10	980.00
USB-4SPDT-A18	4	0.25	1.2	80	10	1180.00
NEW USB-8SPDT-A18	8	0.25	1.2	80	10	2495.00

* See data sheet for an extensive list of compatible software.

† The mechanical switches internal to 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 patents 5,272,458 6,650,210 6,414,577 7,633,361 7,843,289 and additional patents pending.

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U.S. Patents 7739260, 7761442

IF/RF MICROWAVE COMPONENTS

489 rev L

Turn USB Power Sensors into

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- *Power Data Analysis Software*
- *SMA Adaptor (50Ω only)*
- *USB Cable*

Model	Frequency	Price $ ea. (Qty 1-4)
PWR-4GHS	9 kHz-4 GHz	795.00
PWR-2.5GHS-75	100 kHz-2.5 GHz	795.00
PWR-6GHS	1 MHz-6 GHz	695.00
PWR-8GHS	1 MHz-8 GHz	869.00
PWR-8FS	1 MHz-8 GHz	969.00
NEW! PWR-4RMS	50 MHz-4 GHz	1169.00

** Measurement speed as fast as 10 ms with PWR 8 FS. All other models as fast as 30 ms.*

† See datasheets for an extensive list of compatible software.

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IF/RF MICROWAVE COMPONENTS

488 rev N

Commercial Market

Dan Massé, Associate Technical Editor

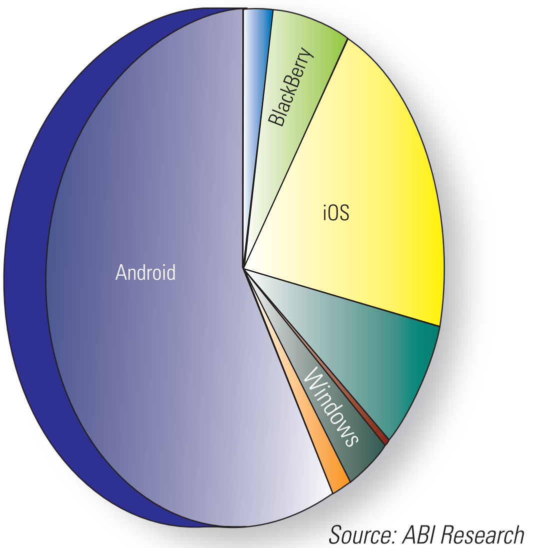
45 M Window Phones, 20 M BlackBerry Phones, 10 M Smartphones in Active Use

The global installed base of smartphones will total 1.4 billion by the end of 2013, according to the latest forecasts from ABI Research. Of this base, 57 percent will run on Android and 21 percent on iOS. Meanwhile, there will be 268 million tablets in active use, with 62 percent of them built on iOS and 28 percent on Android. The annual growth rate against 2012 will be 44 percent for smartphones and 125 percent for tablets. Despite Apple's and Google's strong hold of the market, ABI Research anticipates that the future won't be quite as duopolistic as it may seem now.

Outside of the leading two operating systems, how will the world look for the two main challengers, Windows Phone and BlackBerry 10? Senior analyst Aapo Markkanen comments, "2013 should be seen as relative success for both Microsoft and BlackBerry. For the end of the year, we expect there to be 45 million Windows phone handsets in use, with BlackBerry 10 holding an installed base of close to 20 million. Microsoft will also have 5.5 million Windows-powered tablets to show for it."

Importantly, the figures refer to actively used devices, which is what app developers – with certain caveats in mind – should generally treat as an addressable market for their releases. As Markkanen points out, "The greatest fear for both Microsoft and BlackBerry is that the initial sales of their smartphones will disappoint and thereby kill off the developer interest, which then would effectively close the window of opportunity on further sales success. ABI's view is that the installed bases of this scale would be large enough to keep these two in the game. It will definitely also help that both firms have actively kept the developers' interest in mind while designing and rolling out their platforms."

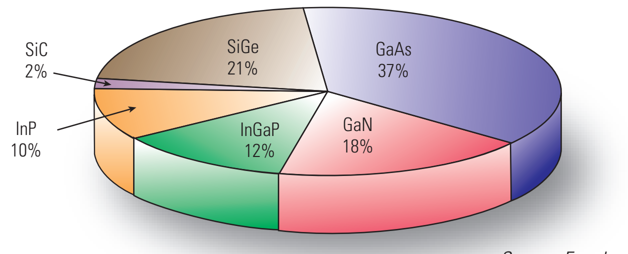
2013 Global Installed Base of Smartphones



Source: ABI Research

Global & Regional Opportunities for CS MMICs into Medium-Volume Applications

Proportions of Players Involved in Each Type of CS MMIC (as of mid-2012)



Source: Engalco

Engalco has recently released an update report on markets for compound semiconductor MMICs (CS MMICs) into medium volume applications. Although silicon technology (notably CMOS) is steadily advancing into some of the territory previously occupied by compound semiconductors, there are many microwave and millimeter-wave systems for which the required performance levels can only be met by CS MMICs. This report provides market data on MMICs fabricated using GaAs, GaN, InP, SiC and SiGe into the following systems applications: adaptive cruise control (ACC); defense (AESAs, EW); industrial, scientific and medical (ISM); Ka-Band VSATs, Ku-Band VSATs, microwave radio, millimeter-wave radio (E-Band).

> *The global market for MMICs into W-Band ACC amounted to low tens of millions in 2012 increasing to low hundreds of millions in 2017...*

Power amplifier MMICs and "non-power" MMICs are considered separately for all segmentations. Annual total market data is indicated for years 2011, 2012 and each forecast year to 2017. Regions covered include Europe, North America and "the rest of the world." Total global markets were about $1.27 billion in 2011 increasing to $1.65 billion in 2017 but with fluctuations in intermediate years. Markets for GaAs-based MMICs remain strong, albeit increasingly suffering from the GaN competition. Markets for most types of CS MMICs are well entrenched in AESAs, SATCOM (VSATs) and microwave radios.

The most rapid overall growth is exhibited by ACC and millimeter-wave radio applications. The global market for MMICs into W-Band ACC amounted to low tens of millions in 2012 increasing to low hundreds of millions in 2017, mostly SiGe MMICs in Europe. The global market relating to millimeter-wave radio was also low tens of millions in 2012 increasing to around $0.5 billion in 2017 – dominated by GaAs MMICs. This application largely shrugs off the increasing competition from RF CMOS.

Go to mwjournal.com for more commercial market news items

Amongst the 62 players identified principal companies include: Hittite Microwave, M/A-COM Technology Solutions, RF Micro Devices, TowerJazz and TriQuint Semiconductor. These players serve major portions of the total markets and profiles are contained in this report. Leading firms are also listed as "top 5" or "top 10" appropriately.

InGaP-based MMICs represent a variation of GaAs-based. In this report both technologies are essentially combined under "GaAs."

First Joint Plugfest for WiGig Alliance Since Unification Announcement

The Wireless Gigabit (WiGig) Alliance has completed testing its multi-gigabit wireless WiGig technology at the first plugfest since a "memorandum of understanding" of unification with Wi-Fi Alliance® was executed late last month.

This plugfest is the third in the history of the WiGig Alliance and featured attendance from both organizations' member companies. The plugfest helped to progress interoperability with further real-world testing and the results will be used in the development of a certification program.

"The continuation of our plugfest program is a critical part of our ongoing progress toward certification. With each plugfest, we move closer to achieving a fully commercialized new standard," said Dr. Ali Sadri, WiGig Alliance president and chairman. "The vision to introduce this technology, which will enable new applications and an unprecedented user experience, is already becoming a mainstream reality and when certification becomes available, we will see an explosion in WiGig products coming to market."

The plugfest was held at international testing center TUV Rheinland in San Jose. Sarbjit Shelopal, director at TUV Rheinland commented on the Plugfest, "It has been great to work with the WiGig members on achieving this important milestone in the course of bringing the 60 GHz technology to market. We have a wealth of experience in areas such as product certification, consumer electronics and training and knowledge services, and believe there is great potential in this new technology."

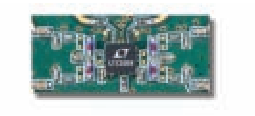
> *"The continuation of our plugfest program is a critical part of our ongoing progress toward certification."*

During the plugfest, WiGig and Wi-Fi Alliance members tested their products to develop interoperability within the ecosystem and provide end-users with highly reliable and compatible devices. ABI Research is predicting that 60 GHz enabled device shipments will exceed one billion units per annum by 2017 and the plugfest along with the certification program are the important steps to get there.

4G 4 U

Dual RF Mixer Needs Only 600mW

Actual Size



LTC5569 Total Solution Size: <220mm^2
Including External Components

300MHz to 4GHz, 26.8dBm IIP3 Dual Active Mixer

The LTC®5569 is the lowest power dual mixer with the highest performance and widest bandwidth. Its small form factor is optimized so you can pack more diversity or MIMO receiver channels in compact Remote Radio Heads. The mixer's wide frequency range allows you to build a wide range of multiband radios cost effectively. With integrated RF and LO balun transformers, the LTC5569 saves cost and precious board space. Each channel can be independently shut down, providing maximum flexibility to efficiently manage energy use.

▼ Dual Mixer Family

Part Number	Frequency Range	IIP3 (dBm)	Conv. Gain (dB)	NF/5dBm Blocking (dB)	Power (mW)	Package
LTC5569	0.3GHz to 4GHz	26.8	2	11.7/17.0	600	4mm x 4mm QFN
LTC5590	0.6GHz to 1.7GHz	26.0	8.7	9.7/15.5	1250	5mm x 5mm QFN
LTC5591	1.3GHz to 2.3GHz	26.2	8.5	9.9/15.5	1260	5mm x 5mm QFN
LTC5592	1.7GHz to 2.7GHz	26.3	8.3	9.8/16.4	1340	5mm x 5mm QFN
LTC5593	2.3GHz to 4.5GHz	26.0	8.5	9.5/15.9	1310	5mm x 5mm QFN

▼ Info & Free Samples

www.linear.com/product/LTC5569

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LINEAR TECHNOLOGY

Around the Circuit

Laura Glazer, Staff Editor

MERGERS & ACQUISITIONS

National Instruments announced its acquisition of Dresden, Germany-based **Signalion GmbH**. The acquisition delivers strong wireless communications talent and technologies to the NI platform, which are critical to NI's goal to continue to drive long term growth in the communications test industry. Signalion founders, Dr. Tim Hentschel and Dr. Thorsten Dräger, will remain with the company as co-managing directors, and work closely with NI R&D to evolve the capabilities of NI LabVIEW system design software and modular PXI hardware for wireless test applications. Signalion will continue to operate as a wholly owned NI subsidiary and to sell and support its products through its direct, distributor and OEM channels.

Elektrobit Corp. (EB) and **Anite plc** have signed an agreement whereby EB agrees to sell its Test Tools product business to Anite. The transaction comprises the sale of the shares of EB's subsidiary Elektrobit System Test Ltd., a company based in Oulu, Finland, and certain related other assets in the USA and China. The cash consideration payable to EB by Anite as a result of the Transaction is €31.0 million on a cash and debt free basis.

COLLABORATIONS

Wavefront and **Anritsu Electronics Ltd.** announced they have formed a partnership expected to lower the costs and increase the availability of LTE development and testing in Canada for SME-level businesses, device manufacturers and mobile virtual network operators. The LTE pre-screen testing capabilities available as part of this partnership offer a turnkey approach to quality assurance and certification of the test scripts for LTE applications prior to their submission to a mobile carrier.

Huawei and **Zain** have announced the successful launch of a commercial LTE 1800 MHz network that covers the entire country of Kuwait. The network is the largest of its kind in the region and marks a major step for the development of the region's mobile broadband market. Zain and Huawei expanded their LTE partnership after the successful deployment of GSM and UMTS networks in Kuwait. Zain has launched LTE services under the banner of Wiyana Connect LTE, a newly-built LTE network that realizes Circuit Switched Fallback as a LTE voice solution and achieved download speeds exceeding 90 Mbps.

Skyworks Solutions Inc. has secured a reference design with **Texas Instruments Inc.** (TI) for smart energy, industrial and networking applications including electric/gas/water meters, street lighting, telematic and tracking systems.

Rohde & Schwarz announced it is collaborating with **Dolby Laboratories Inc.** to provide audio test technology to Dolby and its licensees. Rohde & Schwarz has updated its R&S UPP and R&S UPV audio analyzer platforms with new firmware that enables Dolby licensees to perform compliance self-testing and simplifies configuration management, at no additional cost to Dolby licensees. This collaboration between Rohde & Schwarz and Dolby will not only simplify the procedure, but also significantly reduce the compliance testing time for Dolby licensees.

RuSat, a satellite service provider for enterprise customers, Internet service providers and government agencies in Russia, is launching a new satellite broadband service using **Newtec**'s latest VSAT hub and end-user terminal technology. The service will be offered over the Yamal-402 satellite that was launched on December 8, 2012. Until now, VSAT services in Russia were expensive and only available in limited parts of the country. Using the new Yamal-402 satellite, RuSat is now providing satellite broadband services all over the Russian territory.

Anite has signed a further three-year agreement with **Deutsche Telekom**, which owns the T-Mobile brand, to provide interoperability test solutions. Deutsche Telekom is a five-year user of SAS, Anite's interoperability test solution, creating customized test cases to rigorously test new device features prior to launch. This ensures that devices operate as intended on the network and improves end-user satisfaction. As a result, Deutsche Telekom has experienced a reduction in customer support calls and the number of requests for device swaps and repairs.

Agilent Technologies Inc. announced the largest in-kind software donation ever in its longstanding relationship with the **Georgia Institute of Technology**. The donation is valued at approximately $90 million (book value) over three years and will comprise Agilent EDA software, support and training. The donation is being given as part of the Agilent EEsof EDA University Alliance program. It includes a tailored, three-year custom license program that provides member companies of ECE's Georgia Electronic Design Center with access to Agilent's EEsof EDA solutions.

NEW STARTS

CEA-Leti, which has developed opportunistic radio technologies (or cognitive radio) since 2005, is the first research center in France to be granted a government license to experiment with television white space equipment in the field. The license application stemmed from the innovative wireless cognitive radio systems developed by Leti's Communication and Security Department. Cognitive radios are able to dynamically allocate and exploit spectral resources to optimize wireless communication networks' capacity and/or the quality of service. Although this dynamic spectrum management is not allowed in France yet,

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HIGH POWER PRODUCTS

POWER DIVIDERS

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	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	5	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	5	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

◊ In excess of theoretical split loss of 3.0 dB

~ With matched operating conditions

HYBRIDS

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
CSDK3100S	30 - 1000	0.8 / 1.2	0.05 / 0.2	0.2 / 3	25 / 18	1.15:1	50	378
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

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] ~	Package
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KFK-10-1200	10 - 1200	40 ±0.75	±1.0	0.4 / 0.5	22 / 15	150	376
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	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	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

* Add suffix - LF to the part number for RoHS compliant version.

~ With matched operating conditions

Unless noted, products are RoHS compliant.

SYNERGY® MICROWAVE CORPORATION

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this paradigm is seen by many stakeholders as an efficient means to de-saturate the crowded radio spectrum.

BAE Systems Australia and industry partners have designed, manufactured and tested hardware and software for a space-qualified GPS receiver. As part of Project Biarri in collaboration with the Defence Science and Technology Organisation (DSTO) – part of Australia's Department of Defense DSTO – the receivers will be integrated into three small CubeSats that will be launched into low earth orbit. The CubeSat bodies are 300 × 100 × 100 mm and are fitted with small deployable solar panels. Their size and miniaturized sensors make them a cost-effective and innovative option for space missions compared with larger spacecraft.

Following the completion of a £700,000 funding round to expand its overseas sales and device characterization capabilities during the second half of 2012, **Mesuro** has announced the enhanced services and capabilities it is now able to offer its customers. The funds have enabled the business to move forward in two ways; first, Mesuro has relocated to the Pencoed Technology Park, within the Sony UK Technology Centre in Pencoed, Wales. Second, the new space enables the company, for the first time, to centralize its office and engineering-based functions under one roof.

Plextek Ltd. has announced a restructuring of its business to separate the consultancy from several lines of business including Plextek RF Integration, Telensa, Blighter and Redtail Telematics. The move is intended to catalyze the growth of the businesses by giving each a greater focus, while fostering a culture dedicated to innovation within the consultancy business. As of January 2013, the Plextek Group is chaired by co-founder Dr. Colin Smithers. Simon Cassia has become CEO of the rebranded Plextek Consulting business, while Paul Martin and Henk Koopmans become CTO and CMO, respectively.

The Thales Centre of Excellence (CoE) for Radar and Integrated Sensors in Singapore has been officially opened and is the result of a close cooperation between **Thales** operations in the Netherlands and Singapore. The mission is to increase the amount and speed of innovation in naval radar and integrated sensors. This new centre will complement and leverage the Singapore R&T environment in the field of radar and integrated sensors.

An update to the Status of the LTE Ecosystem report released by the **Global Mobile Suppliers Association** (GSA) confirms that 87 manufacturers have announced 666 LTE-enabled user devices, including frequency and carrier variants. Alan Hadden, president of the GSA, said, "Around 400 new LTE user devices were announced in the past year, and in this time the number of manufacturers grew by 52 percent. Smartphones are now the largest LTE device category."

Cassidian and **Northrop Grumman Corp.** achieved a major milestone with the first full system test flight of the EuroHawk® unmanned aircraft system equipped with the signals intelligence (SIGINT) advanced sensors for detection of radar and communication emitters. The EuroHawk took off from Manching Air Base, Germany and climbed to a ceiling of more than 15,000 m within military controlled airspace, far above and in safe distance from civilian air traffic. After six hours aloft, the aircraft landed safely back at the air base.

Cassidian has successfully passed the first factory acceptance test for the newly developed TRS-4D naval radar system, which was carried out by its customers, the German procurement authority BAAINBw and Blohm + Voss Naval. The German Navy's F125 class frigates will be equipped with the new TRS-4D naval radar. The first unit, which will equip a land-based system in Wilhelmshaven, was set to be delivered last month, while the first TRS-4D for the Baden-Württemberg lead ship is scheduled for delivery in August 2013.

RF Micro Devices Inc.'s board of directors has authorized an extension of RFMD's 2011 share repurchase program to repurchase up to $200 million of the company's common stock through January 31, 2015. Since January 2011, the company has repurchased $49.9 million of its common stock under this program, leaving it with additional authorization of up to $150.1 million under the program as a result of this extension.

ABI Research forecasts that outdoor small cells will reach 500,000 units in 2013. Outdoor small cell units will grow at 52.7 percent CAGR to reach over 3.5 million units by 2018. The fastest growing outdoor class of small cells is 4G LTE small cells which will grow to reach almost 1 million unit shipments in 2018 as operators begin to differentiate their LTE services by adding capacity in key strategic locations.

CONTRACTS

Lockheed Martin received a $197 million contract option from the **U.S. Army** for Guided Multiple Launch Rocket System (GMLRS) Unitary rocket production. This contract option was attached to the GMLRS Production Lot 7 contract, which was originally awarded to Lockheed Martin in July 2012 and now has a total funded value of $550.8 million. This move enables the service to pay less for each rocket than if a separate 2013 production contract were issued. The new allotment of rockets will be delivered to the U.S. Army and Marine Corps beginning in September 2014.

Mercury Systems Inc. has been awarded a three-year IDIQ contract by the **U.S. Naval Research Laboratory** Tactical Electronic Warfare Division. Worth up to $16.7 million, the contract calls for Mercury to supply advanced mixed signal digital receivers for prototype electronic warfare applications on airborne and surface shipboard platforms.

The **U.S. Marine Corps** awarded **Raytheon Co.** a contract for the design, development and demonstration of a new production representative 120 mm long-range, guided-mortar munition. Once fielded, the Precision Extended Range Munition (PERM) will be used with the M327 rifled towed mortar, the primary weapon system of

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- I/Q Vector Modulators
- Limiters & Detectors
- Log Amplifiers
- Pulse & Bi-Phase Modulators
- Phase Shifters
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- Receiver Front Ends
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14.4 to 15.4 GHz
20 Watt, SPDT SMT


2.35 GHz, 100 Watts also,
9.5 to 10.7 GHz, 120 Watts


1.0 to 18.0 GHz
10 Watt, SPDT


8.0 to 18.0 GHz
20 Watt, SP8T

MODEL NUMBER	Style	Frequency Range (GHz)	Insertion Loss (dB)	Isolation (dB)	Switching Speed (nSec)	Operating Input Power (W)	DC Voltage & Current
P1T-0R310R0G-80-R-SFF-20W	SPST	0.3 – 18.0	2.5	60	250	20W Peak, 7W Ave.	+5vdc@100mA -12vdc@50mA
P1T-1R0G18R0G-80-R-SFF-75W	SPST	1.0 – 18.0	2.5	80	25	75W Peak 2W Ave.	+5vdc@65mA -12vdc@20mA
P1T-0R5G2R0G-80-R-SFF-LVT-10W	SPST	0.5 – 2.0	1.0	80	25	10W Peak 2W	+5vdc@50mA -5vdc@5mA
P1T-0R6G1R3G-70-SFF-4W	SPST	0.6 – 3.0	1.5	70	30	4W	+5vdc@100mA -5vdc@100mA
P2T-335M535M-30-R-SFF-20W	SPDT	0.335 – 0.535	0.9	45	100	20W	+5vdc@31mA
P2T-1G18G-10-R-528-SFF-HIP10W	SPDT	1.0 – 18.0	3.0	25	40	10W	+5vdc@5mA -28vdc@5mA
PEC-2D35G-100W-SFF	SPDT	2.2 – 2.5	2.4	40	150	100W	+12vdc@80mA -28vdc@30mA
P2T-17G18G-60-33DBM-5-SFF	SPDT	17.0 – 18.0	1.5	70	100	+33dBm	+5vdc@60mA -5vdc@60mA
P2T-0R1G2R0G-40-SFFF-100W	SPDT	1.0 – 2.0	1.5	40	<1μSec	100W	+5vdc@150mA -15vdc@70mA
PEC-9R510R7-100W-SFF-120W	SPDT	9.5 – 10.7	1.5	40	400	120W	+5vdc@160mA -28vdc@15mA
P2T-0R5G18G-60-SFF-10W	SPDT	0.5 – 18.0	1.5	60	150	10W	+5vdc@100mA -15vdc@75mA
P2T-14D415D4-15-SMT-20W Surface Mount, Driverless	SPDT	14.4 – 15.4	0.5	15	50	20W	Bias 50mA
P3T-0R1G2R0G-40-SFF-100W	SP3T	0.1 – 2.0	1.5	40	<1μSec	100W	+5vdc@150mA -15vdc@70mA
P3T-0R5G18G-70-SFF-200W	SP3T	0.5 – 18.0	3.75	70	100	200W Peak 12W	+5vdc@150mA -15vdc@100mA
P4T-2G18G-45-TFF-100W	SP4T	2.0 – 18.0	3.1	45	200	100W Peak 1W	+5vdc@105mA -15vdc@70mA
P4T-0R1G2R0G-40-SFF-100W	SP4T	1.0 – 2.0	1.5	40	<1μSec	100W	+5vdc@150mA -15vdc@70mA
P4T-0R1G18G-65-SFF-75W	SP4T	0.1 – 18.0	2.6	65	50	75W Peak 1W	+5vdc@150mA -15vdc@50mA
P4T-900M1300M-35-SFF-50W	SP4T	0.9 – 1.3	2.0	35	<1μSec	50W	28vdc
P8T-2R37G2R39G-60-SFF-10W	SP8T	2.37 – 2.39	2.5	60	<1μSec	10W	+5vdc@500mA -27vdc@10mA
P8T-8G18G-50-SFF-10W	SP8T	8.0 – 18.0	4.0	50	75	10W Peak 4W	+5vdc@450mA -15vdc@150mA

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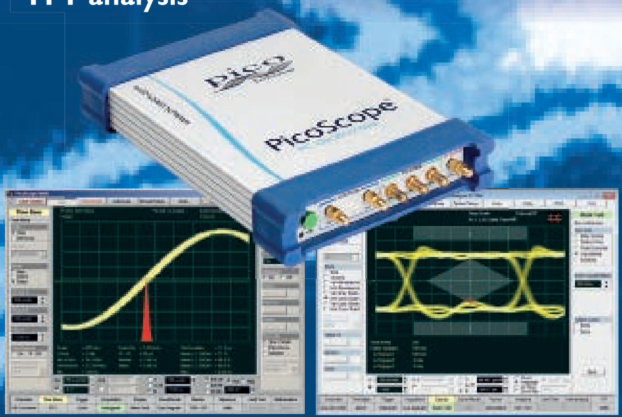

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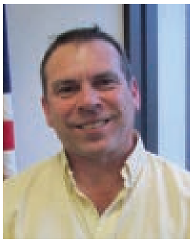
the Expeditionary Fire Support System. Under the PERM contract, Raytheon will design, develop, test and deliver mature, production-representative mortars for a live-fire demonstration by the Marines in 18 months. The company has partnered with Israeli Military Industries, an experienced provider of weapon systems.

Integrated Microwave Technologies LLC (IMT), a business unit within the Vitec Group's Videocom Division, has been awarded a Technical Investigative Surveillance (TechOps) contract by the **U.S. Department of Homeland Security** (DHS). IMT's contract is a competitive five-year IDIQ agreement, awarded in the video category, which includes covert video equipment such as transmitters and receivers offering mobile, fixed and multiple concealment technologies. IMT will deliver interoperable technical investigative surveillance solutions in support of federal agency requirements.

Boeing recently achieved two important milestones on the **U.S. Air Force** Family of Advanced Beyond Line-of-Sight Terminal (FAB-T) program, which will provide protected wideband satellite communications among ground and airborne terminals for the command and control of U.S. nuclear forces. The Boeing FAB-T team has completed software qualification testing and systems integration testing on the FAB-T development program. The team also has demonstrated FAB-T's integration with the Advanced Extremely High Frequency (AEHF) and Milstar mission control subsystem, which commands both satellite constellations.

PEOPLE

Aeris Communications announced the addition of **Mohsen Mohsenia** as the vice president of market development for Europe. Mohsenia brings more than 18 years' experience to the role, serving most recently as the head of the M2M business in the UK for Logica as well as being a leading member of the global M2M leadership team responsible for development of strategy and market development. Mohsenia will be responsible for extending and growing the Aeris solution throughout Europe, in particular its connectivity platform for carriers.


▲ *Bob Carbonell*

San-tron Inc. has hired **Bob Carbonell** to join its growing team as eastern regional sales manager. Carbonell brings over 24 years of military and RF/microwave experience to the position. He will be responsible for spearheading sales and acquisition of new prospects at San-tron while providing support to engineering and senior-level management. Carbonell is also an active reservist in the U.S. Air National Guard. He is a trained integrated avionics craftsman and supervisor.

AR RF/Microwave Instrumentation has announced the addition of **Joseph DiBiase** to its staff of application engineers. DiBiase will assist AR customers and provide sup-

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Around the Circuit

▲ *Joseph DiBiase*

port to various AR engineering groups. DiBiase joins AR with over 25 years of EMC design and test experience. He most recently held a position of senior manager of compliance engineering at Motorola Mobility where he led product regulatory qualification efforts and managed an accredited test laboratory. He has a Bachelor's degree in electrical engineering from Villanova University, is a member of IEC CISPR I, and is iNARTE and Six Sigma Green Belt certified.

REP APPOINTMENTS

AR Europe announced its new exclusive distribution agreement with **Eastern OptX**. Eastern OptX's fiber optical delay system products are now available for the European market through the AR Europe sales channels as of December 1, 2012. At present this agreement does not include the German market.

CST and **Delcross** announced that Delcross Technologies' Electromagnetic Interference Toolkit (EMIT) and Savant are now available worldwide through all CST sales channels. The software will be fully supported by CST's team of electromagnetic specialists.

Optenni, **CST** and **EMSS** announced that the Optenni Lab™ matching circuit optimization software is now available through the global CST and EMSS sales channels. Optenni Lab will be fully supported by the sales and technical support teams of both CST and EMSS and their distributors worldwide.

Pronghorn Solutions announced the appointment of **Dura Electronic Sales** (Santa Clara, CA) as its sales representative in northern CA, **Dura Sales** (Diamond Bar, CA) as its sales representative in southern CA, and **Tekmar Sales** (Dix Hills, NY) as its sales representative in the, NY, NJ, CT and eastern PA area.

Richardson RFPD Inc. announced it has completed an agreement to distribute Silicon Carbide power products from **Cree Inc.** Under the agreement, Richardson RFPD will distribute Cree's SiC Schotty diodes, MOSFETs and power modules worldwide.

Sonnet Software Inc. announced a new sales and customer technical support representative for customers located in Germany, The Netherlands, Austria and France. Effective as of January 1, 2013, Sonnet Software will be partnering with **advICo microelectronics GmbH** to provide exclusive sales distribution and technical support for Sonnet Suites high frequency 3D planar EM software products.

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IF/RF MICROWAVE COMPONENTS

Using Test Equipment to Extract Behavioral RF Device Models for Communications System Design

Electronic design automation (EDA) is a well-established method for modeling the performance of RF systems for communications products. System level simulation software enables engineers to accurately model and predict system characteristics such as gain, 1 dB compression point (P1dB), noise figure, error vector magnitude (EVM) and adjacent channel power ratio (ACPR). But as wireless networks have evolved, it has become increasingly important to be able to predict the performance of the entire system prior to manufacture, driving the need for accurate models for each device within the system.

For example, in the design of a complex radar system, engineers might design some of the simpler and more specialized components such as filters and antennas themselves, but elect to buy general and/or more complex components such as mixers and amplifiers off the shelf. Obtaining the behavioral models for the designed components is straightforward, since the very process of building them in the EDA environment produces a model. Getting accurate models for the off-the-shelf components, however, can be a challenge.

Typically, in order to obtain a generic device model, the published data from the specification document would be used. While published specifications are a good way to roughly model device behavior, this method is not foolproof. Specification documents are often incomplete and are rarely capable of predicting the performance of modulated signals through the device. A more exact method would be to use instrumentation to extract behavioral models in order to improve the accuracy of RF device models.

Behavioral model extraction is somewhat of an art, requiring experience and detailed knowledge of both instrumentation and the RF device itself. This article will explain two methods for obtaining behavioral RF device models. The first performs simple AM-AM and AM-PM model extraction using instrumentation and is useful for narrowband applications. The second, more complex method, builds a time delay neural network (TDNN) for modeling the behavior of devices that use broadband modulated signals.

David A. Hall
National Instruments, Austin, TX
Janne Roos
AWR – APLAC Division, Espoo, Finland

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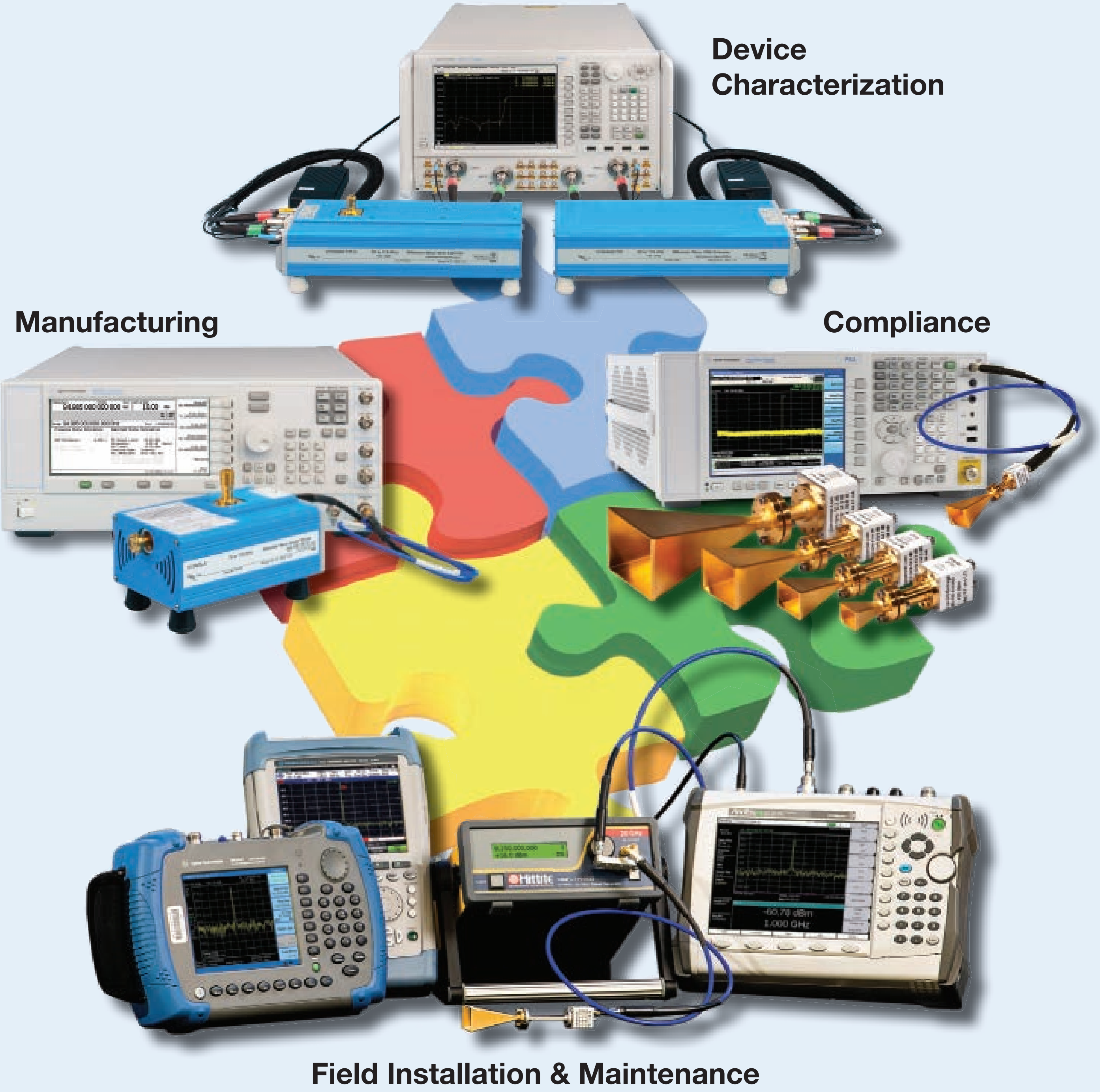

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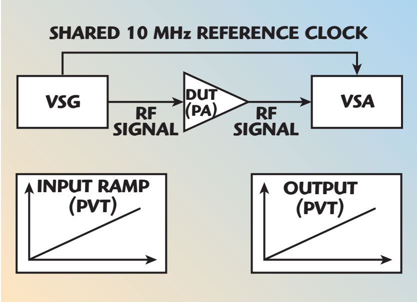

Fig. 1 AM-AM/AM-PM can be measured using a VSG and VSA.

and phase are easily calculated from IQ samples using Equations 1 and 2.

$$\text{Power}_{\text{Sample}} = 10\log\left(20\frac{r^2}{2}\right) \quad (1)$$

The instantaneous power of each sample can be calculated from I and Q.

$$\Theta = \tan^{-1}\left(\frac{Q}{I}\right) \quad (2)$$

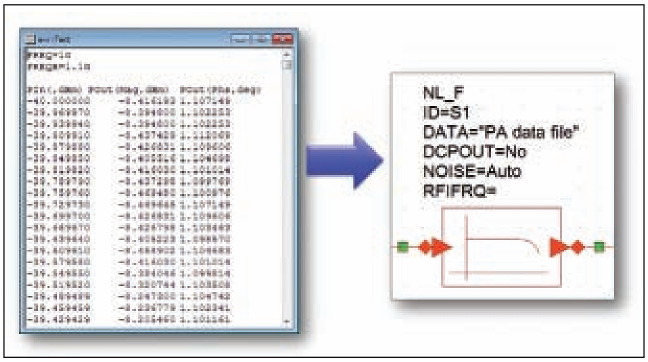

Fig. 2 The NL-F element in VSS can use AM-AM/AM-PM measurements to build a simple behavioral model of an RF amplifier.

The instantaneous phase is the inverse tangent of Q/I. Once AM-AM/AM-PM are measured with a VSA, this data can be directly imported into the system simulation environment to model the behavior of active RF components. For example, as can be seen in ***Figure 2***, the NL_F element in AWR's Visual System Simulator™ (VSS) simulation environment natively uses AM-AM/AM-PM measurements to construct a behavioral model of an RF device.

METHOD 1: AM-AM AND AM-PM EXTRACTION FOR PA BEHAVIORAL MODELING

Measuring both the output amplitude and phase modulation of an active device, such as an amplifier, is a straightforward process that can be accomplished either with a vector network analyzer (VNA) or the combination of a vector signal generator (VSG) and vector signal analyzer (VSA). This article will focus on the theory, limitations and hardware setup, for performing AM-AM/AM-PM measurements with a VSG and VSA.

The theory behind AM-AM/AM-PM measurements is that the behavior of an active device, such as a PA, can be predicted simply by measuring the output amplitude and phase as a function of input amplitude and phase. In order to measure this response, an RF VSG is used to generate a ramped continuous wave signal through the device under test (DUT). This waveform features a gradually increasing power level, but with constant phase. By using a signal with ramped power, the device can be characterized in both linear and nonlinear operating regions.

As can be seen in ***Figure 1***, a VSA is used to capture the output of the amplifier as I and Q signals. Power

Benefits and Limitations of AM-AM/AM-PM

While AM-AM/AM-PM extraction is a useful modeling technique, due to the simplicity of the extraction process, this method does involve inherent limitations in some applications. As observed in the previous section, using AM-AM/AM-PM as a behavioral modeling technique assumes that the magnitude and phase at the output of a device can be directly predicted from the magnitude and phase of a signal at the device input. While this assumption is reasonable for narrowband signals or memoryless RF devices, this cannot be assumed for all cases. For example, active devices such as a PA will often exhibit memory effects. In these conditions, the output signal magnitude and phase are also functions of the input signal history.

In general, continuous-wave (CW)-based model extraction techniques are most effective at predicting device behavior in the simulation environment, when they are used on relatively narrowband signals where the effects of memory are much less. As a result, alternative methods of model extraction should be considered when creating a model that will be used to simulate the behavior of a broadband signal.

METHOD 2: BUILDING A TDNN FOR PA BEHAVIORAL MODELING

The second method for extracting behavioral models discussed in this article is to build a TDNN. This method is a good technique for modeling the behavior of a device using broadband modulated signals. TDNNs use intelligent signal processing to represent each output IQ sample as a nonlinear combination of the present IQ input and previous IQ inputs in time. Using this mechanism, a TDNN is able to inherently represent the memory behavior of an RF PA.

The process of using TDNNs to model active RF devices requires us to "train" the TDNN, using a series of input and output IQ samples. As a general rule, the ability of the TDNN to predict the behavior of the RF device is heavily influenced by how closely the characteristics of the training signals mirror the characteristics of the signals being modeled. As a result, the first step in extracting a TDNN model is to drive the active device with a modulated signal and capture the output IQ samples with an RF VSA. Both the input IQ waveform to the device and the IQ output can then be used to train the TDNN.

As shown in ***Figure 3***, one technique used to produce a highly accurate TDNN model is to capture IQ samples at a wide range of power levels. The figure shows the "power versus time" profile of the output of a PA. In this particular case, the input waveform to the PA is a modulated

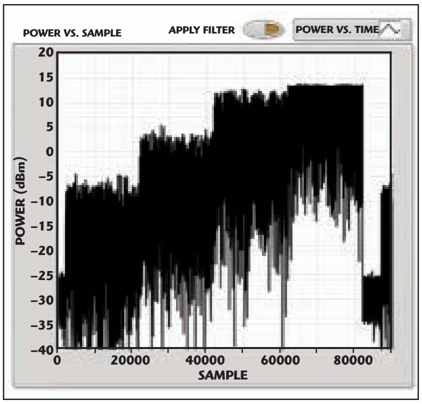

Fig. 3 A modulated signal with content at various power levels is used to train the TDNN.

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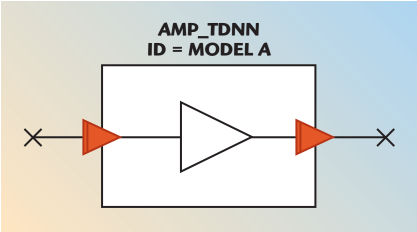


Fig. 4 The TDNN model is represented by an element in the system diagram that can be connected to other RF components.

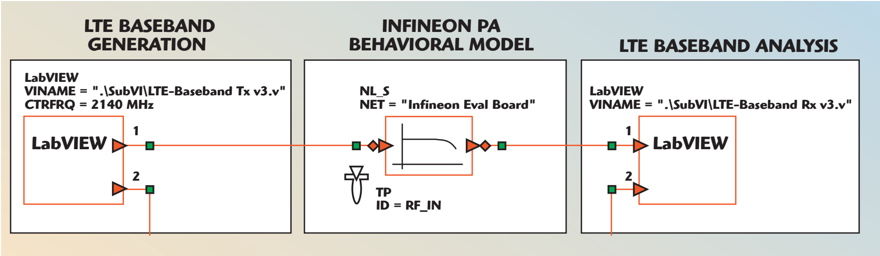


Fig. 5 The same LabVIEW signal creation and analysis routines can be used in both the simulation environment and with physical measurements.

signal that is stepped over various power levels. This technique lets designers capture device behavior at a much broader range of power levels, enabling them to build a more accurate TDNN model.

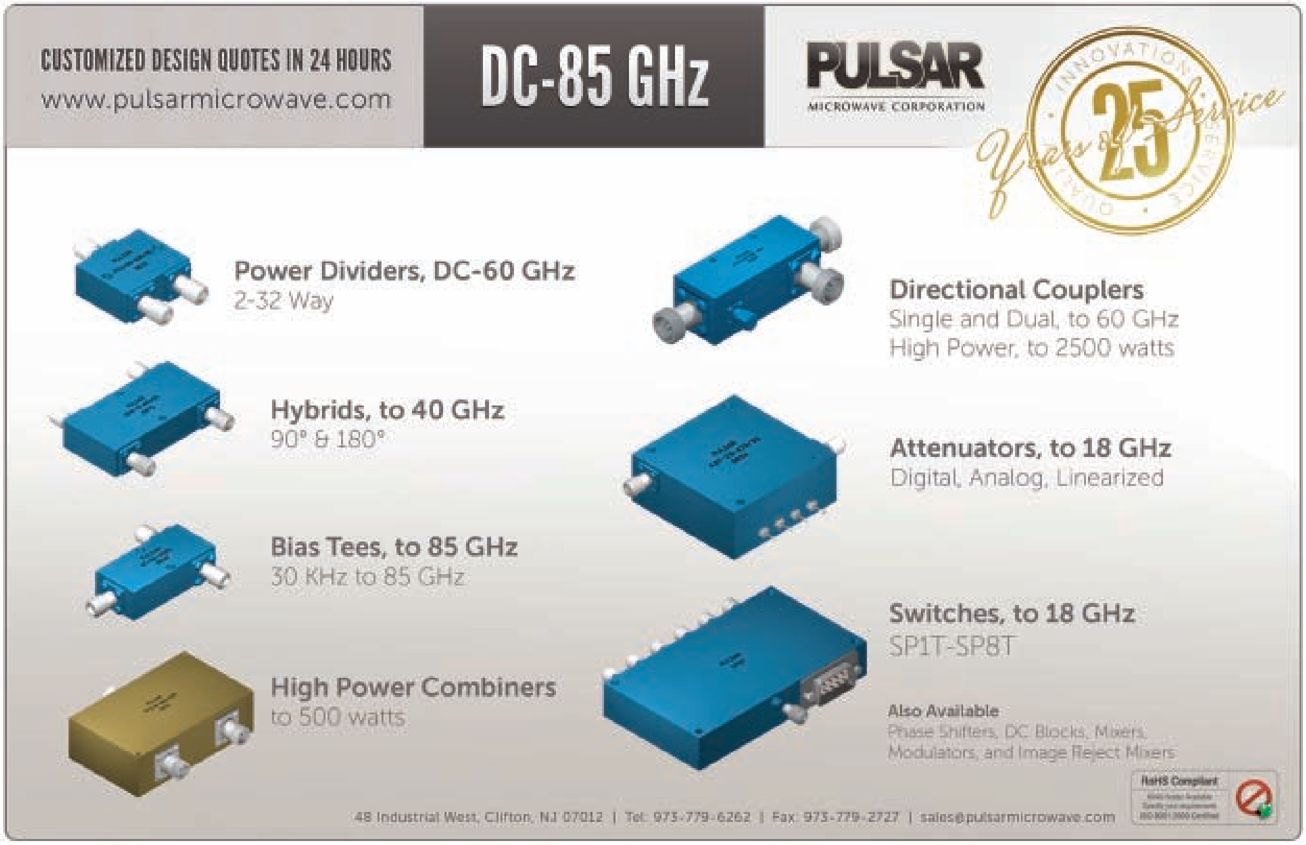
In order to build a TDNN behavioral model, captured IQ samples (along with the original input waveform) can be fed into a TDNN model creation wizard within the simulation software environment. AWR's VSS software, for example, includes a wizard that uses sampled IQ data to both train and validate the TDNN. The output of the wizard is a TDNN model element (shown in ***Figure 4***) that can be used in future system simulations.

PROVING MODEL ACCURACY

Once a model has been extracted and is available in the simulation environment, the final step is to validate the model's ability to predict the performance of the actual device. A basic way to validate a model is to compare its performance versus the actual device for modulation quality measurements, such as EVM, and spectral measurements, such as ACPR. In addition, for models that are not constructed from AM-AM/AM-PM measurements (such as TDNN), it is useful to compare the model's AM-AM/AM-PM with the actual device.

When comparing EVM and ACPR results between the model and actual device, it is critical to ensure that the waveform used to drive each device (either actual or model) is identical. In addition, on the measurement side, it is also important to ensure that identical measurement algorithms are used to compute EVM and ACPR to eliminate the potential for differences in measurement algorithm implementation.

The system diagram in ***Figure 5*** shows a method for ensuring algorithm uniformity that uses measurement routines based on National Instruments (NI) LabVIEW system design software that are within the AWR VSS environment. In this scenario, one can use LabVIEW generation and analysis toolkits for wireless standards such as WCDMA, LTE and



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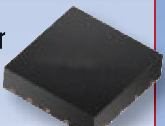

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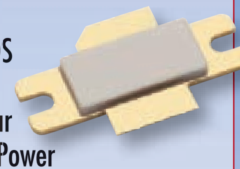

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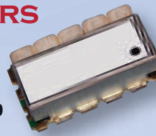

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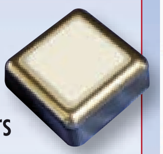

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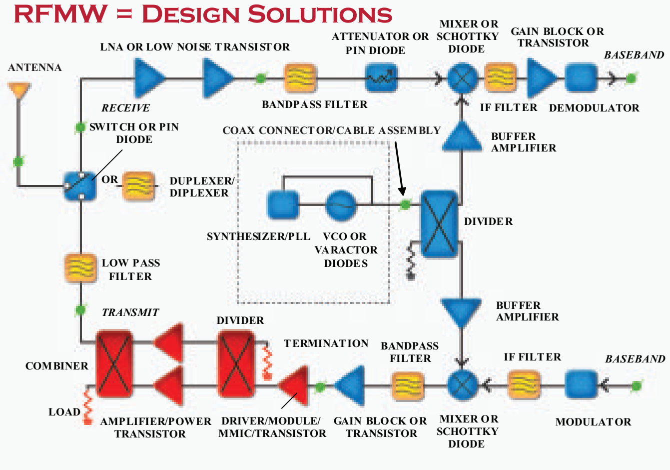

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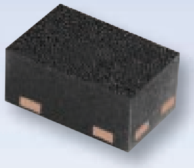

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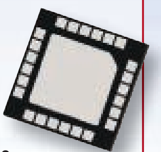

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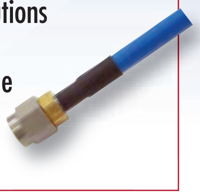

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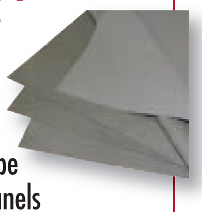

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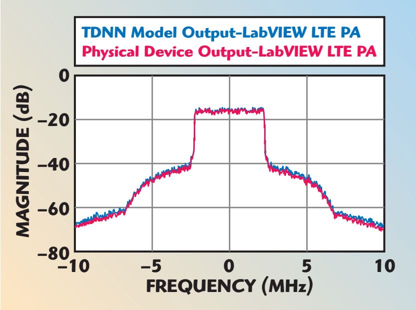
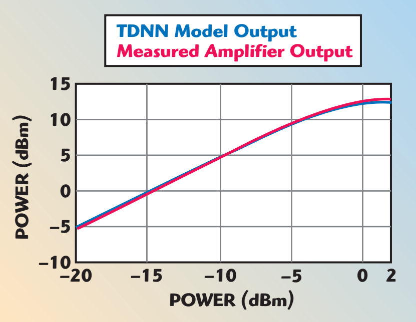


▲ *Fig. 6 Spectrum profile of a TDNN model vs. the performance of the physical device.*

802.11. As shown in the figure, the LabVIEW code can be directly used within the VSS system diagram to perform measurements on simulation models.

Using the techniques just described, it is easy to assess the model's ability to predict RF behavior, by comparing its performance to the real device. ***Figure 6*** shows the spectrum profile of an LTE signal being generated through a TDNN model. It can be seen that the spectrum profile of the model matches very closely the actual signal output. This indicates, as evidenced by the spectral regrowth, that the model is able to reasonably predict the amplifier's performance in a nonlinear region.



▲ *Fig. 7 The AM-AM response of the TDNN model closely correlates with the actual device performance.*

Finally, in ***Figure 7***, the AM-AM performance of the TDNN model is compared with the behavior of the measured amplifier itself. The "modeled" AM-AM measurements are made by using a virtual network analyzer in the simulation environment. The figure illustrates that the TDNN model is able to predict the appropriate gain and compression point of the physical device.

CONCLUSION

While there are many ways to produce a device model for use in the communications system simulation environment, model extraction using test and measurement equipment is a useful and accurate way to build device models to predict system performance. For systems using narrowband signals, simple methods such as AM-AM/AM-PM measurements are often sufficient to build a simulation model. For capturing memory effects on broadband signals, more complex methods like TDNN modeling are a convenient and more accurate way to build a device model and the model's ability to predict the performance of the actual device can be validated using a hardware/software solution, such as measurement routines based on National Instruments (NI) LabVIEW system design software that are within the AWR VSS environment.

Using either the simple AM-AM/AM-PM or TDNN method, this article demonstrates that models extracted with instrumentation are often able to very efficiently and accurately predict the performance of the RF device itself, saving design time and ultimately producing higher performing communications products. ■

TOP PERFORMING SYNTHESIZER FOUND OPERATING WITHOUT PLL

A rare digital-analog hybrid RF synthesizer has been discovered which intentionally uses no PLL whatsoever. The proprietary architecture is demonstrating a high number of performance advantages over synthesizers that incorporate even the most unique of phase-locked loop designs.

HSM6001A (OPTION SYS1): 0.57in [14mm] High

The non-PLL synthesizer is said to be from the HSM Series, designed and manufactured by Holzworth Instrumentation Inc. in Boulder, Colorado. With a footprint of only 3.8in x 6in, this compact marvel is an equal to high end bench top units. The small form factor and incredible performance-to-price ratios have sparked the interest of engineers and systems integrators worldwide with field reliability data that surpasses calculated MTBFs of greater than 180k hours.

Free running, steady state power consumption is below 9 Watts, while environmental tests demonstrate full specification compliance over a broad temperature range of -40C to +75C. "That's amazing", noted one HSM Series integrator, "especially for broadband sources [up to 20GHz] that cost a fraction of what many lower performing options do".

In my research, this writer discovered a long list of unique qualities in the 6 available models from the HSM Series RF Synthesizers. Highlights include:

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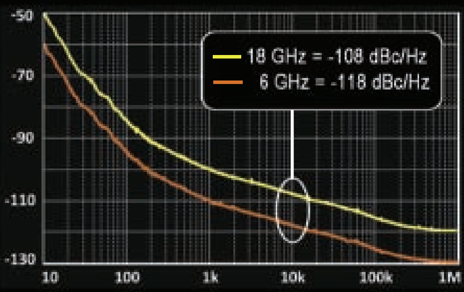

With all the excitement around a non-PLL design exceeding the phase noise performance of most high end, PLL based designs, we went directly to the source (pun intended). One Holzworth engineer commented, "we work hard to bring innovation to every design because there is no ingenuity in duplicating what others have already done". - BOULDER, CO, USA

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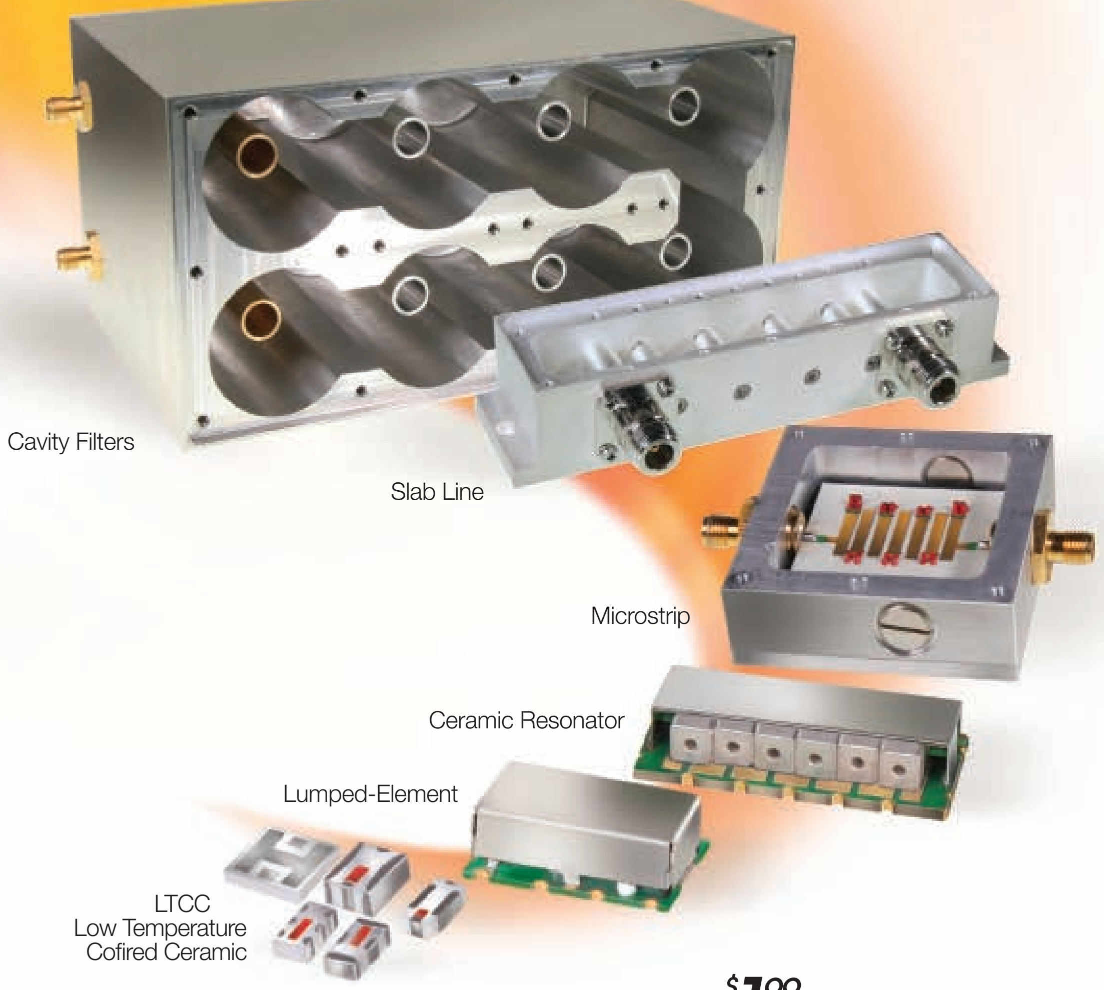

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Design of Linear SiGe IC Downconverters

Base station radio receivers convert high frequency signals at the antenna port to lower intermediate frequencies (IF) by mixing them with a local carrier signal. To detect weak signals in the presence of strong interferers, the receiver hardware requires a mixer function with low noise figure (NF) and high linearity. As the frequency of the received signal increases, it becomes a challenge to design mixers that meet the requirements of both loss and distortion simultaneously.

In the past decade, silicon integrated circuit (IC) downconverters, with built-in driver amplifiers and an integrated IF gain function, have emerged as the preferred solution to this system function. These ICs save cost and help make system operation more predictable and repeatable. The objective of this article is to explain the trend for this function being increasingly realized by manufacturers using BiCMOS technologies, and provide an overview of the key challenges that face the designer through a design example for base station receivers.

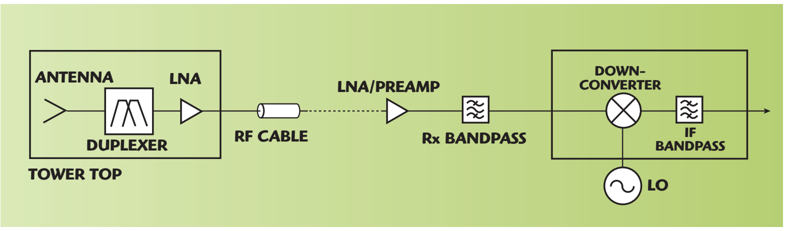

Fig. 1 Typical RF input architecture of a base station receiver.

DOWNCONVERTERS: A LUMPED, DISCRETE COMPONENT APPROACH VERSUS FULLY INTEGRATED SOLUTIONS

Most base stations for cellular infrastructure have low noise amplifiers at the tower-top, close to the antenna. The amplification of unwanted interferer tones as well as the signals of interest imposes tough linearity requirements on the downconverter. Conventional downconverters have used passive quad mixers (< 7 dB loss)[1] driven by external local oscillator amplifiers (LOA). In a base station downconverter system, the mixer is followed by linear gain at the IF frequency, before the interfering tones are rejected by narrowband filters. The local oscillator signal requires significant boosting before it is applied to the mixer quad with typical drive powers greater than 20 dBm to achieve the required high linearity and low noise performance.

Whether the downconverter in ***Figure 1*** uses either a single mixer (with an image reject pre-filter), or an IQ downconverter with a dual mixer function, the design challenges for both are identical. The composition of the mixer can be represented by the required functional blocks shown in ***Figure 2***. The external 50 Ω LOA, IF amplifier, LO BPF and diplexer oc-

Kathiravan Krishnamurthi, Zhiyang Liu and Ian Gresham
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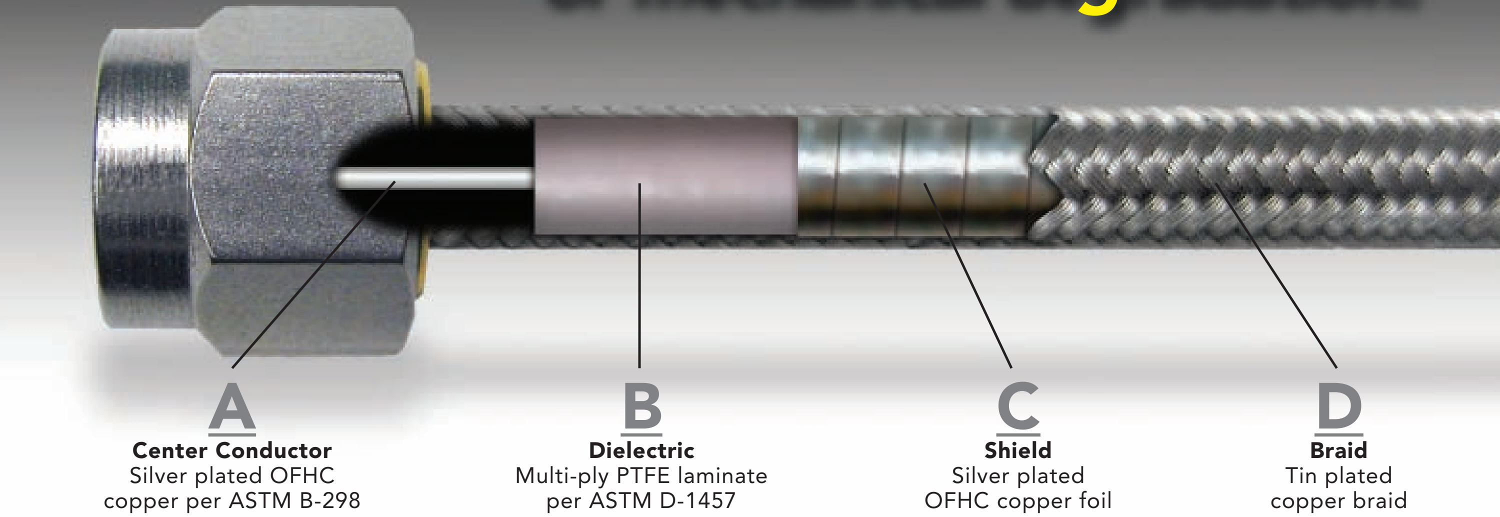

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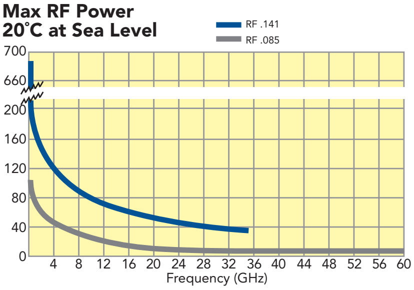
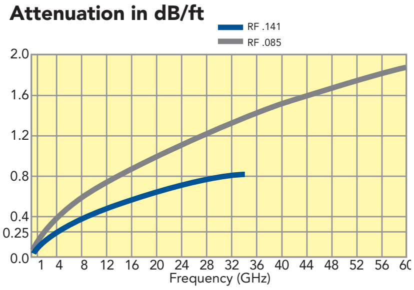
Impedence:	50 Ω	**RF leakage:**	Equivalent to semi-rigid cable
Time delay:	1.4 ns/ft	**Temp range:**	-55˚C to 135˚C
Cut off frequency:	60 GHz for RF 085 34 GHz for RF 141	**Bend radius:**	1/16 inch for RF 085 1/8 inch for RF 141





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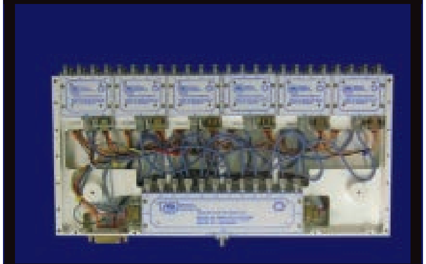

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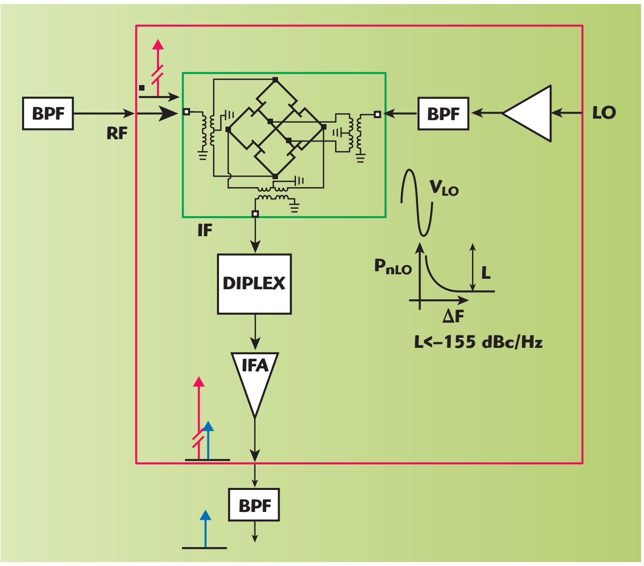
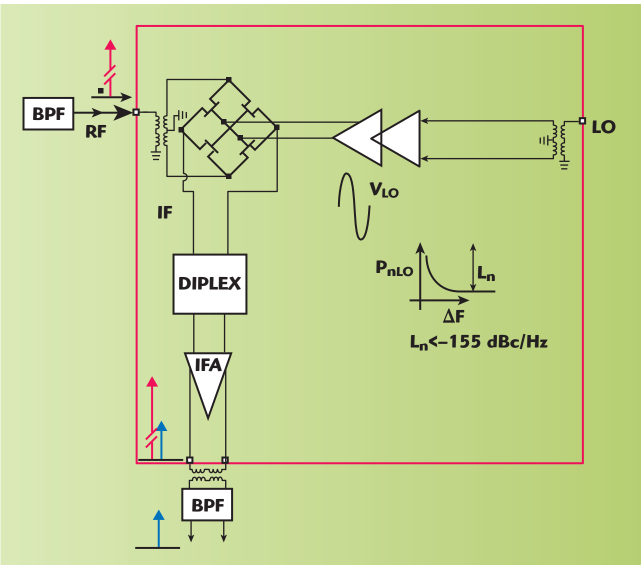
cupy a considerable area on the PCB, require many additional bias and matching components and increase the total variation in performance of the system parameters. This figure illustrates how the mixer is in fact comprised of several sub-function blocks – LOA, LO bandpass filter, diplexer, IF amplifier and a packaged 4 FET quad – with each block accounting for several components on the board. Ease of fabrication and test drives the selection of these to be 50 Ω single-ended components.



▲ *Fig. 2 A conventional base station downconverter implementation.*

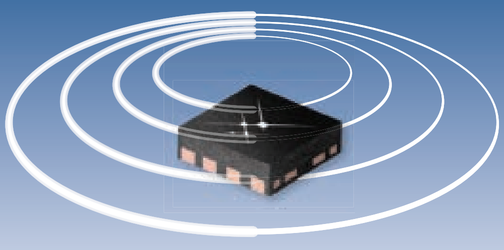
Conversely, the integrated circuit downconverter shown in ***Figure 3*** embeds all of these functions integrated within the silicon. A passive quad-FET ring mixer, baluns, LOA, diplexer and IF amplifiers can be integrated into a single chip that fits within a 5×5 mm package enclosed within the red box. The freedom to choose optimum impedance levels and signal formats can then be leveraged in the IC design. The IF output can be made differential and therefore compatible with high quality differential surface acoustic wave (SAW) filter technology. In addition, signals can be transformed on-chip from their single-ended board representation into a differential format, which brings the benefit of providing intrinsic second harmonic suppression. Reference impedance levels can also be transformed, allowing the level of voltage swings at critical nodes in the circuit to be controlled and optimized, thus improving efficiency. Lastly, the differential drivers can be operated in a controlled and saturated state with minimal variation. This limiting behavior is conducive to achieving drive-independent performance specifications.



▲ *Fig. 3 A Si IC downconverter encompasses all the high performance functions that make a downconverter in a base station.*

One approach that permits all of these functions to be integrated into a single small IC is to use a Silicon BiCMOS process technology that combines high performance, low noise, bipolar transistors for realizing the amplifiers, low-loss multi-layer transformers for baluns and a triple-well NMOS or NMOS-on-insulator device for the realization of the passive mixing quad.[2]

Modern technologies typically include multiple transistor types within a single process, where the speed (transition frequency f_t) and BV_{CEO}



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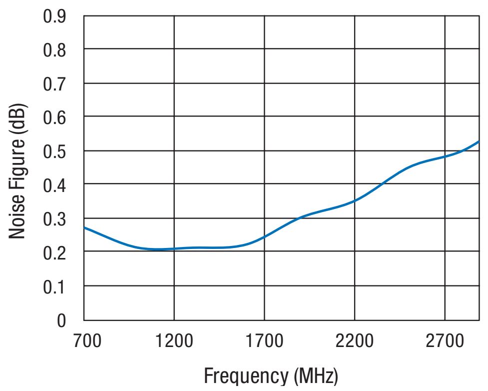

SKY67151-396LF Noise Figure Performance

Frequency (MHz)	Noise Figure (dB)	Gain (dB)	OIP3 (dBm)	$OP_{1 dB}$ (dBm)	Supply Voltage (V)	Supply Current (mA)
700–1500	0.25	26.0	34	21	5	80
1600–2200	0.35	20.5	36	20	5	70
2300–2900	0.45	19.0	36	20	5	70
3000–4000	0.70	16.5	36	18	5	80

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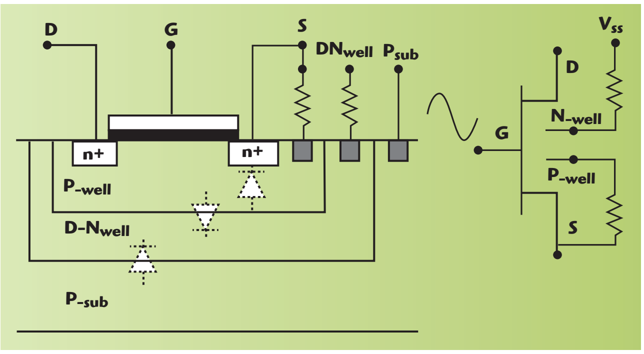


▲ *Fig. 4 Triple-well NMOS used as a building block for four FET quad.*

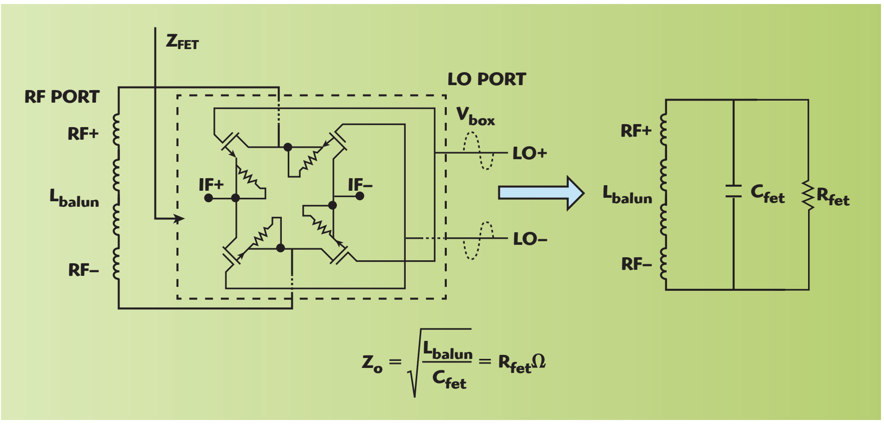
can be traded off against each other. Higher f_t devices usually have a lower NF at the cost of a decreased breakdown voltage, which limits the maximum potential signal swing. However, commonly available devices with an f_t of more than 100 GHz offer sufficient performance that can meet both the noise and distortion requirements in standard and cost-effective SiGe:C process technology.[3]

Silicon MOSFET devices used as passive switches, driven dynamically with the carrier signal, operate with low loss and importantly, low-distortion. ***Figure 4*** illustrates a typical implementation of a triple-well NMOS device used in the passive mixing quad. The device cross-section shows a typical process implementation of an isolated NMOS device. The device is configured for use as a passive switch for use in a quad FET ring by the circuit representation on the right. The P-well is bootstrapped to the source to improve the available voltage swing and the deep N-well is reverse biased to further increase the isolation to the substrate by reducing the size of the depletion capacitance. The implanted deep N-well isolates the active P-well region of the NMOS device from the bulk substrate and this greatly reduced shunt capacitance has the effect of reducing signal loss at high frequency.

By keeping the D-N-well reverse biased, the impedance between P-well and D-N-well is increased (small intrinsic depletion capacitance), and the addition of a large resistor between the bulk and source node keeps the P-well floating at RF frequencies, thus enhancing linearity by reducing the diode clipping. The key parameters and the associated challenges facing the designer by means of a design example will now be reviewed.

BiCMOS FET-BASED MIXER DESIGN

A complex design problem can often be simplified or made more tangible by partitioning the problem into separate steps. This is especially true when the additional complication of frequency conversion is involved. In this example, the design is considered in four steps: the design of the mixer core, the design of the diplexer and sum terminations and the design of the two amplifier stages – the high linearity, low-noise differential IF amplifier and the driver amplifier used in the LO path.



▲ *Fig. 5 Simplified RF equivalent circuit of a fully driven and matched FET core.*

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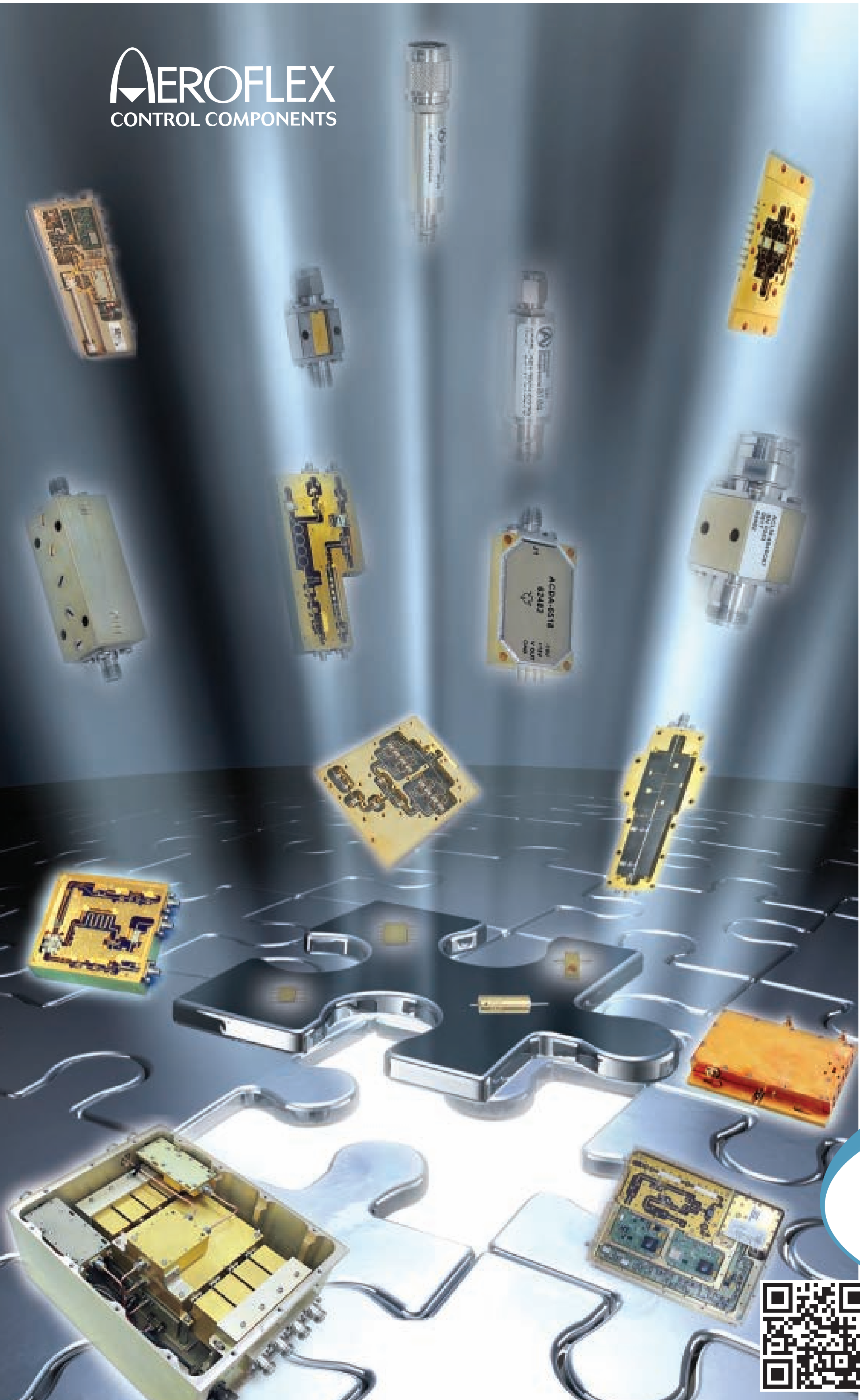

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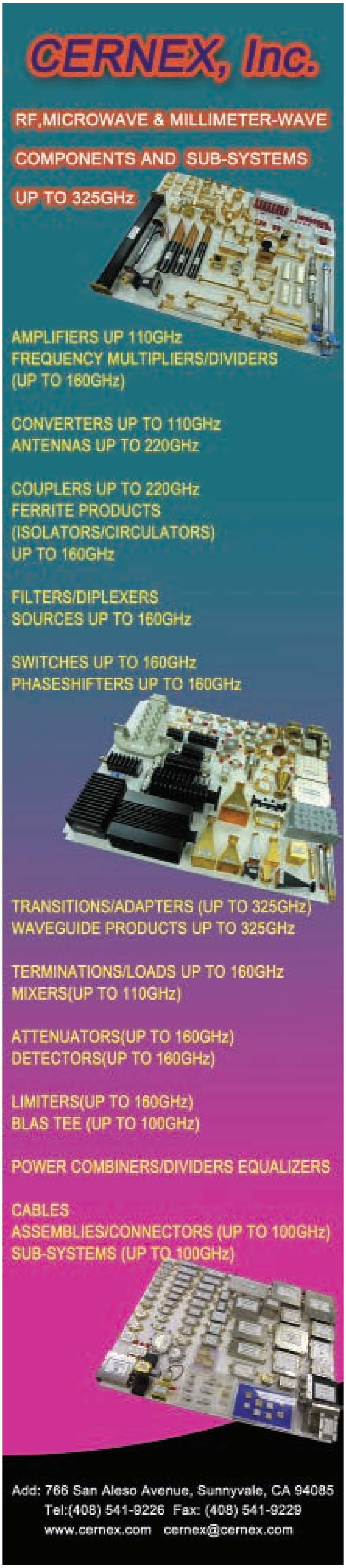

Mixer Core Design

A high linearity FET mixer with a quad arrangement of NMOS devices driven by a large signal amplifier can be modeled for design purposes by the equivalent circuit shown in ***Figure 5***. Assuming that the maximum allowable carrier swing ($v_{LO} = V_p \cos(\omega_c t)$) at the LO port of the quad can be generated, the first step is to proceed to model the input impedance seen at the RF port. On-chip RF and LO baluns are used to convert single ended signals to differential signals at the input terminals of the FET ring. The peak swing of the LO drive signal, V_p, is selected to be as close to V_{box} – the breakdown voltage of the FET device gate oxide – as possible to achieve high P_{1dB}. The pumped N-FET quad can then be simply represented by a capacitance, C_{fet} in parallel with a resistance R_{fet}. The value of the capacitance C_{fet} is a function of the geometry of the FET device (W/L). The resistance R_{fet} originates from the dynamic switching of the mixer devices' conductance. This pumped nonlinear conductance can be represented by the first term of a Fourier series expansion of the mixer's time-varying conductance. The fundamental term responsible for the down-conversion, G_1, is a function of both the LO drive amplitude, V_p, and the geometry of the NMOS device.

Mathematically, this time varying conductance, G (t), can be expressed as:

$$G(\omega_{LO}t) \approx G_0 + G_1 \cos(\omega_{LO}t) + G_3 \cos(3\omega_{LO}t) \quad (1)$$

In a true double balanced mixer, the even harmonic terms are canceled. The input impedance of the mixer, as seen from the RF port, can therefore be modeled as the time-varying conductance of the FET-quad (with $R_{fet} = 1/G_1$) in parallel with C_{fet} and the RF transformer's magnetizing inductance L_{bal}.

It is important to ensure that the RF port of the mixer is well matched to the system source impedance for two reasons. First, as the input stage of the downconverter, the overall NF of the block will be dominated by the conversion loss of the mixing stage. Second, by providing a good matched load to the prior stage, it becomes easier to integrate the required image-reject or RF bandpass filters.

Ideally, this is equal to the characteristic impedance of the system at the frequency of operation (usually 50 Ω). However, by careful selection of both the device size (W/L) and the LO drive level such that $R_{fet} = Z_o$, broadband performance is achievable from this circuit. The transformer loss is minimized and impedance matching is achieved by choosing L_{bal} and resonating with the capacitance of the NFET core (C_{fet}) such that:

$$f_{rf} = \frac{1}{2\pi\sqrt{L_{bal}C_{fet}}} \quad (2)$$

The mixer core in such a design can be thought of as having characteristic impedance, Z_o equal to:

$$Z_o = \sqrt{\frac{L_{bal}}{C_{fet}}} = R_{fet}\Omega \quad (3)$$

This model of the mixer core is used for the subsequent design steps.

Highly linear performance is achieved by fully driving the gates as close to V_{box} as practical. A typical value in a 0.5 µm NFET technology, peak V_{box} is typically approximately 6 V, although the full-drive is limited to 5 V for reliability reasons. For a given NMOS technology, the P_{1dB} achievable for a fully-driven quad at various RF frequencies is a function of the device size within a given Z_o environment.

Equations 2 and 3 indicate that for a fixed system characteristic impedance, the operating frequency is inversely proportional to the equivalent capacitance of the mixer core. Therefore – all other things being equal – doubling the frequency of operation of the circuit necessitates halving the effective capacitance of the mixer core. The conclusion that therefore follows is that higher RF frequency mixers require shorter gate length devices to achieve low conversion loss, although the key parameter remains the matching of the time varying conductance of the mixer core to the characteristic impedance of the system at the optimum drive level. ***Table 1*** shows how this approach may be used to scale a design within a specified technology for various operating center frequencies. This analysis is based upon the NXP QuBIC4X SiGe:C BiCMOS process with a 0.25 µm NFET. In this

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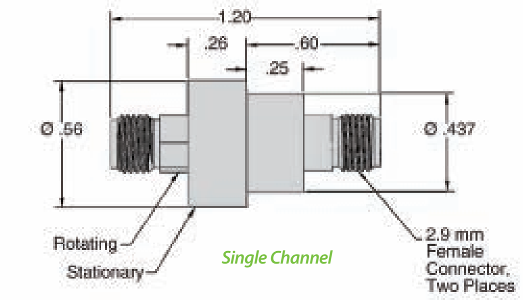

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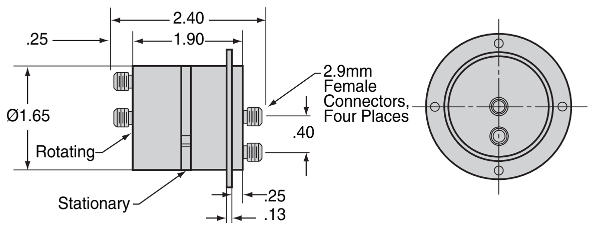

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VSWR	DC - 10 GHz	1.20 : 1 MAX.
	10 - 26 GHz	1.35 : 1 MAX.
	26 - 40 GHz	1.75 : 1 MAX.
WOW	1.05 MAX.	
INSERTION LOSS	DC - 10 GHz	0.2 dB MAX.
	10 - 26 GHz	0.4 dB MAX.
	26 - 40 GHz	0.6 dB MAX.
PEAK POWER	Equal to connector rating	

DUAL CHANNEL SPECIFICATIONS:

ELECTRICAL	Channel 1	Channel 2
FREQUENCY	7.0 - 22.0 GHz	29.0 - 31.0 GHz
VSWR	1.50:1 MAX.	1.70:1 MAX.
WOW	0.15	0.25
INSERTION LOSS	0.5 dB MAX.	1.0 dB MAX.
ISOLATION	Channel to Channel	50.0 dB MIN.

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TABLE I

A COMPARISON OF THE KEY PERFORMANCE PARAMETERS FOR MULTIPLE NMOS FET MIXER CORES AS A FUNCTION OF DEVICE GEOMETRY

Parameter	Design 1	Design 2	Design 3	Design 4	Design 5
LO Frequency (GHz)	0.875	1.75	3.5	7	14
NFET Gate Width (µm)	1600	800	400	200	100
R_{fet} (Ω)	37	39	43	49	58
C_{fet}(pF)	4.0	1.8	0.84	0.38	0.17
RF Transformer Magnetizing Inductance-L_{bal} (nH)	8.3	4.5	2.5	1.3	0.70
Conversion Loss (dB)	4.4	4.4	4.6	5.1	5.9
NF (dB)	4.0	4.2	4.6	5.4	6.6
P_{1dB} (dBm)	22	21.6	20.5	18.6	16.0

Simulation Conditions:
1. Pure sinusoidal drive, LO drive 5 V p-p, v_{LO} common-mode = 0.65 V.
2. RF transformer modeled as an ideal 1:1 transformer in parallel with its magnetizing inductance resonating with C_{fet}.
3. RF and IF impedance = 50 Ω
4. L_{bal} resonates with C_{fet} with Q = 15

example, based on a typical technology, the peak-drive $V_p < V_{box}$ is approximately 2.5 V.

Two observations can be made from the power-frequency table. For a given technology, the maximum P_{1dB} achieved – with low conversion loss into a 50 Ω system – drops with increasing operating frequency. Increasing the W/L ratio (device periphery) at a given frequency not only yields lower conversion loss, but also allows more sweeping of dynamic conductance and hence achieves a higher P_{1dB}. A lower Z_o Ω mixer core, achieved by scaling C_{fet} and L_{bal}, can yield higher P_{1dB} at peak LO drive.

Sum Termination and Diplexer Design

The four-FET quad mixer is a double sided mixer; both sum and difference frequencies are produced at the IF port at the same level. The signal of interest for the receiver ($f_{LO} - f_{RF}$ or $f_{RF} - f_{LO}$ for high-side or low-side injection respectively) is amplified inside the chip by the IF amplifier. However, the sum signal ($f_{LO} + f_{RF}$) is also generated and is incident upon the IF amplifier. The presence of this sum-signal will have the effect of deteriorating the dynamic performance of the downconverter, as the high frequency signal is reflected by the IF amplifier and re-mixed with the LO at the IF port. Therefore, to maximize the linearity of the downconverter, the sum signal should be rejected prior to the IF amplifier's input. To prevent reflection of the sum signal and re-mixing with the LO at the IF port, the sum signal has to be absorbed[4] by a termination. This can be achieved by incorporating a simple differential diplexer between the mixer and the IF stage to terminate the sum and pass the wanted difference signal with minimum loss.

Figure 6 shows how the diplexer can be implemented with a simple highpass

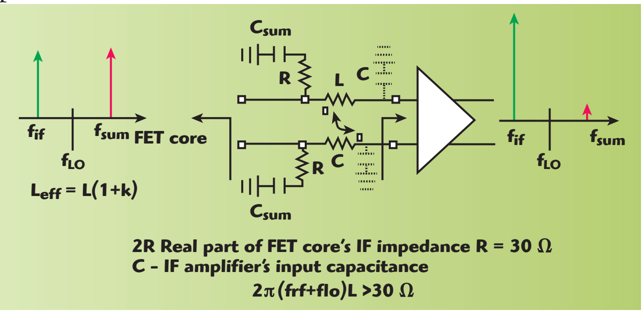

Fig. 6 Principle and implementation of the diplexer design used to maintain maximum linearity from the IF amplifier.


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AF00118173A AF00118253A AF00118333A	0.01 - 18	17 25 33	±1.0 ±1.4 ±1.8	3.0 3.0 3.0
AF00120173A AF00120243A AF00120313A	0.01 - 20	17 24 31	±1.0 ±1.5 ±2.0	3.0 3.0 3.0

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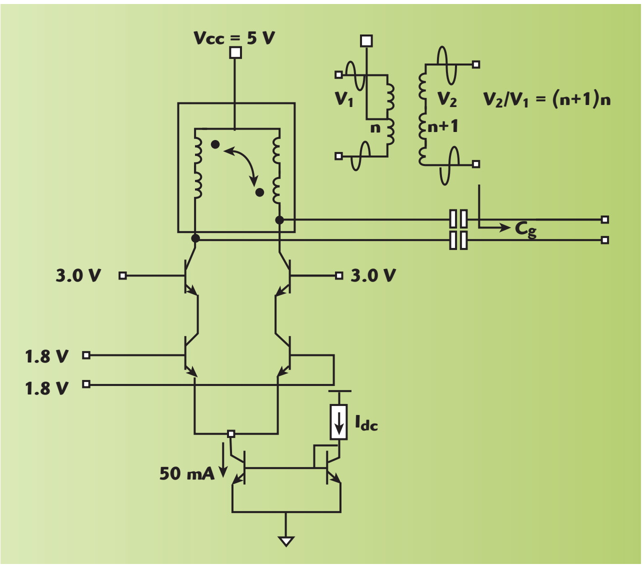
R-C section where the sum frequency is absorbed (terminated); R is half of the differential IF termination. A coupled series L connection tuned with the IF amplifier's input capacitance (Miller capacitance for CE amplifier) works well to function as a low pass, high frequency reject section.



▲ *Fig. 7 Transformer or tank resonated amplifier to generate voltage drives for NFET cores.*

LO Driver Amplifier Design

The ability to drive the mixer core to present the correct dynamic conductance and optimize linearity requires optimizing the signal voltage swing at the FET quad. Signal voltage swings of 2.5 to 5 V translate to LO power levels of approximately 18 to 24 dBm, when referenced to a 50 Ω characteristic impedance. The magnitude of this LO voltage swing can be controlled in an IC implementation of the mixer quad-core by using a resonated amplifier technique,[5] as shown in ***Figure 7***. In this technique, the gate of the mixer quad is seen as a load that can be resonated by the tank connected to the open-collector of a cascode or CE differential BJT pair. A variant of this approach uses an n:n+1 transformer that can boost (step-up) the voltage drive into the mixer. This approach allows additional flexibility by allowing for the optimum LO signal swing at the mixer core to be treated somewhat separately to the peak signal magnitude at the output of the LO amplifier. In this example, SiGe HBTs are used in a cascode configuration to ameliorate the breakdown effects and improve the high-frequency performance.

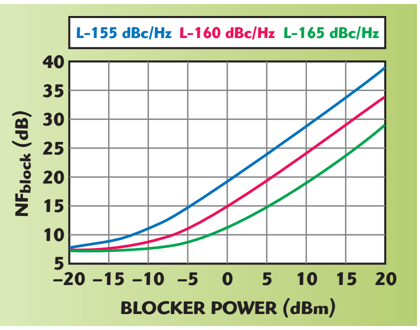
Blocker and LO Noise Performance

The driver design in the last section emphasizes building up a large-signal to switch the NFETs at the local oscillator frequency. A large drive ensures linear operation of the mixer. While most driver designs address generation of large signals at the gate of the mixer, the noise performance of the drivers also need special attention.

In the presence of a large jammer at the RF port of the mixer, the noise at the local oscillator skirt will end up at the IF port due to reciprocal mixing.[6] To minimize the signal-to-noise degradation, special care must be taken to design the LOA current source (I_{dc}), whose low-frequency noise ends on both sides of the LO phase noise profile. The degradation of the noise figure due to jammers can be expressed in a closed form equation for an integrated circuit downconverter.[7] NF_{block} is given as:

$$NF_{block} = 10\log_{10}\cdot\left[1+\frac{(L_{cn}-1)T_p}{T_o}+\frac{(LP_{block})}{1000kT_o}\right] \quad (4)$$

with $L = 10^{(Ln/10)}$, where L_n is the LO noise in dBc/Hz; T_p is the operating temperature; T_o = 290 K; P_{block} is the blocker power in mW; k is the Boltzmann's constant = $1.381\times10^{(-23)}$ J/K and the conversion loss $L_{cn} = 10^{(Lc/10)}$, where L_c is in dB. ***Figure 8*** shows how the



▲ *Fig. 8 Noise figure under blocking conditions as a function of input blocking signal power and LO buffer noise.*

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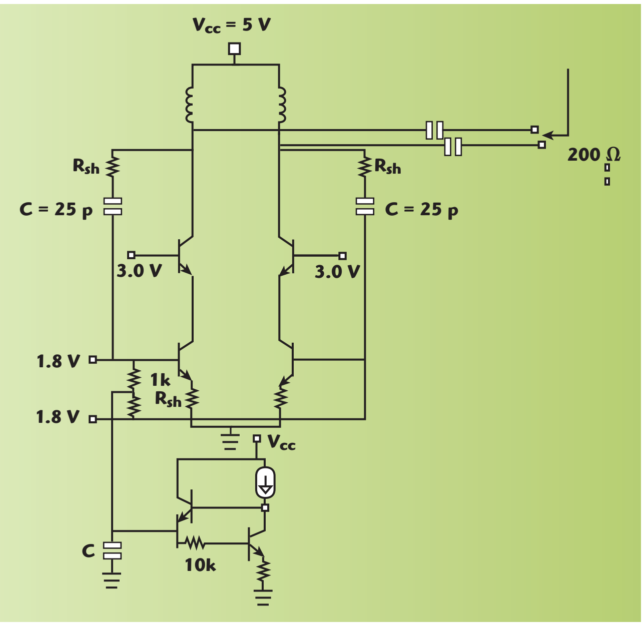
noise figure (dB) of the downconverter under blocking conditions varies as a function of the input blocking signal power. The operating temperature in this plot is T_p = 25°C. It shows how the magnitude of the noise generated by the LO signal affects the total NF of the downconverter. Careful consideration of these plots give a guideline for the amount of allowable LO buffer noise (L_n in dBc/Hz) in the design so that the NF_{block} requirement can be met. The dominance of LO noise in determining the total signal-to-noise ratio degradation beyond P_{block} = –5 dBm can be observed.

Design of the IF Amplifier

The load network of the IF amplifier is a narrowband IF Filter (typically a surface acoustic wave (SAW) type) that are naturally differential. It is convenient for the output of the IF amplifier to be differential thus simplifying this interface connection. ***Figure 9*** shows a series-shunt feedback cascode amplifier for superior bandwidth and reverse isolation. Series-shunt resistive feedback designs are common with the use of cascode configurations for broadband IF (50 to 800 MHz). High reverse isolation and low output capacitance of the high f_t SiGe transistors and cascode amplifiers facilitate high (200 Ω) output impedances that match with the SAW filters.

The bias injection in the IF amplifier a) maximizes the headroom for output swing and b) minimizes the bias noise upconversion under blocking conditions. Base-ballasting and careful current mirror design ensures proper isolation between the bias circuit and IF. A capacitor C filters the noise and unwanted injections into the bias circuit. The classical tail current source is avoided for noise and headroom reasons.

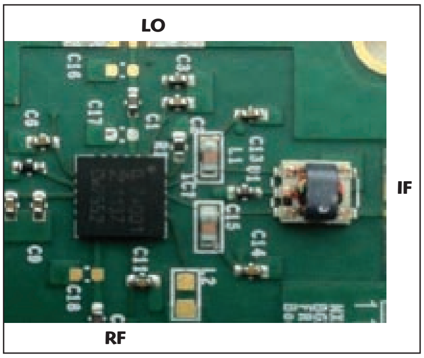


▲ *Fig. 9 Series-shunt feedback cascode amplifier for superior bandwidth and reverse isolation.*

SiGe BiCMOS DOWNCONVERTER DESIGN EXAMPLE

The following example uses the steps outlined above to design a 2.5 to 3.5 GHz downconverter, fabricated using the NXP QUBiC4X SiGe BiCMOS process from NXP.[3] The 2.5 to 3.5 GHz RF frequency band is chosen for the design, due to its importance for LTE and WiMAX applications. With the model described in Design 3 of Table 1, the balun design is optimized to be centered at 3 GHz. The LOA design is optimized for f_{if} = 300 MHz and a high-side injection LO (f_{lo}) band of 2.8 to 3.8 GHz is assumed.

The IC is packaged in an industry standard 5 × 5 mm QFN-20 plastic package as shown in the photograph of ***Figure 10***. For characterization purposes, the differential IF port is transformed to a single-ended 50 Ω



▲ *Fig. 10 Photograph of the QFN-32, 5 × 5 mm packaged downconverter IC, designed using the principles and procedures outlined.*

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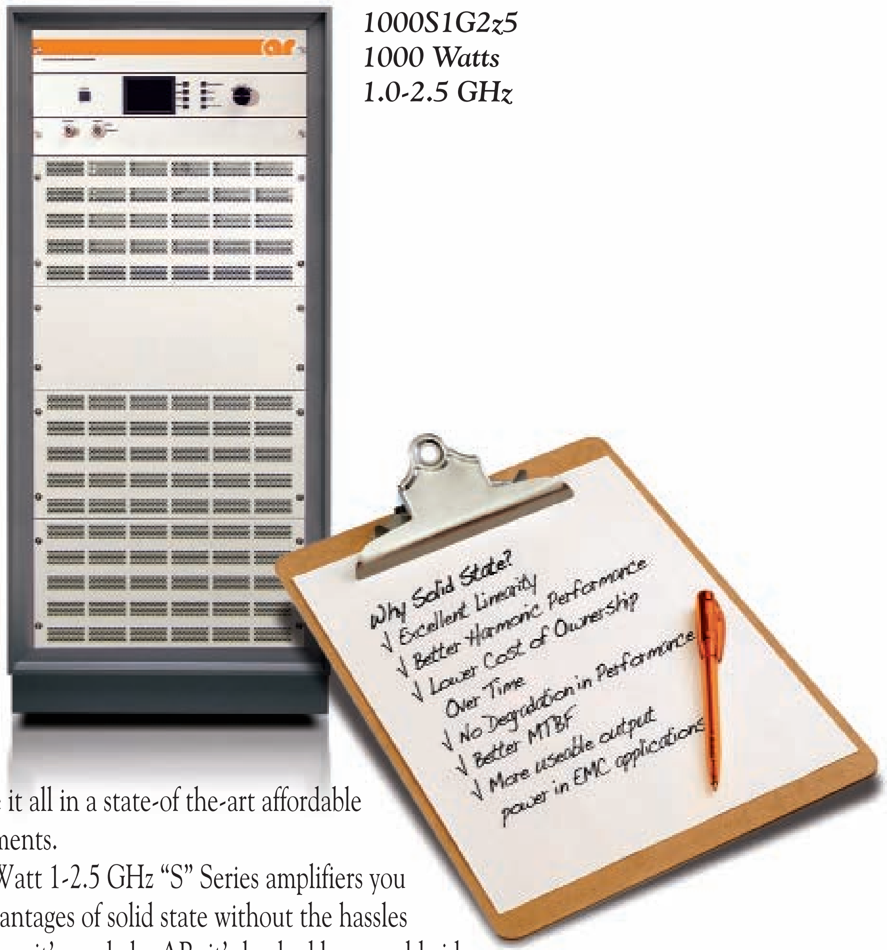

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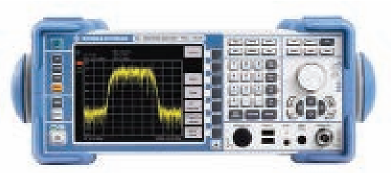

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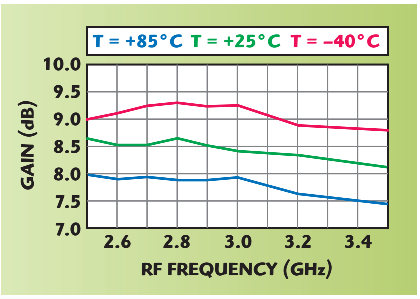
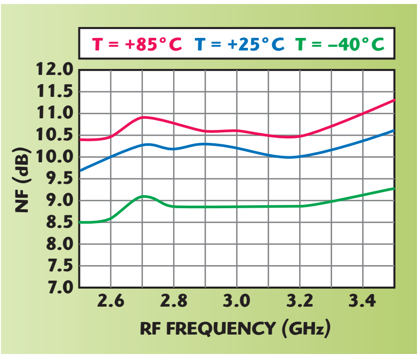


▲ *Fig. 11 Conversion gain of the BGX7401 downconverter with NFET mixer and HBT IF amplifier.*



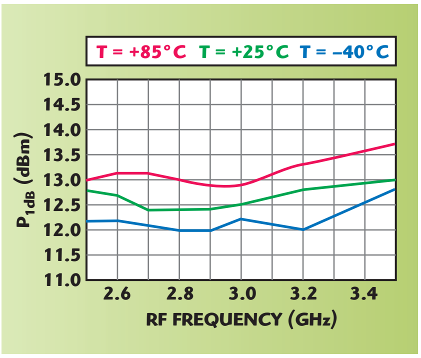
▲ *Fig. 12 SSB noise figure of BGX7401 vs. RF frequency and temperature.*

termination by means of a lumped external balun as seen on the extreme left of the image.

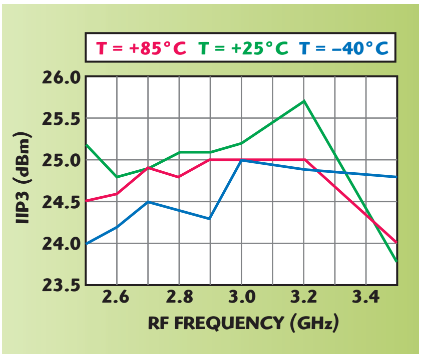
The mixer IC draws 175 mA from a +5 V supply. With a typical IIP3 of +25 dBm and 8.5 dB gain and 10 dB noise figure, the measured results validate the design procedure outlined in this article. Typical gain, noise figure, P_{1dB} and IIP3 measurements, as a function of both RF input signal frequency and ambient operating temperature (–40°, +25° and +85°C), are shown in ***Figures 11, 12, 13*** and ***14***, respectively.

CONCLUSION

A systematic design technique is shown that partitions the design problem into independent parts resulting in the dual-benefits of miniaturization and cost reductions. Old circuits simply do not die. They evolve and find their ways into newer designs with better performance. The design approach reviewed and implemented here takes a classic 4 FET quad and combines it with the benefits of small-size and high predictability, available from Si integrated circuit techniques. By also including the LO driver and IF amplifier functions in the integrated solution, higher efficiency circuits can be realized without compromising performance. ■



▲ *Fig. 13 Input P_{1dB} compression point of BGX7401 as a function of RF frequency and temperature.*



▲ *Fig. 14 Input IIP3 vs. RF frequency and temperature.*

ACKNOWLEDGMENT

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A Broadband Millimeter-Wave Rectangular-to-Coplanar Waveguide Transition

This article presents a broadband, low-loss transition from rectangular waveguide (RW) to coplanar waveguide (CPW) at U-Band (40 to 60 GHz). The transition uses a transverse E-plane probe to get a wide bandwidth. The ground of the CPW is extended into the waveguide to obtain a well matched transition. The transition is implemented through a coupling to the waveguide bend, avoiding the inconsistency in the direction of signal transmission and facilitating the overall structure. A back-to-back (BTB) structure is used to demonstrate the feasibility of the transition. The reflection of a scalar network analyzer (SNA) affects the measurement results seriously. To solve this problem, this article performs an error analysis and offers an appropriate test method to reduce that influence. The return loss is measured with a matching load and the insertion loss is tested by adding a 20 dB attenuator between the device under test (DUT) and the detector of the SNA. The measured results of the BTB structure show that a return loss better than 20 dB and an insertion loss of 0.35 dB are achieved over the entire U-Band, which are close to the simulated results. The design had been used for a W-Band doubler and W-Band RW-to-CPW BTB transition.

CPWs on thin dielectric membranes are proved to have very satisfactory transmission properties, because of the absence of substrate modes, low losses and low dispersion.[1] Due to RW's low loss, simple topology, high-power handling capability and interconnect ability, it continues to be an important transmission line, especially in the millimeter-wave band.[2] Thus, a transition between CPW and RW is needed, which should have a low insertion loss, a good return loss and a wide bandwidth.

Present reports about RW-to-CPW transitions use different forms of transition,[3-5] but the probe transition is more attractive because of its low insertion loss, simple structure, tuning flexibility and broadband performance. Many articles have reported that using a transverse E-plane probe is the preferred method to

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achieve a wide bandwidth,[6,7] but most of them are transitions from waveguide to microstrip. Other articles have introduced an extra structure, for example a stepped-impedance filter, used to suppress spurious radiation in unenclosed waveguide.[5,8] This article improves these forms of transition, to design an enclosed simple broadband low-loss RW-to-CPW transition.

A vector network analyzer is difficult to obtain at U-Band or higher frequencies. An SNA cannot be calibrated to eliminate the detector's reflection completely, which usually increases with frequency. Because of this, a measurement error analysis has to be discussed, but many articles ignore this analysis, resulting in significant difference between simulations and measurements.[3,9,10] The measured reflection loss is worse than the simulation results by more than 5 dB and there is no reason given for this situation.[3] In Xu Jun's article,[9] there are no measured results of return loss mentioned to verify the design. In Y.C. Shih's article,[10] there is a very large fluctuation, which is most likely caused by an incorrect test method, but no explanation has been made.

In this article, a RW-to-CPW transition at U-Band is proposed. This design makes some improvement to enhance its performance. The waveguide bend is coupled to avoid the inconsistency in the direction of signal transmission and make the overall structure suitable. The ground of the CPW, on both sides of the strip, is extended into the waveguide to make the transition well-matched. Finally, a BTB structure is used to evaluate its effect. In order to ensure the accuracy of the measurements, an analysis is performed on the influence of the reflection of the test equipment on measured results and offers an appropriate way to reduce this influence. This transition has been used in a W-Band doubler research and W-Band RW-to-CPW BTB transition study.

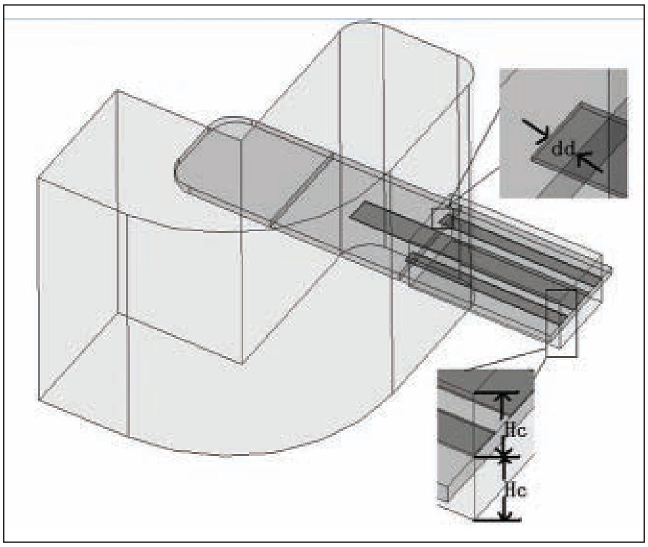

Fig. 1 Model of the RW-to-CPW transition.

DESIGN AND SIMULATION OF THE RW-TO-CPW TRANSITION

Figure 1 shows the structure of the RW-to-CPW transition, which consists of a waveguide bend, an E-plane probe and a coplanar transmission line. The input waveguide is a standard R500 waveguide with inside dimensions of 4.775 × 2.388 mm.

The CPW Line and the CPW Channel

The coplanar line is set in the middle of a channel and the bulk of the circuit operates in an enclosed region, so the CPW does not need some other structure to reject parasitic modes of the input signal, which is conducive to a miniaturized system. The fact that the electromagnetic field is distributed mostly in the air decreases greatly the dispersion and the loss is reduced.

The width of the CPW channel is certain, since the transition is designed for doubler applications at W-Band, which needs a standard R900 waveguide used as an output. Thus, the width is defined to be 1.270 mm based on the dimensions 2.540 × 1.270 mm of R900. Next, the height of the CPW channel (H_c) is set at 0.5 mm to avoid any waveguide mode by minimizing the height, while the CPW mode is not strongly affected. The impedance of the coplanar line can be maintained close to 50 Ω.

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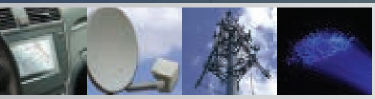

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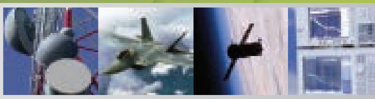

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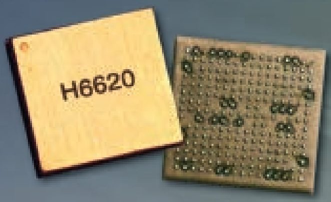

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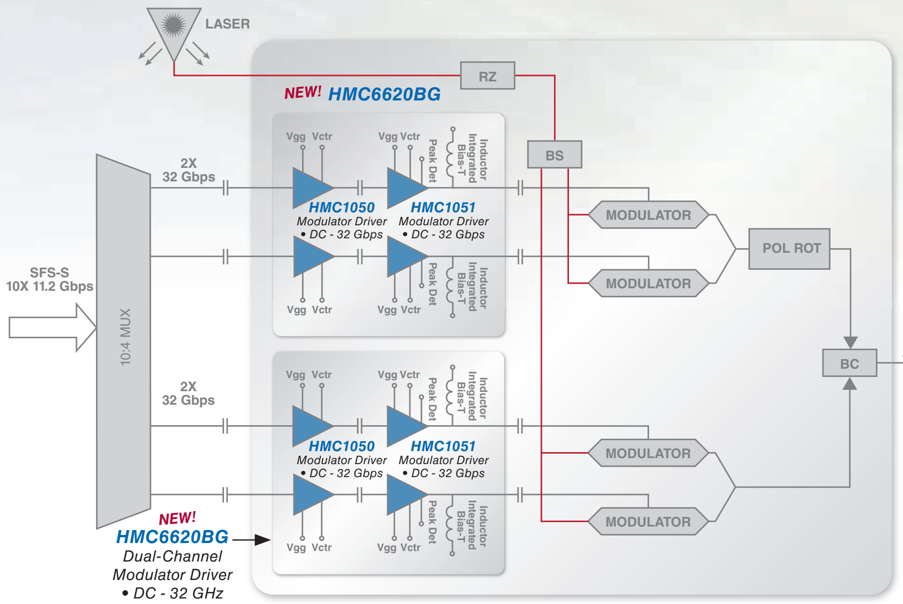

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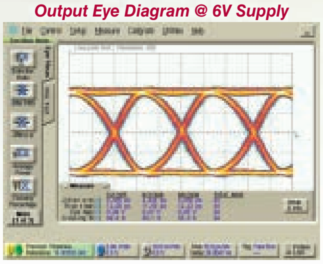
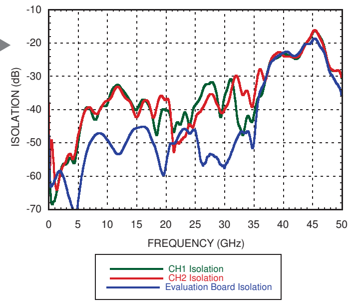


Channel-to-Channel Isolation



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	HMC1051	32	8Vp-p Optical Modulator Driver / Wideband Amplifier	16	±5	0.3	8	Chip
	HMC5850BG	32	Optical Modulator Driver	29	±7	0.23	8	BGA
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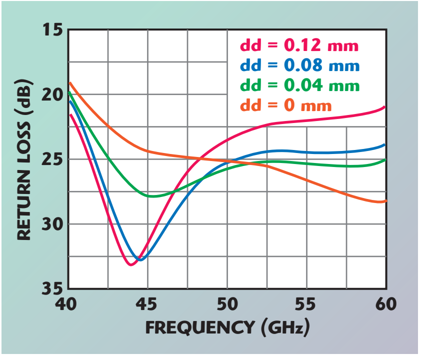
The Waveguide Bend

In a traditional E-plane probe transition, the input and output ports are perpendicular. To make them parallel, to solve the inconvenience of the structure, a waveguide bend is coupled to the transition. An important thing is that the inner angle cannot be fabricated by an existing processing technology. The RW is machined on the inside of a copper block. Considering these, the waveguide bend is manufactured with a round angle bend with an optimal radius of 3.05 mm and the two round corners at the back-short of the waveguide are designed with radius of 0.5 mm.

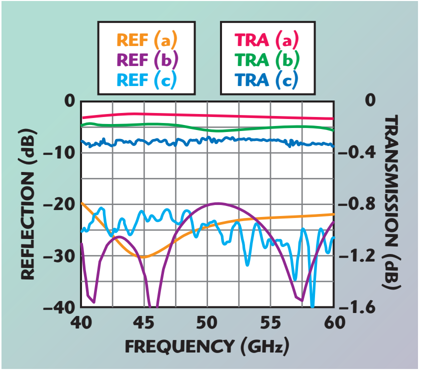
The Waveguide Probe

The design of the waveguide probe is the most important feature of this approach. Using a transverse E-plane probe, which is inserted into the waveguide, can achieve a wider bandwidth. Besides, the waveguide probe is set away from the waveguide back-short approximately $\lambda_g/4$ at 50 GHz, which is approximately 1.6 mm. There are four parameters of the probe, all of which are simulated at various distances to each other except that the width and the length of the probe are not independent during the process, which also has to be optimized. Furthermore, the ground plane of the CPW line is extended a short distance into the waveguide to make a better match. ***Figure 2*** shows the simulation results for different distances (dd), extended from the channel. It proves that the matching and the bandwidth of the transition can be further adjusted while the dd is changing. Finally, the distance is confirmed to be 80 μm.

The RW-to-CPW transition has been simulated. A BTB configuration is designed to facilitate the test. The final simulation results of the transition and the BTB structure are shown in ***Figure 3***. The line (a) shows the simulations results of the single transition. The figure shows the transmission and reflection of the BTB transition, while (b) is the simulation results and (c) is the measured results. The simulations show that the transition achieves less than 0.15 dB insertion loss and the BTB configuration gets less than 0.25 dB, while both of them get a better than 20 dB rejection.



▲ *Fig. 2 Simulated return loss as a function of dd.*



▲ *Fig. 3 Simulated results (a) of the single transition and simulated and measured results of the BTB configuration.*

MEASUREMENT ERROR ANALYSIS

Usually, a vector network analyzer is used in many situations. But it is difficult to obtain at U-Band or higher frequencies because of its high cost. Thus, the S-parameters over U-Band are tested most often with an SNA. The commonly used SNA has three detectors: one is used as reference through a power splitter, another is used to receive the reflected signal through a directional coupler, and the last is connected to the output port directly. Usually, the DUT's performance is tested directly by connecting it with SNA. But, actually, there is not a perfect match between the DUT and the SNA's detector. An SNA cannot be calibrated to eliminate the reflection, which usually increases as the frequency increases. It is clear that S-parameters, whether S_{11} or S_{21}, are defined on the basis of the port match. When the reflection of the DUT's load is large, the measurement results are away from its actual value, which would bring a large error.

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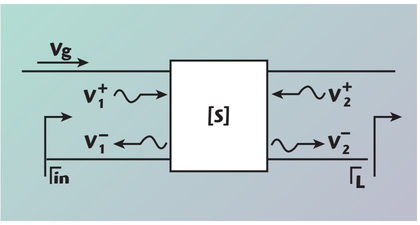

Fig. 4 A two-port network.

Some analysis can be performed to explain this, which provides a precondition to obtain an appropriate test method. All the parameters are shown in ***Figure 4***. V represents the voltage magnitudes at the ports and V_g represents the source voltage magnitude. When the DUT and the output load are mismatched, there is a load reflection coefficient which is assumed to be Γ_L. The reflection coefficient seen from DUT's input port to its load port is assumed to be Γ_{in}. The relationship between them is as follows:

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \qquad (1)$$

Since the phase information cannot be obtained using an SNA, another equation is needed, which is just about the magnitude of the reflection coefficient. The final equation obtained from Equation 1 comes out as follows:

$$|\Gamma_{in} - C_L| = R_L \qquad (2)$$

Equation 2 shows a circle in the complex plane with the center C_L and the radius R_L given below, in which $\Delta = S_{11}S_{22} - S_{12}S_{21}$.

$$C_L = \frac{S_{11} - |\Gamma_L|^2 \Delta S_{22}^*}{1 - |\Gamma_L|^2 |S_{22}|^2} \qquad (3)$$

$$R_L = \frac{|\Gamma_L||S_{12}||S_{21}|}{\left|1 - |\Gamma_L|^2 |S_{22}|^2\right|} \qquad (4)$$

From the equations above, the range of $|\Gamma_{in}|$ can be known if $|\Gamma_L|$ is confirmed. When $|\Gamma_L|$ becomes smaller, the radius becomes smaller also. Only when $|\Gamma_L|$ is zero does $|\Gamma_{in}| = S_{11}$. If $|\Gamma_L|$ changes from 1 to 0, it seems intuitive that CL will gradually close to S_{11} and R_L will approach 0.

Figure 5 shows the reflection coefficients of different loads. It is obvious that the reflection of the matching load (a) and the 20 dB attenuator (b) are lower than that of the detector (c). The detector connected to the output port of DUT directly could seriously affect the measurement results of the BTB transition. Moreover, the reflection of the 20 dB attenuator presents more obvious peaks than the matching load. Thus, the reflection loss should be tested by a matching load connected to the output of DUT, which can make the measurement results close to its actual value.

In the same way, the insertion loss is to be analyzed to see how it is in-

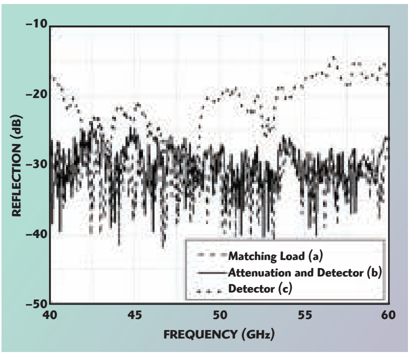

Fig. 5 Reflection coefficient of a matching load (a), a 20 dB attenuator set before the detector (b) and the detector (c).

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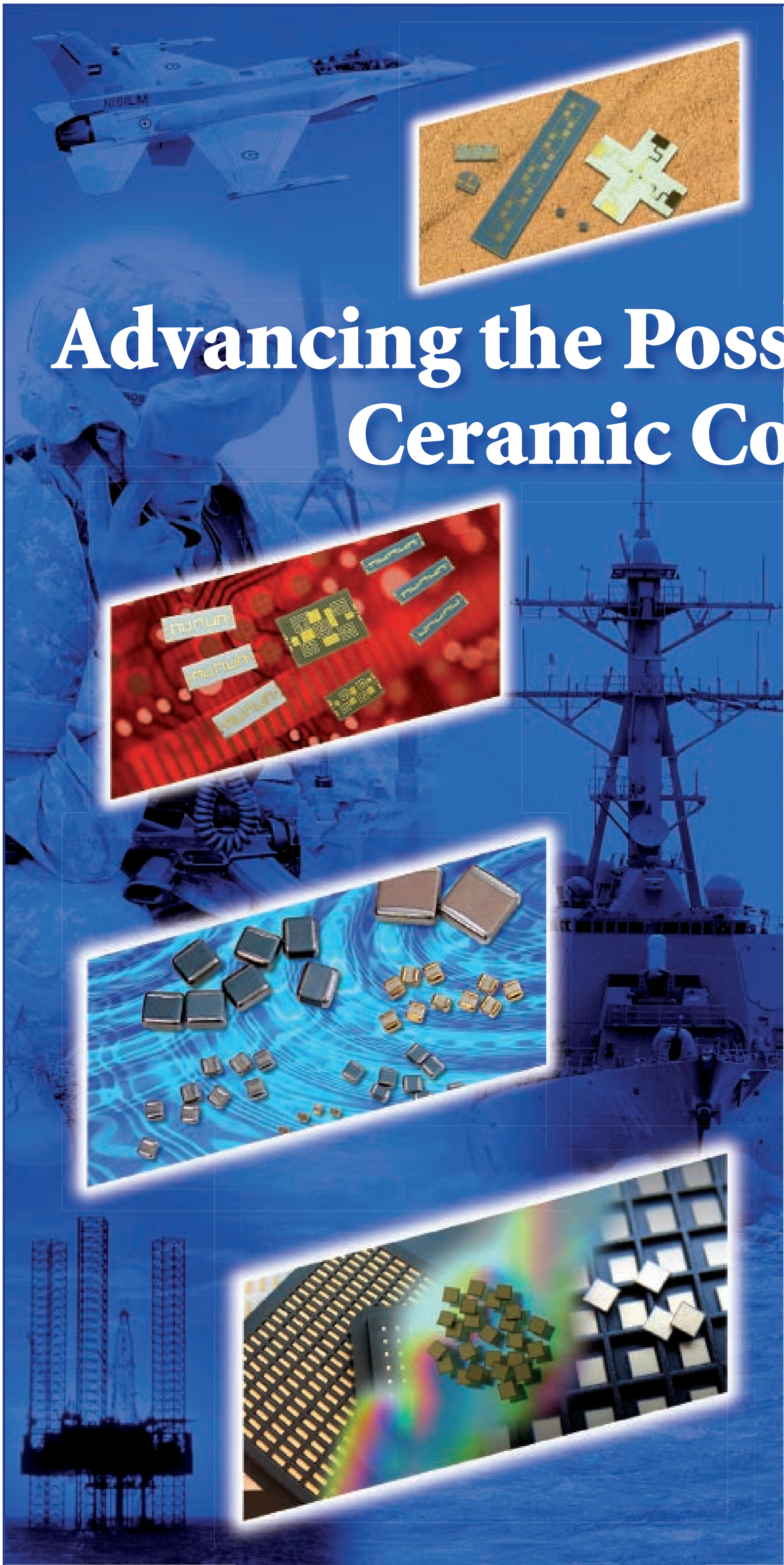

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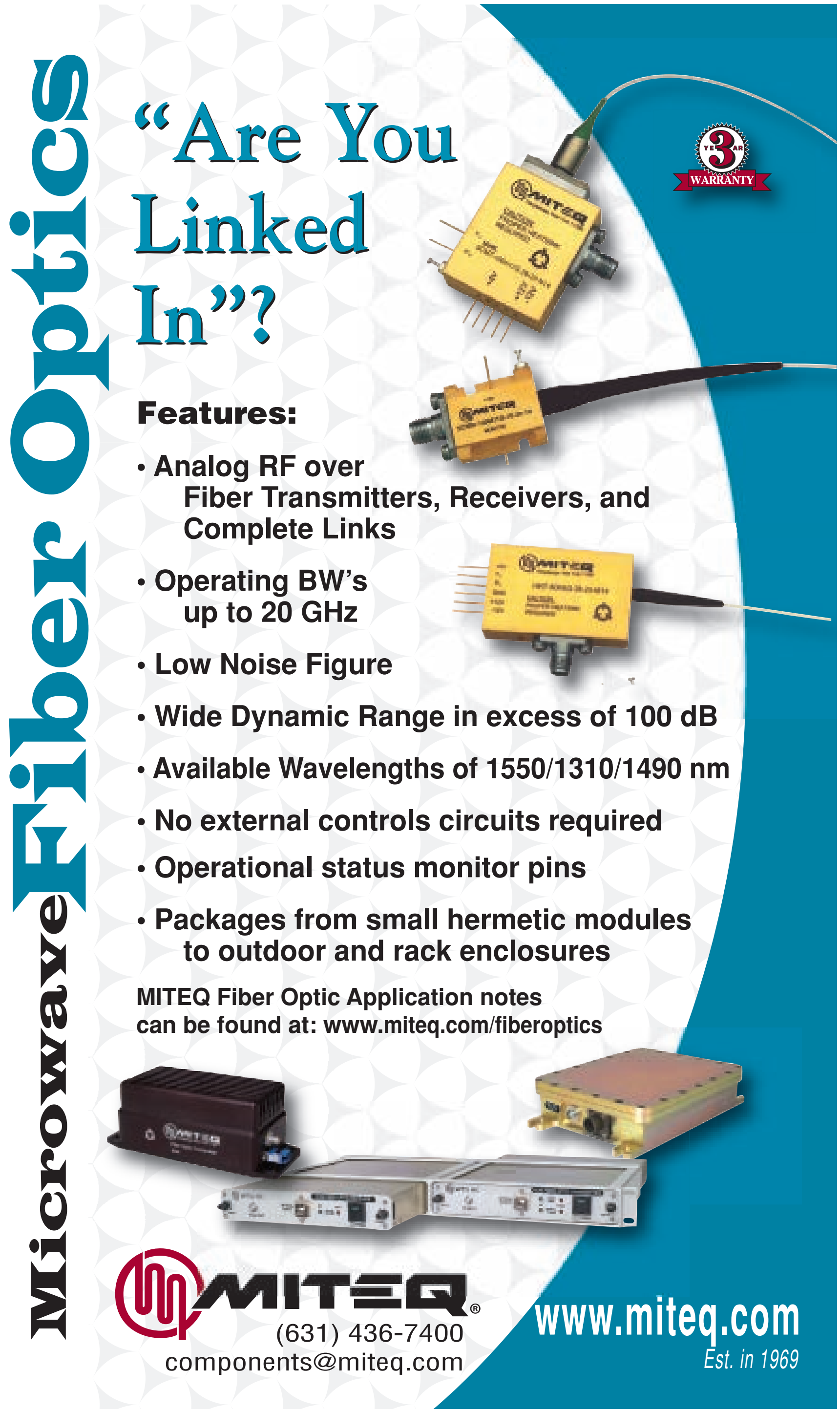
fluenced by the reflection coefficients of different loads. First, let us realize the definition of the insertion loss (IL) while the influence of the source is very small, which can be assumed to be zero. IL is the ratio of the output voltage amplitude of the signal source to that of the output port of the DUT after it is inserted.

$$IL = 20\log\left|\frac{V_g}{V_2^-}\right| \quad (5)$$

In this formula, V_g is the voltage amplitude of source, just when the source is matched, and V_2^- is the amplitude of signal given to load. From the voltage relationship of two-port network, another equation can be obtained as follows:

$$IL = 20\log\left|\frac{1-S_{22}\Gamma_L}{S_{21}}\right| \quad (6)$$

When $|\Gamma_L|$ is zero, IL = –20 log $|S_{21}|$. This equation also shows the range of |IL|.



$$\frac{|1-|S_{22}||\Gamma_L|}{|S_{21}|} \le |IL| \le \frac{1+|S_{22}||\Gamma_L|}{|S_{21}|} \quad (7)$$

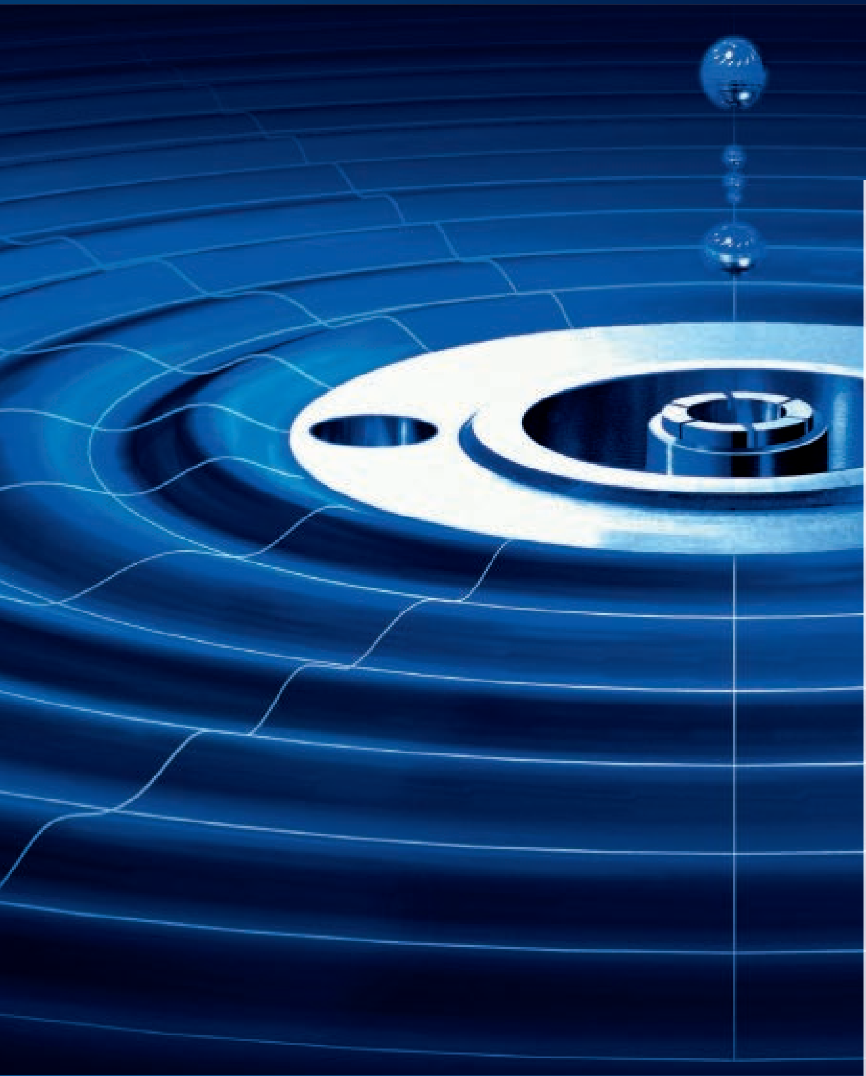
The range of |IL| is also closely related to $|\Gamma_L|$ and |IL| is closer to $1/|S_{21}|$ when $|\Gamma_L|$ becomes small.

The analysis proves that a lower load return loss makes the measured results more realistic. From Figure 5, it is found that the 20 dB attenuator has a lower reflection loss, so the load with the attenuator has a smaller effect on the measured results, compared with using the detector directly. Thus, a 20 dB attenuator, whose insertion loss can be eliminated by calibration, is set between the DUT and the detector of the SNA when the insertion loss is to be measured.

To understand the possible range of the measured error with different loads, the amplitude and phase of S-parameters of the BTB transition can be obtained from HFSS. Thus, the error range can be calculated and figured out with different reflection coefficient of loads, using the above equations. There are two examples where a specific frequency is assumed, such as 51.5 GHz. When $|\Gamma_L|$ = – 25 dB, that is 0.056, the reflection coefficient –27.5 dB $\le|\Gamma_{in}|\le$–16.4 dB can be obtained from equation 2 and the insertion loss 0.2 dB≤IL≤ 0.3 dB from Equation 7. When ΓL = –18 dB, the reflection coefficient –28.4 dB $\le\Gamma_{in}\le$–13.6 dB and the insertion loss 0.14 dB≤IL≤0.36 dB are achieved. Comparing these two examples, it can be found that the measured reflection would be away from the real value when the reflection of the load is larger than that of the DUT. The insertion loss is in the same situation. This analysis will be proved in the measurements.

MEASUREMENTS

The BTB configuration was fabricated in a copper block whose measurement results, shown in Figure 3, were taken with an Agilent 8757D SNA. By using the method proposed in this article, the influence of the reflection of the load that affects the measured results is decreased. The better the load and DUT match, the closer the measured results and actual values are. Even so, there is still an obvious difference between measured results and simulation results. This is



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because the influence of the load's reflection is significantly improved, but not completely eliminated, especially when the practical reflection is very small.

Figure 3 shows that the insertion of the BTB transition is better than 0.35 dB with the curve changing slightly. The measurement of the return loss implies that a good performance in a wide band was achieved. The fractional bandwidth for the 20 dB return loss is greater than 40 percent, covering the whole operating frequencies of the U-Band.

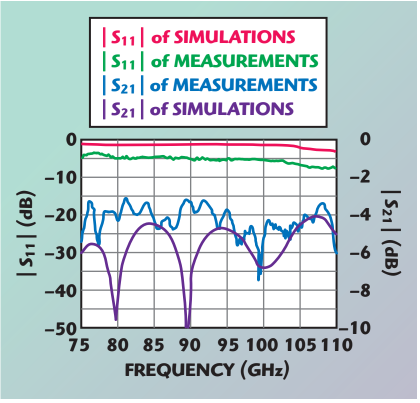
The analysis of the previous section shows that the measurements at one frequency have a difference in a certain range. Considering the processing and other factors, the final measurement of reflection loss, shown in Figure 3, is in line with the simulation results reasonably. Similarity, since the skin depth and the surface roughness are neglected, the measured insertion loss is slightly larger than the simulated one. Therefore, the measured results of insertion loss are in line with actual situation. Comparing these results with other published transitions,[4-13] the measurement results of the BTB transition described here are much better than those given in papers where the reflection is worse than –15 dB, while the fractional bandwidth is less than 25 percent, or a 0.4 dB insertion loss can be found only in X-Band or near it. All these show that this approach uses a good configuration and an appropriate measurement method.

Because of the advantage of this transition, it has been used as the input part of a W-Band doubler, whose output is a R900 standard waveguide. This doubler uses parallel diodes to achieve frequency doubling and its best efficiency is approximately 6.4 percent at 40.5 GHz.

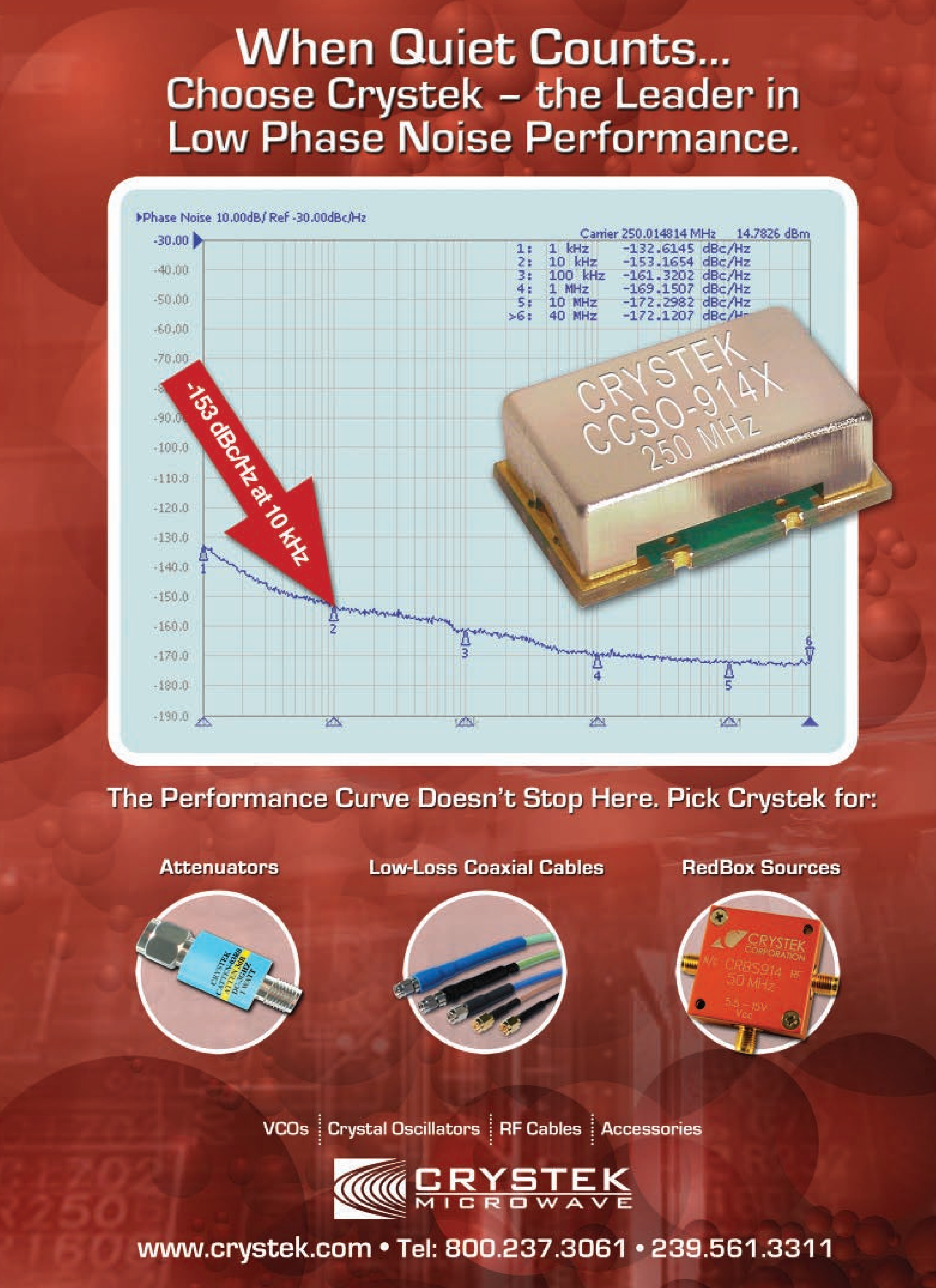
A W-Band RW-to-CPW transition's BTB configuration is designed and measured based on the study in this article. A better than –15.65 dB reflection and a lower than 1.53 dB insertion loss are obtained, as shown in ***Figure 6***. The actual insertion loss is better since the length of the back grounded coplanar transmission line is approximately 6.8 mm.

CONCLUSION

This article presents the design of a RW-to-CPW transition at U-Band. The transition achieves a low loss over a full bandwidth by using a transverse E-plane probe. In order to eliminate the parasitic mode, the coplanar line is clamped in the middle of the CPW channel and its enclosed structure



▲ *Fig. 6 Simulated and measured results for the W-Band RW-to-CPW transition BTB configuration.*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does not need any filter. A waveguide bend is coupled to the transition to solve the inconvenience of the structure. To make the match much better between waveguide and CPW, the ground of the CPW line is extended slightly into the waveguide. Finally, a BTB structure is fabricated to verify the transition.

Since the reflection of an SNA's detector cannot be eliminated by calibration, this article gives a measurement error analysis and proposes an appropriate method to achieve a more realistic measured value. The reflection is measured with a matching load connected to the output port of the DUT. The insertion loss is tested while a 20 dB attenuator is set between the DUT and the detector of SNA. A rejection of better than 20 dB and an insertion loss of 0.35 dB are achieved. The fractional bandwidth for the return loss is estimated to be 40 percent over the operating bandwidth. This transition has been successfully used in W-Band doubler and W-Band RW-to-CPW BTB transition. ■

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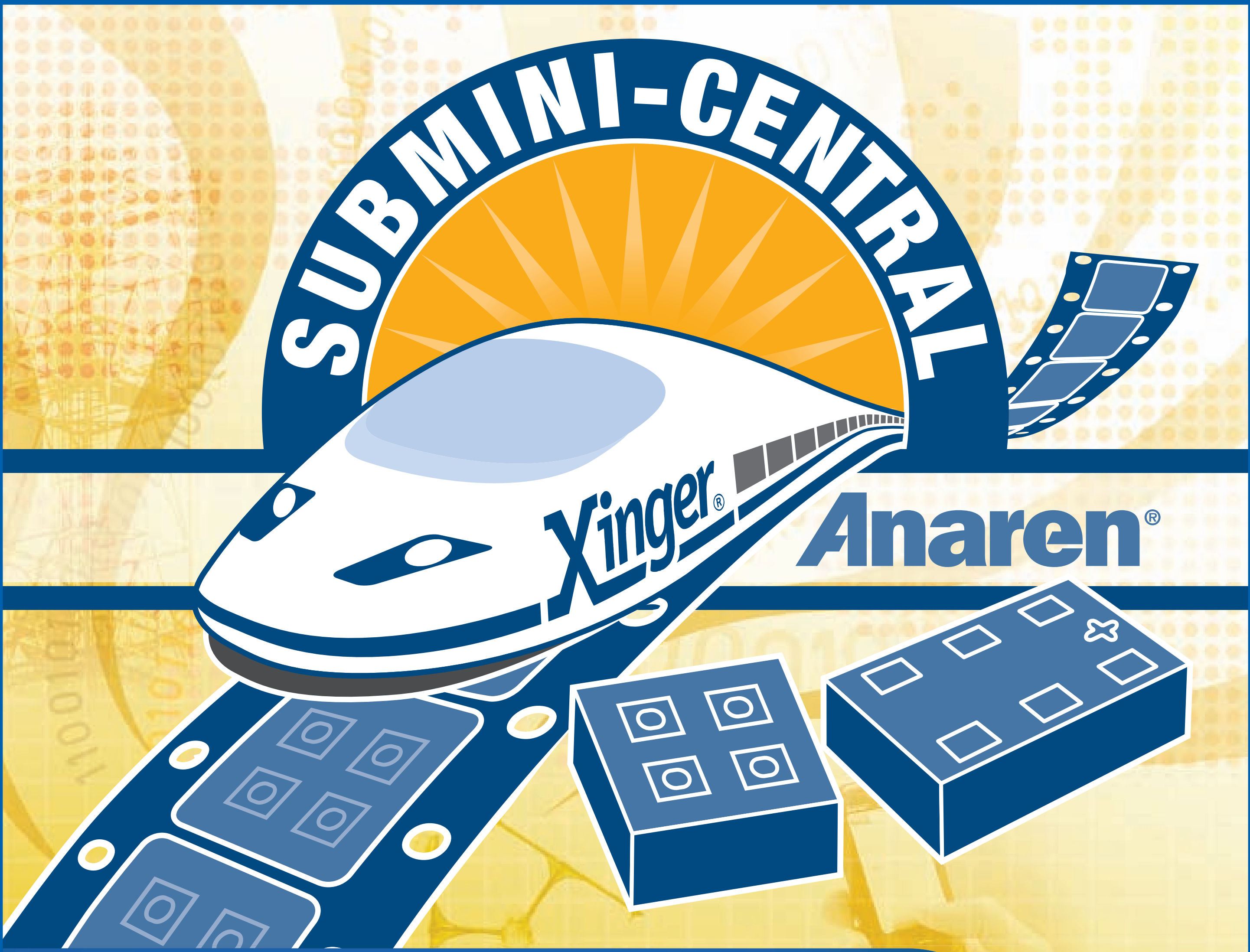

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When looking for power sensors that can be used for applications in the millimeter-wave range, the selection is very small. This is especially true for the frequency range from 67 to 75 GHz and for W-Band (75 to 110 GHz). Also, those sensors that are available cannot be used to detect signals below the cut-off frequency for the type of waveguide used by the sensors, for example. This makes it difficult to perform power measurements on wideband sources such as photodetectors and photoreceivers for the 100 G Ethernet.

Similar problems exist for level calibration of network analyzers having 1 mm test ports. Previously, the only possibility was to measure individual frequency ranges sequentially using the appropriate power sensor for that range. In addition, an adapter was needed between a waveguide power sensor and the coaxial connector at the source. Aside from the effort involved and the fact that automation was not possible, this method is also associated with greater wear and tear on the sensitive 1 mm connector. This is caused not only by the repeated connections that are required, but also by the mechanical stress resulting from the greater weight and larger dimensions of conventional waveguide power sensors.

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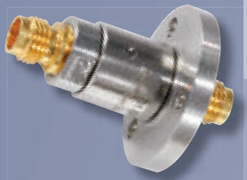

Single channel specifications	
Interfaces	2.4 mm-f (50 Ω)
Frequency range	DC - 50 GHz
Average power, max.	50 W @ 1 GHz
VSWR, max.	1.3 @ DC - 10 GHz
VSWR WOW, max.	0.05 @ DC - 26.5 GHz
Insertion loss, max.	0.3 dB @ DC - 10 GHz
Insertion loss WOW, max.	0.05 @ DC - 26.5 GHz

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Dual channel specifications		
Channel designation	Channel 1	Channel 2
Interfaces	2.92 mm-f (50 Ω)	2.92 mm-f (50 Ω)
Frequency range	19.7 - 21.2 GHz	29.5 - 31 GHz
Average power, max.	1 W	10 W
VSWR, max.	1.5	1.5
VSWR WOW, max.	0.1	0.1
Insertion loss, max.	0.8 dB	0.8 dB
Insertion loss WOW, max.	0.1 dB	0.1 dB

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0.3 µW (–35 dBm) to 100 mW (+20 dBm), thus covering the entire range to be measured. The new power sensor is light and easy to use, it can be operated directly from a PC via a USB interface and it offers additional features, including high measurement speed, excellent linearity, full traceability to renowned national metrology institutes and a means of internal verification option.

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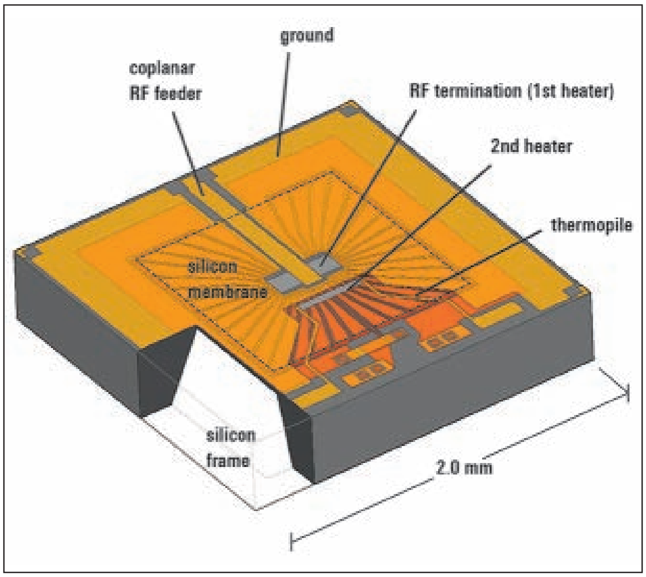
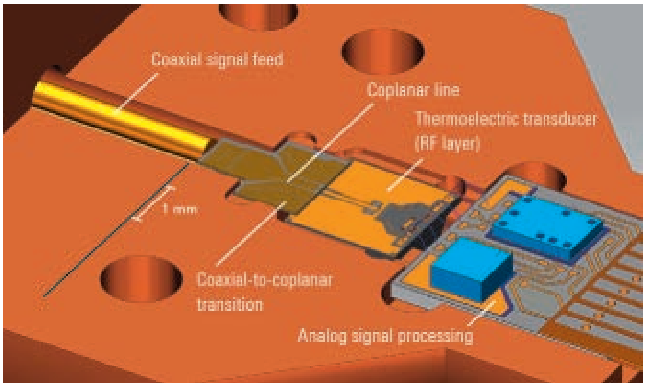


▲ *Fig. 1 Structure of the thermoelectric transducer.*



▲ *Fig. 2 RF front-end with coaxial-to-coplanar transition.*

FAMILY RESEMBLANCE

The R&S NRP-Z58 110 GHz power sensor is part of the R&S NRP family of products and it incorporates the main features of the family. At the core of the new power sensor is the indirectly heated thermoelectric transducer – a Rohde & Schwarz development that combines very good impedance matching values with a high dynamic range and a response time of only a few milliseconds (see ***Figure 1***).

The connection to the RF front-end is via a patent-pending wideband transition that converts the radially symmetric field of the incident wave to the field distribution of the coplanar transducer input, while at the same time providing excellent thermal isolation, as shown in ***Figure 2***. These and other thermal design measures ensure that the zero drift remains negligible, even with ambient temperature changes or when screwing on the sensor.

Virtually no drift is expected under constant ambient conditions, because the architecture of the signal processing chain ensures that the 1/f measurement noise is suppressed. This is why the zeroing performed at the factory is sufficient in many cases. In addition, the R&S NRP-Z58 does without the internal zeroing function; as it would cause long, asynchronous interruptions in the measurement without providing any advantages.

DC REFERENCE CIRCUIT

To verify the thermoelectric transducer and the connected analog signal processing chain, the R&S NRP-Z58 power sensor has a DC reference circuit, shown in ***Figure 3***, that makes calibration to an external 50 MHz reference source unnecessary. During calibration, the power sensor can remain connected to the DUT for as

Fairview Microwave Inc.

ADAPTERS

SM5250 $58.16 SMA SWEPT 27 GHZ	SM4979 $38.77 SMA 27 GHZ	SM4923 $97.25 SMA FLANGE 27 GHZ	SM3224 $226.17 2.92 BULKHEAD 40 GHZ	SM3221 $148.48 3.5-3.5 34 GHZ	SM3935 $440.50 1.85-1.85 65 GHZ	SM8867 $195.00 SMP-2.4 40 GHZ	SM2927 $138.94 GMS-SMA 23 GHZ
SM3358 $226.17 7mm-3.5 18 GHZ	SM3397 $51.76 7/16 90° 6 GHZ	SM4531 $172.00 N 90° 18 GHZ	SM3547 $38.77 TNC-BNC 8 GHZ	SM5514 $145.40 ZMA-SMA 18 GHZ	SMW75ACN $297.95 WR75-N 10-15 GHZ	28AC206 $363.60 WR28-2.92 26-40 GHZ	SM4835 $172.53 SSMA-2.92 40 GHZ

ATTENUATORS

SA18N5WA $60.17 N 5W 18 GHZ	SA18N25WA $232.24 N 25 W 18 GHZ	SA18N507 $343.09 N 50 W 18 GHZ	SA3015 $13.55 SMA 2 W 3 GHZ	SA18S50W $337.81 SMA 50 W 18 GHZ	SA3N511 $162.41 N 50 W 3 GHZ	SA4020 $738.96 2.92 10 W 40 GHZ	SA5074 $274.47 2.4 1 W 50 GHZ

COUPLERS, POWER DIVIDERS

MC0626 $1,045.15 2.92 COUPLER 6-26 GHZ	MC0618 $341.38 SMA COUPLER 6-18 GHZ	MC4061 $757.50 N-SMA COUPLER 1-12 GHZ	SMC4037 $52.52 N COUPLER 700-2700 MHZ	MP0218-4 $600.95 SMA 4-WAY 2-18 GHZ	MP1540-2 $1,045.15 2.92 2-WAY 15-40 GHZ	MP8769 $472.68 N 2-WAY 2-8 GHZ	MP8758-4 $82.98 N 4-WAY 800-2500 MHZ

TERMINATIONS

ST27N301 $434.98 N 700-700 MHZ LOW PIM	ST3N501 $129.56 N 50 W 3 GHZ	ST3D-50 $206.96 7/16 50 W 3 GHZ	ST1831 $19.57 SMA PUSH ON 1 W 18 GHZ	ST2671 $51.11 SMA 2 W 27 GHZ	ST6T-5W $53.29 TNC 5 W 6 GHZ	ST4021 $521.98 2.92 5 W 40 GHZ	ST5038 $299.05 2.4 1 W 50 GHZ

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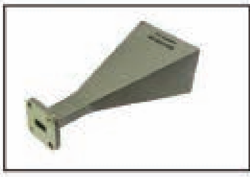

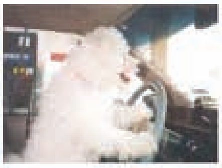

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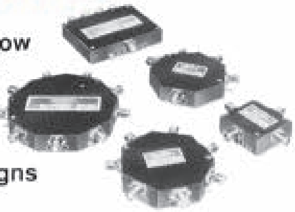

SPST thru SP8T and Transfer type models are offered and all switches are low loss with isolation up to 100dB. Reflective and non-reflective models are available along with TTL compatible logic inputs. Switching speeds are 1µsec.—30nsec. and SMA connectors are standard. Custom designs including special logic inputs, voltages, connectors and package styles are available. All switches meet MIL-E-5400

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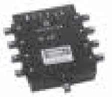

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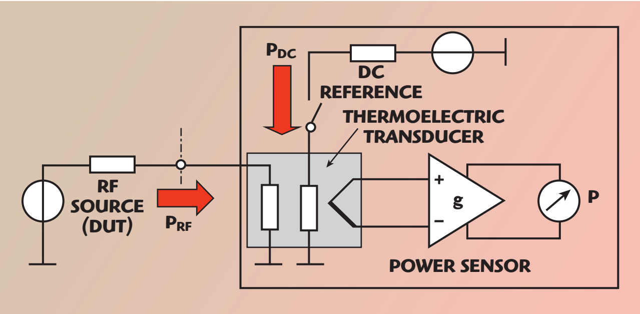
Product Feature

long as the DUT supplies a sufficiently stable signal. With a reproducibility in the range of 10^{-4}, verification via the integrated DC reference circuit far exceeds an external calibration with an RF signal.



▲ *Fig. 3 Circuitry for internal verification with DC.*

The more than 226 frequencies calibrated at the factory are fully traceable to the Physikalisch-Technische Bundesanstalt (PTB) national metrology institutes in Germany and the National Institute of Standards and Technology (NIST) in the United States.

In addition, Rohde & Schwarz makes use of a recently introduced microcalorimeter from the PTB that covers the entire W-Band. In this range, the calibration uncertainties of the new power sensor are 6 to 7 percent (calculated using GUM with a coverage factor of two).

LINEARITY

A high priority during development of the power sensor was to ensure a high degree of linearity for the power display, because this attribute is important for relative measurements. These include scalar attenuation, amplification and reflection measurements, as well as indirect power measurements using directional couplers, etc.

The absolute reference for indirect power measurements is normally obtained by means of a system calibration at a single level. With a linear uncertainty of maximally 0.23 percent (0.01 dB), the R&S NRP-Z58 is comparable to conventional, thermistor-based power sensors that use DC substitution to ensure high linearity. In the R&S NRP-Z58, the DC substitution was omitted in favor of measurement speed. Instead, a numeric linearity correction is used. This linearity correction is based on a calibration of the thermoelectric transducer with DC voltages performed at the factory, and it can remain unchanged for the life of the sensor.

Although the attainable measurement speed is comparable to that of state-of-the-art thermoelectric power sensors, it can vary significantly depending on the application. If the only goal is to record as many readings as possible within a given time span, the buffered mode can be used to record more than 300 readings per second. The aperture for a measurement point can be set very precisely to the millisecond, and the measurement can be either triggered or run continuously. Even if every reading is output separately instead of being buffered, about 250 triggered test results per second are still possible.

AVERAGING FACTORS

Of course, the rate of measurement will be slower when measuring low power values when it becomes necessary to average multiple test results in order to obtain a stable reading. However, the R&S NRP-Z58 can use averaging factors that are lower than those required by other W-Band products because its inherent noise is significantly lower. As a result, the settling times are more than ten times shorter than previously obtained, which means that even levels in the range of –10 dBm can be measured virtually without delay, while maintaining a satisfactory degree of stability.

The 1 mm connector on the R&S NRP-Z58 is essential for the impedance matching, reproducibility and stability of the new product. The coupling nut on the connector is fitted with ball bearings, which make it possible to hand-tighten the power sensor so precisely that there is no need for a torque wrench. The reduced friction also prevents the outer conductor from rotating when the coupling nut is tightened, thereby reducing wear and tear on the connector.

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MLPNC-7102-SMT680	21 @ 400 MHz	23 @ 600 MHz	> -8 @ 4 GHz	> -16 @ 12 GHz	> -20 @ 20 GHz
MLPNC-7103-SMA800	21 @ 800 MHz	23 @ 1300 MHz	> -5 @ 6 GHz	> -15 @ 18 GHz	> -20 @ 30 GHz
MLPNC-7103-SMT680	21 @ 800 MHz	23 @ 1300 MHz	> -5 @ 6 GHz	> -15 @ 18 GHz	> -20 @ 30 GHz

* Contact the factory for additional information or for products not covered in the table.

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CST STUDIO SUITE 2013: Performance, Usability and Versatility

Feature range and user experience are sometimes seen as mutually exclusive. The ever-increasing complexity of design tasks means that engineers need a broad range of powerful simulation tools and features at their disposal, but only a few of these will be helpful in any one situation. Knowing which feature to use and when to use it can be a skill in its own right. CST STUDIO SUITE® 2013 streamlines the simulation process without compromising on its power or flexibility.

The redesigned user-interface guides the engineer through simulation projects, while behind the scenes, the solver technology has been further optimized to speed up the modeling of large and complex systems. The 2013 version also adds an array of new features to extend the capabilities of its solvers, broadening the range of tasks that CST STUDIO SUITE can be applied to.

RIBBON-BASED USER INTERFACE

The most noticeable change in version 2013 is the new Ribbon GUI. The Ribbon is an easy-to-use tab system that groups features and menus together according to their place in the simulation process, so that only the most relevant options are shown for each stage of the workflow.

More than just a way to display icons, the Ribbon can guide the engineer at each step of the way. The Ribbon offers benefits to both new and experienced users, flattening the learning curve and providing easier access to tools and options.

PROJECT WIZARD

Engineers often end up running similar types of simulation over and over again. The project wizard makes the process of setting up a simulation quicker; the engineer can select from an extensive palette of preconfigured simulation types covering a wide range of applications. Not only does the project wizard instantly set the units and boundary conditions to those appropriate for the job, it also suggests the best solvers for the situation.

The configuration can be easily adjusted by the user based on the experience gathered from past designs or from onsite testing, and this modified configuration can be stored within the project wizard and reused easily. Using custom configurations can speed up the process of modeling and simulating many similar devices.

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PERFORMANCE IMPROVEMENTS

Through the company's close co-operation with Intel®, CST's solver technology has also been optimized to take advantage of the power offered by the latest generation of processors. The mesh set-up process runs more efficiently, with the accurate curved tetrahedral mesh now the default for the frequency domain solver, and both the transient solver and the frequency domain solver will run significantly faster on the latest Intel infrastructure.

As well as being faster, the transient solver is now more versatile too. Models with more than 2 billion mesh cells can now be simulated, meaning that the transient solver is now suitable for simulating very complex models, greatly increasing its flexibility.

HIGH-PERFORMANCE COMPUTING

CST integrates more high-performance computing (HPC) simulation techniques into its products every year, and this trend continues with CST STUDIO SUITE 2013. The use of GPU acceleration offers significant speed advantages for simulations on compatible hardware.

While previous versions offered GPU acceleration for the transient solver, particle-in-cell (PIC) solver and integral equation solver, the 2013 version adds to that the transmission-line matrix (TLM) solver. The new version also extends the range of compatible GPUs to include the Nvidia Kepler architecture, which is substantially faster than earlier GPU types.

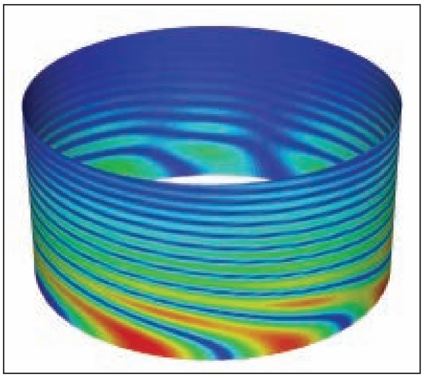
As well as enhancing GPU support, version 2013 also improves the Message Passing Interface (MPI) and distributed computing capabilities of CST STUDIO SUITE, widening the possibilities for using the software on computer clusters and networked systems to solve very large or very complex systems.

FARFIELD CYLINDER SCANS

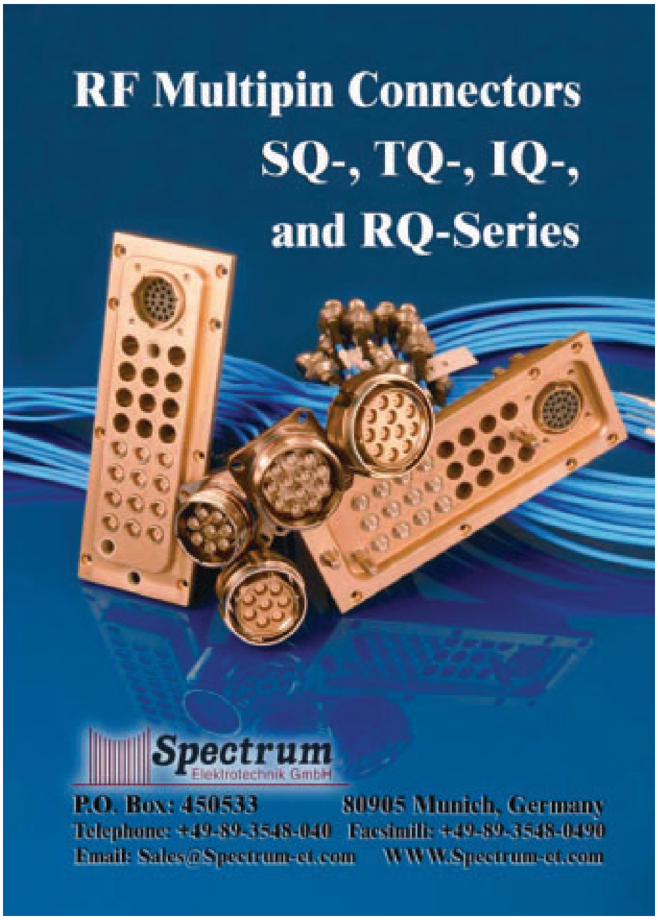
The cylinder scan is a standard laboratory measurement used to investigate the electromagnetic compatibility (EMC) characteristics of devices. Cylinder scans give the fields around the device at a fixed distance around it; because of EMC regulations, such scans are often mandatory before a product is approved for sale. With version 2013, CST STUDIO SUITE can now simulate cylinder scans automatically in any solver that supports far fields (see ***Figure 1***). This means the EMC compliance of a design can be calculated before the first prototype is built, potentially reducing the number of prototyping stages needed.

LOSSY AND NONLINEAR MATERIALS

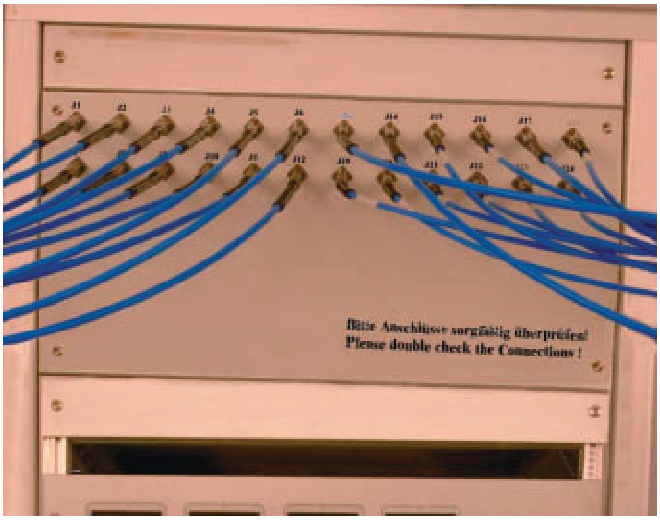
Nonlinear materials are a critical part of many devices. To that end, ver-



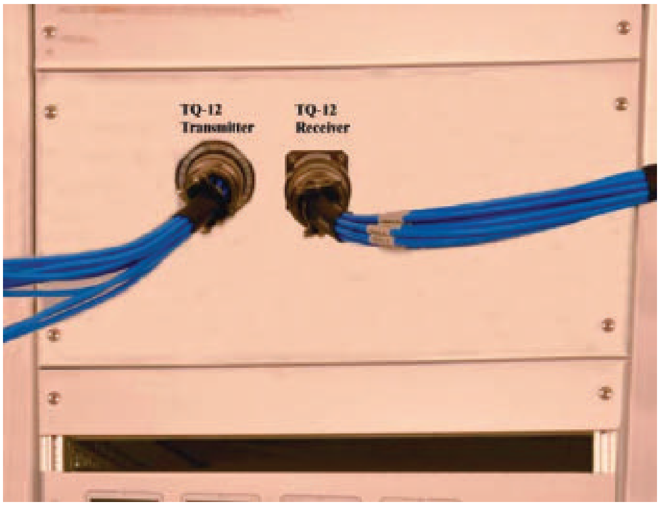
▲ *Fig. 1 Cylinder scan of an electronic device with housing.*



Catalogue RF Multipin Connectors 52 pages showing in detail 4 coaxial Multipin Connector Series, demonstrating how to connect and disconnect up to 23 coaxial lines in seconds and saving space.



The Problem: In various applications many coaxial microwave links have to be connected and disconnected. This means threadening and unthreadening, torquing and untorquing. Very dense packaging is not possible, as there is still room needed for manual threadening and for the use of a torque wrench. In helicopters and aircrafts all connectors usually have to be safely secured, wiring the coupling nuts of the connectors, using wire holes, a time-consuming process.



The Solution: Spectrum's Multipin Connectors are available with four (4), seven (7), eight (8), twelve (12) and twenty three (23) coaxial inserts (terminating the coaxial cable assemblies) at the Multipin end, and connecting all the coaxial cable assemblies at once and in seconds with no need of a torque wrench, no need for safety wires and using minimum space.

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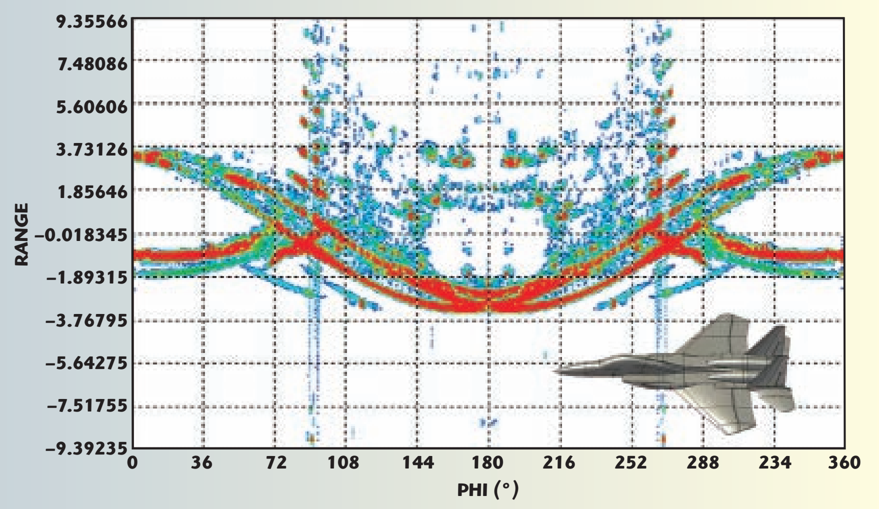
sion 2013 includes several innovations to improve the simulation of these complex materials. The transient solver now supports nonlinear frequency-dependent materials, such as Raman and Kerr materials, while the fast eigenmode solver can now handle lossy dielectric materials. The performance of these simulations has also improved, with transient simulations of higher-order lossy and dispersive materials now quicker and more memory-efficient.



▲ *Fig. 2 Sinogram of a fighter plane.*

RANGE PROFILES FOR RCS

CST STUDIO SUITE has long supported radar cross-section (RCS) calculations with the ray-tracing asymptotic solver. Version 2013 increases the utility of this tool further, adding the ability to calculate range profiles and sinograms. A range profile is a dataset showing reflected energy as a function of object depth for a given direction, and a sinogram, as shown in ***Figure 2***, is a 2D image showing the range profiles over a number of incident directions. These help the designer identify which parts of the object produce the most backscatter, and allow users to build up a database of characteristic range profiles to identify objects based on their RCS.

CST STUDIO SUITE 2013 contains innovations at every level of the software, combining a new user-friendly, workflow-oriented user interface with a more powerful back-end and an assortment of new features to extend its capabilities. Together, these advances result in a simulation tool that ties together performance, usability and versatility.

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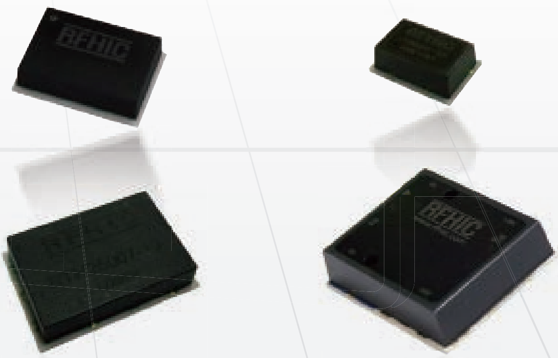

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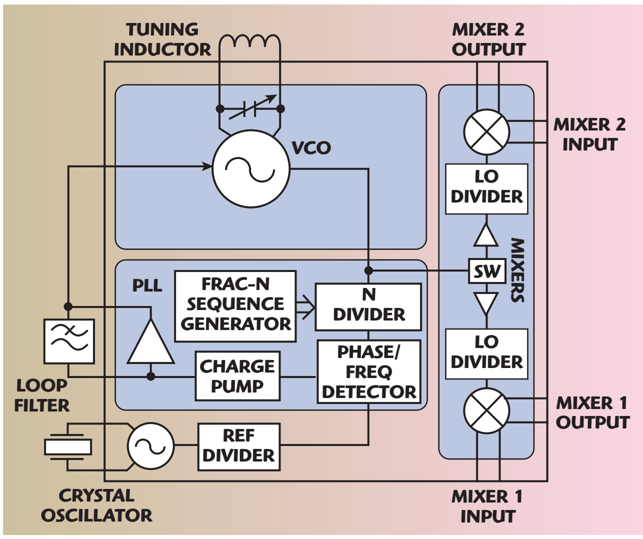
Frequency conversion is at the heart of many modern communication systems. At its most basic level, a frequency converter requires a low noise local oscillator (LO) with a phase locked loop and an up/down-conversion mixer. Excellent phase noise, low spurious levels and a mixer with high IIP3 are key requirements for high performance converters that can frequency translate highly complex input signals carrying multiple channels and modulations. Designing a frequency converter for battery powered applications adds the extra challenge of low voltage operation and low current consumption in order to maximize battery life.



▲ *Fig. 1 Block diagram of RF2054.*

The RF2054 IC addresses these market requirements. It can be used as a 2.2 V frequency converter which is ideal for use in battery-powered wireless, consumer and professional devices. The RF2054 belongs to a family of wideband integrated frequency converters available from RFMD that support RF/IF frequencies from 30 to 2500 MHz.

Figure 1 shows that the RF2054 IC contains two Gilbert cell mixers, a fractional-N synthesizer, a voltage controlled oscillator (VCO) and reference oscillator circuitry. This is all integrated in a 5 × 5 mm QFN package. The

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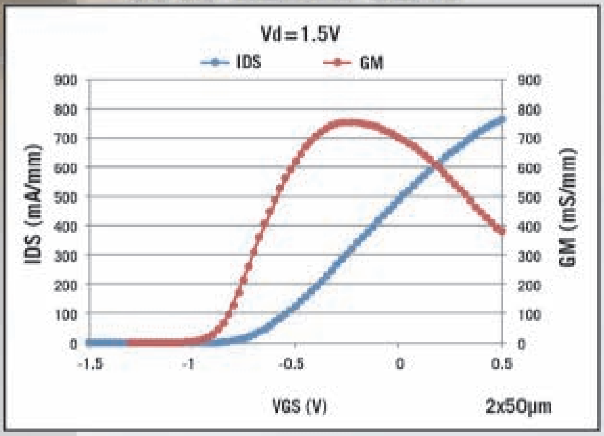
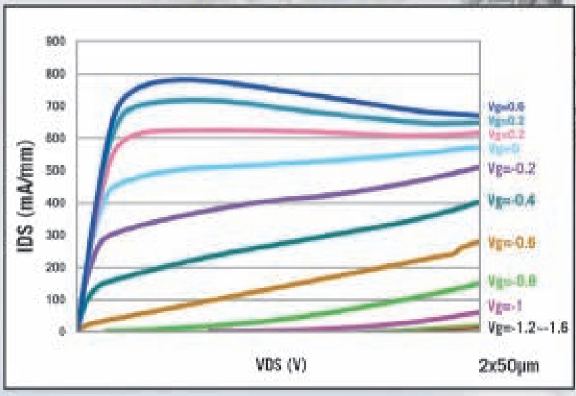
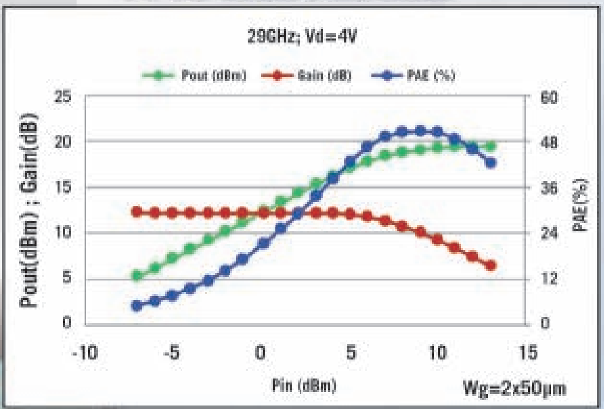


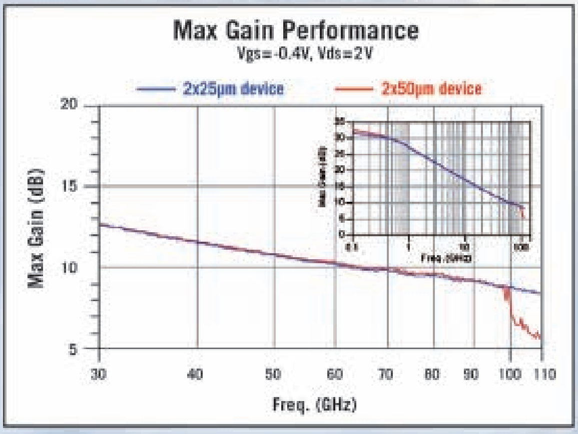
PP10 I-V Curves



PP10 Load Pull Data



PP10 Max Gain



VCO can be tuned to cover a specific frequency range by selecting the appropriate value of external inductors. Sharing the same LO frequency, one mixer can be used for up-conversion and the other mixer for down-conversion making the RF2054 a very compact, single-chip frequency converter or band-shifter. Alternatively, the two mixers could both be used for down-conversion in order to implement a highly integrated diversity receiver.

The fractional-N synthesizer in the RF2054 takes advantage of an advanced third order sigma-delta modulator that delivers ultra-fine step sizes and low spurious products. The integer boundary spurs are typically below –55 dBc. The fractional-N synthesizer also has the advantage of fast lock times; the synthesizer can be configured to lock within 40 µs of enabling the device. Another feature of the synthesizer is the on-chip crystal sustaining circuit with programmable loading capacitors. This allows a crystal of between 10 and 26 MHz to be used for the reference, and by programming the correct load capacitance, the frequency error can be minimized. Using a standard low cost crystal in this way minimizes the total solution cost, and saves on the added current consumption of an external crystal oscillator circuit, typically 2 mA. Alternatively, an external reference of between 10 and 104 MHz can be used.

TABLE I
SUMMARY OF TYPICAL RESULTS FOR RF2054 AT +2.2 V (MIX_IDD = 1)

Total supply current, one mixer enabled	47 mA
Total supply current, two mixers enabled	58 mA
Mixer conversion gain (including balun loss)	–5 dB
Mixer input IP3	+11 dBm
Mixer input power for 1 dB compression	+1 dBm
Mixer noise figure	9 dB
LO leakage at mixer output	<–45 dBm
Synthesizer RMS integrated PN (1K to 40M)	<0.5°

The VCO is a differential structure and the tuning range is defined by the value of two external inductors in parallel with a bank of switched capacitors integrated into the VCO resonator, which give 128 overlapping bands. These are used to achieve a tuning range of up to 40 percent whilst maintaining low VCO tuning gain (MHz/V) and optimal phase noise performance across the entire VCO frequency range. The chip automatically selects the correct VCO band (VCO coarse tuning) for the programmed frequency when the device is enabled. The LO frequency range is extended further using high frequency dividers between the VCO output and mixer LO ports. These LO dividers can be bypassed or set to divide by 2 or 4.

The normal power supply range specified for the RF205x family of frequency converters is +2.7 to +3.6 V. The RF2054 is a variant suitable for operation at +2.2 V. Dropping the supply voltage extends the battery life and reduces the current draw in the chip with only marginal degradation in performance. Using an external inductor, the VCO can be tuned to run at the LO frequency of choice without using the LO dividers, further minimizing the current consumption. The mixer bias can also be set to give low current operation at the expense of linearity.

To evaluate the RF2054 at +2.2 V, measurements were made with a frequency plan selected to demonstrate the performance at typical RF, IF and LO frequencies. An RF input of 900 MHz was chosen, down converting to an IF output of 70 MHz. Most of the measurements made concentrated on the requirement for low power, so used the lowest mixer bias current setting, MIX_IDD = 1. A standard RF2056 evaluation board was used with some minor modifications as noted. The device was programmed using the "RFMD Slice Programming Tool" graphical user interface (GUI). The RF2056 design kit (evaluation board plus interface cables) and the GUI are available at www.rfmd.com/products/IntSynthMixer.

The evaluation board uses an FTDI UM232R USB-to-serial adapter to enable the RF2054 to be programmed from a PC running the GUI. The UM232R adapter is normally set for 3V3 logic. The limit on the RF2054

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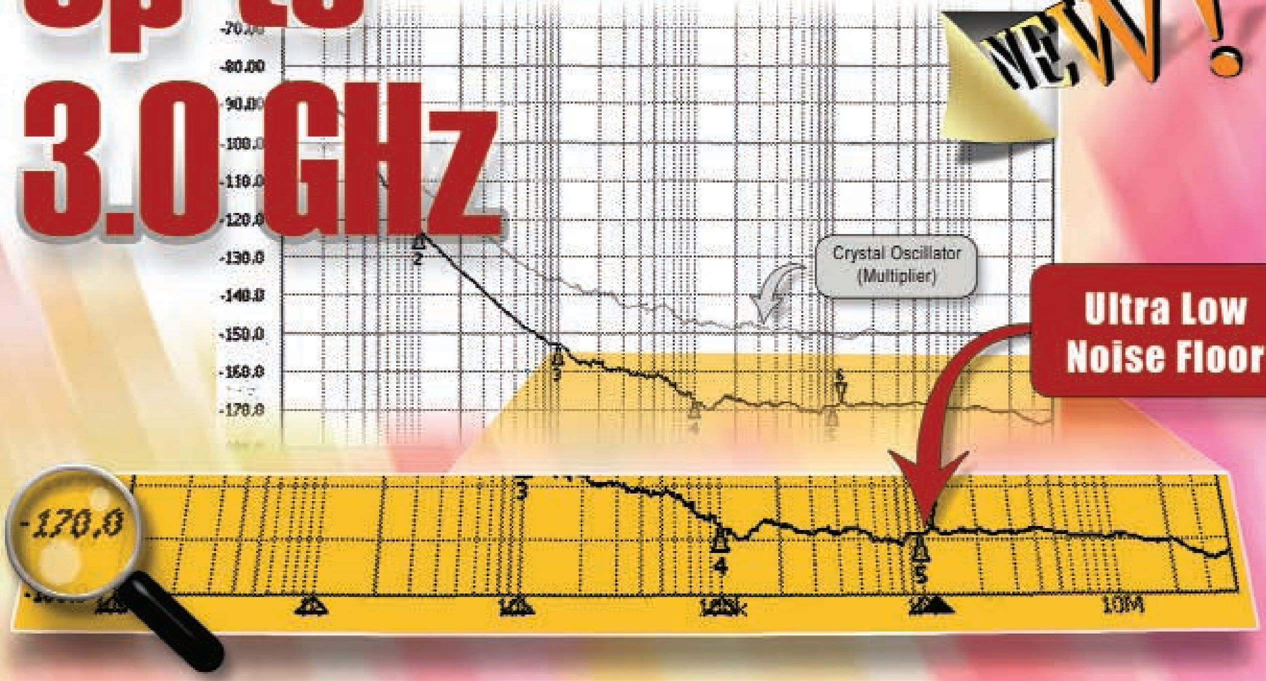

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for the logic high input voltage is Vdd +0.3 V. So for supply voltages below +3 V, the logic high level needs to be reduced. This is easily done by connecting the VIO pin on the UM232R adapter to the evaluation board power supply.

To achieve a high side LO frequency of 970 MHz, two 3.3 nH inductors were used in the differential VCO resonator circuit. These set the VCO frequency range between 850 and 1200 MHz, with the required frequency of 970 MHz coming out near center in the VCO coarse tuning range.

The results of this evaluation, summarized in ***Table 1***, show that the RF2054 can be operated satisfactorily with power supply voltages down to +2.2 V. Lowering the supply voltage from +3 down to +2.2 V reduces current consumption by around 4 mA as shown in ***Figure 2***. This results in a significant drop in power consumption that has little impact on performance. ***Figure 3*** shows that the mixer gain and linearity fall slightly, the input IP3 is reduced by 1 to 2 dB. The synthesizer and VCO phase noise are unaffected. It is not recommended to operate the RF2054 at below +2.1 V.

Operating the RF2054 with the synthesizer and one mixer enabled, at +2.2 V consumes a total power of typically just 105 mW, and with both mixers enabled 130 mW. This represents a 30 percent reduction in power consumption compared to the nominal +3 V supply, making the RF2054 ideal for low power applications.

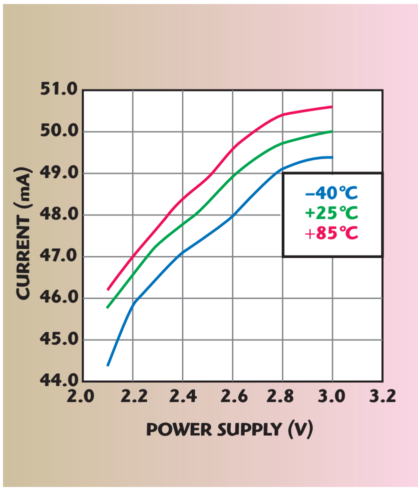

Fig. 2 Total supply current, single mixer enabled vs. temperature and supply voltage.

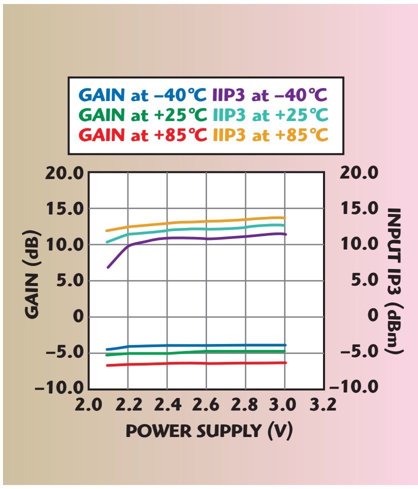

Fig. 3 Mixer conversion gain and IIP3 vs. temperature and supply voltage.

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Model DL82030 is rated for input power levels to 2 W, and delivers output signals with maximum insertion loss of 4.5 dB. It is supplied in a rugged aluminum housing measuring 3.75" × 2.0" × 0.50" with SMA connectors. The finish is a chemical conversion coating per MIL-DTL-5541 Class 3 with optional paint available upon request. The power divider is designed for operating temperatures from -40° to +70°C.

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Portable PIM Tester

From an industry leader in passive intermodulation (PIM) test equipment, Kaelus offers a new portable and rugged PIM analyzer. Designed with tower climbers in mind, the battery powered iPA Series PIM test analyzer is an IEC-compliant high power instrument that is highly portable, rugged and reliable. Specially constructed to support PIM testing at remote radio head (RRH) installations as well as being convenient for any test locations, this small device weighs less than 12 kg (26 lbs) and is equipped with lifting lugs at four points for multi-orientation angles and comfortable tower use.

The iPA can be operated locally through the intuitive touch screen interface, or remotely by any Wi-Fi enabled device, including the iPad Mini, which comes standard with every iPA, ensuring an easy and efficient portable field testing experience.

Additional features of the iPA PIM test analyzer include:

- Multiple measurement modes
  - PIM vs. frequency
  - PIM vs. time
  - Spectrum monitoring
  - Range-to-Fault (available mid-year 2013)
  - Unique overlay of PIM and return loss on a single chart (RTF mode only)
- Powerful reporting capabilities ideally suited for fault finding, and site close-out package
- An optional interchangeable battery case with charging dock allowing two batteries to charge with a third for continuous field operation (one battery comes standard with the iPA)
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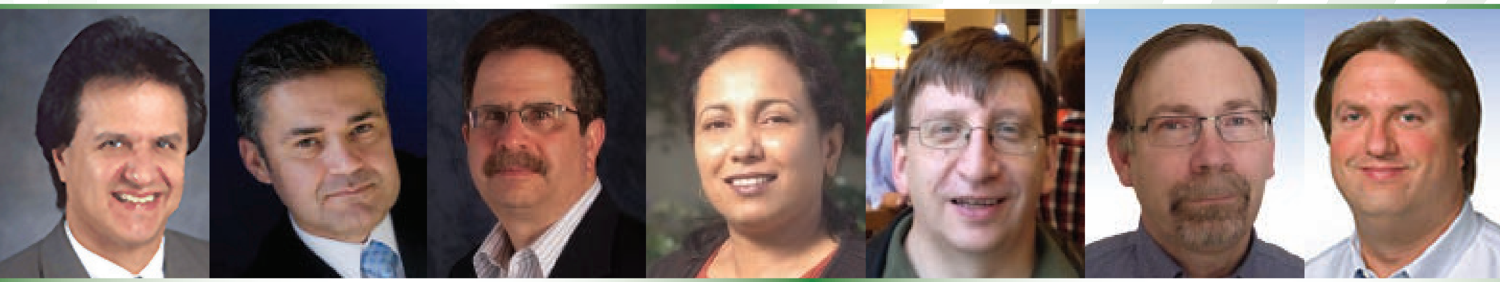

Professor Yahya Rahmat-Samii | Dr. Julio Navarro | Mr. Bill Saltzstein | Dr. Debabani Choudhury | Mr. Harry Skinner | Mr. Scott Prather | Dr. Michael Foegelle

NEW AT IMS2013: WIRELESS INDUSTRY DAY!

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WEDNESDAY, 5 JUNE 2013

Wireless Industry Day will be a full day seminar co-located with IMS2013 showcasing emerging wireless technologies in the Pacific Northwest. From components to systems, the seminar will provide practical, application-oriented information to Symposium attendees as well as to the growing wireless community in the Pacific Northwest. Wireless Industry Day at IMS2013 provides a unique opportunity for the regional community and Symposium attendees to network, share their expertise, and learn about this rapidly growing market.

WIRELESS INDUSTRY DAY SPEAKERS AND TOPICS:

From Maxwell's Equations to Modern Electromagnetics and Antenna Engineering Marvels
By Professor Yahya Rahmat-Samii, IEEE Fellow, *University of California, Los Angeles, CA*

Key Technology Trends in Wireless for the Aerospace Industry
By Dr. Julio Navarro, Senior Technical Fellow, *The Boeing Company, Seattle, WA*

Bluetooth: The Future of Wireless Medical Technology
By Mr. Bill Saltzstein, President, *connectBlue, Inc. Redmond, WA*

Prospects and Challenges of GHz to THz Technologies/Architectures for Future Wireless Communications
By Dr. Debabani Choudhury, Senior Technologist, IEEE Fellow, *Intel Labs, Hillsboro, OR*
and **Mr. Harry Skinner, Senior Principal Engineer,** *Intel Labs, Hillsboro, OR*

Radiated Performance Assessment of Wireless Communications Devices - An Operator's Perspective
By Mr. Scott Prather, Lead Product Development Engineer, *AT&T, Redmond, WA*

Evaluating Over-The-Air Performance of MIMO Wireless Devices
By Dr. Michael Foegelle, Director of Technology Development, *ETS-Lindgren, Cedar Park, TX*

COMPLETE SPEAKER BIOGRAPHIES ARE AVAILABLE AT:
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ATE Website

Advanced Test Equipment Rentals, a company dedicated to supplying complete testing solutions for EMC, electrical, power quality, environmental and similar testing applications for the defense, aerospace, medical and telecom industries, launched its new and improved website, which features improved search capability, user registration for quick checkout, category and manufacturer viewing and sorting options and an overall enhanced look and feel. In addition to improving the browsing experience, the site now offers equipment datasheets, user manuals, information on industry standards and how-to videos.

Advanced Test Equipment Rentals
www.atecorp.com

Find it Fast Guide

VENDORVIEW

AR's new Find It Fast guide lets you quickly find the appropriate RF or microwave power amplifier to meet your most demanding applications. AR features a wide range of both solid state and TWTA wideband designs to satisfy EMC and other markets. The RF guide can be found at www.arww-rfmicro.com/html/find-it-fast-rfamplifiers.asp. The microwave guide can be found at www.arww-rfmicro.com/html/find-it-fast-microwave.asp.

AR RF/Microwave Instrumentation
www.arworld.us

Product Site

VENDORVIEW

AWR Corp. debuted a new website that expands product as well as application specific RF/microwave design content. The new site includes intuitive navigation menus organized both by application and by product line, so finding the right solution is fast and easy. Customers can turn to the AWR website as a reliable resource for technical content including application notes, whitepapers, datasheets and tutorial videos. Check it out at www.awrcorp.com.

AWR Corp.
www.awrcorp.com

CST Website 2013

VENDORVIEW

With simplified navigation and an updated design interface, the re-aligned website gives visitors easy access to information on CST's 3D EM simulation software. Software applications can be explored through the regularly updated articles, whitepapers and videos, helping visitors learn more about how the electromagnetic design and analysis experience can be optimized using CST products. Visitors can also read detailed product pages, stay informed of company news and events, request evaluations and find local representatives.

CST
www.cst.com

Custom MMIC Website

VENDORVIEW

Custom MMIC has launched a new website that includes information related to its growing product library of commercially available amplifiers, mixers, control devices, multipliers and multi-function MMICs. The site also includes a number of free analytical tools including a thermal profile calculator for printed circuit boards, an attenuator calculator for digital attenuators, an image rejection calculator for mixers and a cascade analysis calculator for microwave systems. The calculators are available here: http://custommmic.com/calculators/.

Custom MMIC
www.custommmic.com

Cable Assembly Configurator

East Coast Microwave Distributors is proud to announce the launch of a new web-based "Cable Assembly Configurator" tool. The Cable Assembly Configurator is designed to assist engineers and buyers in defining and creating RFQs for coaxial cable assemblies. The tool facilitates the rapid quotation and delivery of coaxial cable assemblies produced at the company's in-house assembly operation. The new Cable Assembly Configurator can be found by clicking the cable assembly tab of ECM's website.

East Coast Microwave Distributors
www.ecmstockroom.com

Products and Capabilities Site

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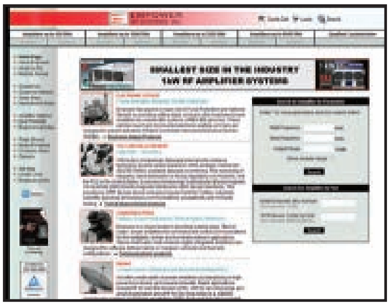


www.EmpowerRF.com provides a comprehensive look at the products and capabilities of Empower RF Systems. Homepage content is organized by target market segments and additional search capabilities enable the user to find recommended power amplifier products for specific frequency coverage (up to 6 GHz) and output power levels (10s of watts, 100s of watts and multi-kW). Convenient tabs and additional features also direct the user to company news, media placements, upcoming tradeshows, sales team contacts and new product introductions.

Empower RF Systems
www.empowerrf.com

IMC Website

Integrated Microwave's new website at www.imcsd.com offers a range of RF and microwave filter solutions for defense, commercial, industrial, GPS, space and wireless applications. Users can explore IMC's range of custom ceramic filters, resonators and diplexers, available in prototype to production quantities. The site's new and improved interactive features enable customers to receive the latest product information and submit specifications or documents in any format for quotation.

Integrated Microwave Corp.
www.imcsd.com

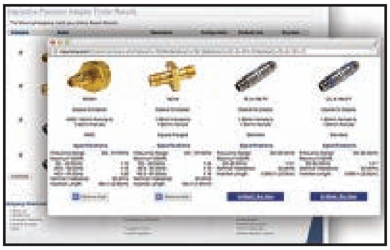
Expanded Products Website

VENDORVIEW

Linear Technology has expanded and updated its RF and wireless products website www.linear.com/RF. The site now includes more efficient parameter search capabilities and easier to find functions based on often-used parameters and related functions. Wireless designers will find the website more useful and easier to navigate when searching for the suitable high-performance RF components.

Linear Technology Corp.
www.linear.com

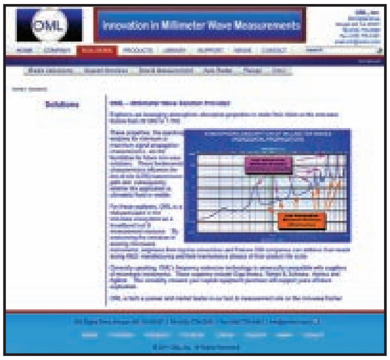
Find and Compare Tool



Maury Microwave has launched an updated Adapter Finder with advanced comparison capabilities. This new tool allows customers to search for specific configurations of waveguide and coaxial adapters among Maury's calibration-grade (metrology), ColorConnect™ and Test Essential™ products lines. Additionally, up to four adapters can be aligned side-by-side and their specifications compared and contrasted.

Maury Microwave
www.maurymw.com

Updated Solutions Site



OML launched a web update that overviews available mm-wave measurement solutions. The popular solutions described include: radio astronomy, gigabit wireless, test & measurement, automotive radar and waveguide flanges. This update communicates how OML's frequency extension technology couples with existing microwave instruments to satisfy emerging mm-wave measurement requirements. The microwave instrument classes include signal generators, spectrum analyzers and vector network analyzers. The supported manufacturers include Anritsu, Rohde & Schwarz and Agilent. OML is available for consultation on how to optimize mm-wave solutions.

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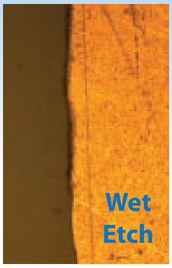

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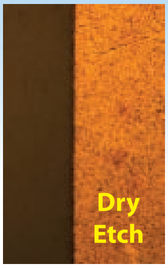

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Web Update

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Renaissance Electronics/HXI

www.rec-usa.com

RFMW Website Updates

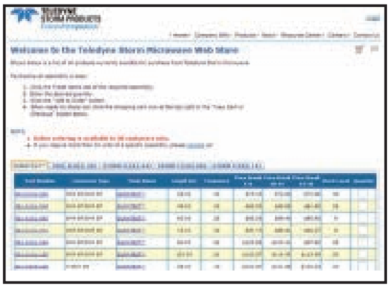
VENDORVIEW

RFMW Ltd.'s RF and microwave focused website now includes updated resources for military and commercial engineers designing for increased price/performance ratios. Datasheets, parametric searches, application notes, access to evaluation boards, technical support, pricing and delivery are all available. Plus, a news blog and tweets keep customers apprised of technology and component advances from the industry's leading manufacturers.

RFMW Ltd.

www.rfmw.com

Web Store



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March Short Course Webinars

Test Wireless Designs with a Low-Cost RF Vector Signal Generator
Presented by: Agilent Technologies
Live webcast: 3/19/13, 1:00 PM ET

Innovations in EDA
Presented by: Agilent Technologies
GaN on SiC: RFMD High Power Design, Modeling and Measurement
Available On Demand after 3/7/13

RF and Microwave Education
Presented by: Agilent Technologies
Signal Analyzer Fundamentals and New Applications
Live webcast: 3/13/13, 1:00 PM ET

Agilent in Aerospace/Defense
Understanding Probability of Intercept for Intermittent Signals
Live webcast: 3/21/13, 1:00 PM ET

FieldFox Handheld Analyzers
Presented by: Agilent Technologies
Techniques for Precise Power Measurements in the Field
Live webcast: 3/27/13, 1:00 PM ET

Agilent in Wireless Communications
LTE and the Evolution to LTE-Advanced Fundamentals: Part 1
Live webcast: 3/26/13, 1:00 PM ET

LTE and the Evolution to LTE-Advanced Fundamentals: Part 2
Live webcast: 3/28/13, 1:00 PM ET

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Jamming and Spoofing Mitigations for Military and Civil GPS/GNSS
Sponsored by: Rohde & Schwarz
Available On Demand after 3/6/13

Small Portable Test Equipment for ATE Applications
Sponsored by: Mini-Circuits
Live webcast: 3/19/13, 11:00 AM ET

AWR/Cree Webinar
Live webcast: 3/26/13, 11:00 AM ET

Past Webinars On Demand

RF/Microwave Training Series
Presented by: Besser Associates
- Passive Components: Couplers, Dividers and Combiners

Market Research Webinar Series
- Technology Trends for Radar Systems

Technical Education Training Series
- MIMO Radar: Demystified
- The Effects of Jamming on GPS/GNSS Signals
- VCO Fundamentals
- RF PCB Design

CST Webinar Series
- Simulation of EMI in Hybrid Cabling for Combining Power and Control Signaling
- Chip/Package/Board: Constraint Driven Co-Design

Innovations in EDA/Signal Generation & Analysis
Presented by: Agilent EEsof EDA/Agilent Technologies
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- Antenna Design Automation with Scripting and Parameterized EM Analysis
- Freescale's Power Amplifier Design Methodology Innovations

Agilent in Aerospace/Defense Series
- EW Testing: Capture, Measurement and Emulation
- RF/uW Measurement Uncertainty: Calculate, Characterize, Minimize

Agilent in LTE/Wireless Communications Series
- NFC Test Challenges for Mobile Device Developers
- Moving Forward to LTE-Advanced with Heterogeneous Networks

RF and Microwave Education Series
Presented by: Agilent Technologies
- Signal Generator Fundamentals and New Applications

FieldFox Handheld Analyzers Series
Presented by: Agilent Technologies
- Techniques for Precise Time Domain Measurements in the Field
- Calibration and Alignment Techniques for Precise Field Measurements
- Techniques for Precise Cable Antenna Measurements in the Field

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Test Solution

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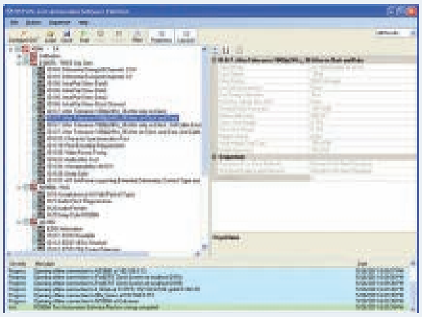
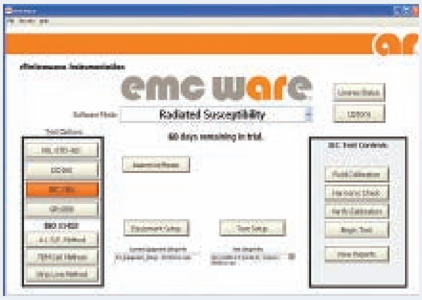


Agilent announced support for the HDMI and MHL sink tests through its M8190A arbitrary waveform generator and enhanced N5990A test-automation software. The solution gives engineers a new way to conduct sink testing and provides a cost-effective and compact alternative to Agilent's well-established E4887A HDMI TMDS signal generator platform. The new test solution reduces development costs while providing accurate test results with greater flexibility than other HDMI and MHL test solutions. Agilent's HDMI and MHL test solution is the only single-box generator solution available today.
Agilent Technologies Inc.,
www.agilent.com.

EMC Test Software

VENDORVIEW



AR's EMC test software combines radiated susceptibility, conducted immunity and emissions testing into one package allowing more control and a more intuitive interface. Built-in standards include IEC, MIL-STD, DO160, automotive standards and the ability to create your own test standards. Download your copy at www.arworld.us. The software has the ability to control more equipment and the report generating feature has been enhanced to offer more control and customization.
AR RF/Microwave Instrumentation,
www.arworld.us.

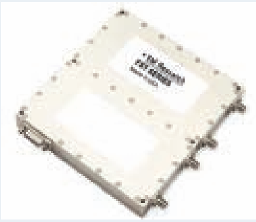
Feed Thru Termination

BroadWave Technologies unveiled its newest feed thru termination designed to match 50 Ω RF components with high impedance test equipment such as an oscilloscope. Model 854153FTT is a 50 Ω, 5 W, BNC male to BNC

female feed thru termination. The device operates DC to 1 GHz, exhibits 1.50:1 maximum VSWR and is available for immediate shipping via BroadWave's eStore. Standard impedances available are 50, 75, 93, 150, 300 and 600 Ω. Custom impedances are also available. Contact the factory with your requirement.
BroadWave Technologies,
www.broadwavetech.com.

Fast-Switching Synthesizer

The FST-3000-XA fast-switching frequency synthesizer switches from 2500 to 3000 MHz in 1 MHz steps in < 500 ns with a frequency accuracy of ±1 Hz. It utilizes 10-bit parallel programming and features exceptionally low close-in phase noise (< –100 dBc/Hz @ 100 Hz offset, < –120 dBc/Hz @ 1 KHz offset, typical) when locked to a 100 MHz external OCXO frequency reference. Output power is greater than +7 dBm, spurious rejection is < –60 dBc typical, and harmonic suppression is < –50 dBc typical.



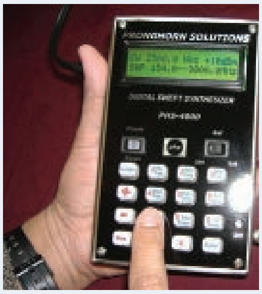
EM Research Inc.,
www.emresearch.com.

Switch Matrix

VENDORVIEW

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 RF switches operate over a wide frequency band from DC to 18 GHz, have low insertion loss (0.2 dB typical) and high isolation (85 dB typical) making the switch matrix perfectly suitable for a wide variety of RF applications.
Mini-Circuits,
www.minicircuits.com.

Synthesizer



The PHS-4000 is a versatile synthesizer in a revolutionary handheld format. It is a full performance signal source that covers the 150 MHz to 9 GHz range with ranges extendable down to 50 MHz and up to 18 GHz. It operates for four hours on its rechargeable battery, boasts a full function front panel and is USB/IVI programmable with controls of frequency, power, and digital frequency and power sweeps. Excellent for lab, field and test systems applications.
Pronghorn LLC,
www.pronghorn-solutions.com.

RF Distribution Unit

Radio Design Group announces the introduction of the RFDU-400 modular RF distribution unit. Designed for use in a variety of receive applications, the RFDU-400 integrates several functions in one compact system, including direction finding commutation, digitally controlled band-reject filtering, signal routing, and system noise testing. The RFDU-400 operates over a wide frequency range of 10 kHz to 18 GHz, and includes up to two band-reject filters per path, with unprecedented passband widths in the multi-decade range.
Radio Design Group Inc.,
www.radiodesign.com.

Temperature Controller

TotalTemp Technologies introduces the Retrofit Synergy Nano temperature controller. It features dual channel capability option for running two systems, independently or simultaneously; optional configurations for GPIB, failsafe systems, different power requirements, etc.; color LCD touch screen; network printing, logging and graphing functions; and selectable resume-control functions. It is Ethernet, USB, and serial communications standard and thumb drive compatible. Flexible inputs allow alternate sensors and expandability.
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www.totaltemptech.com.

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U.S. Patents 7739260, 7761442

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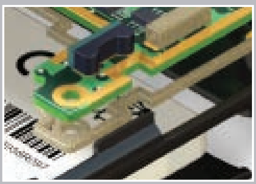


New Products

Components

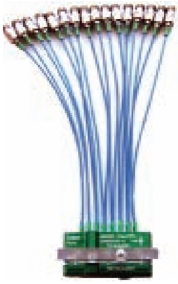
Hybrid Coupler

VENDORVIEW

Anaren Inc. has introduced a new low-cost, low-profile subminiature 3 dB, 90° hybrid coupler (part no. C1517J5003AHF) offering excellent performance characteristics in an easy-to-use surface mount package. Part of Anaren's growing line-up of Xinger®-brand subminiature components, the C1517J5003AHF is ideal for balanced power, low noise amplifiers, signal distribution, and other applications where low insertion loss and tight amplitude and phase balance are required.

Anaren Inc.,
www.anaren.com.

Termination Connector



Ardent Concepts announced a new, patented, high density termination assembly solution for true 40 Gbps/40 GHz coaxial-to-PCB transition. The Terminate-R is a compression mount (solderless) connector designed to provide the lowest loss interface between multiple lanes of high speed digital channels on a PCB to another PCB or measurement instrumentation. They exhibit a return loss of <-20 dB through 20 GHz with phase matching to ± 2 ps. Initial versions are available in 16 up configurations with 2.92 female SMK coaxial cable connectors.

Ardent Concepts,
www.ardentconcepts.com.

Terminations

Coaxicom's innovative 1 W 3900X series terminations are designed to minimize reflected power that often impedes transmission quality. Used across a spectrum of multi-port microwave devices including directional couplers, isolators and high-power transmitter applications, terminations absorb energy and prevent RF signals from reflecting back from open-ended or unused circuit ports. The Coaxicom DC to 26.5 GHz design maintains the mechanical integrity of 18 GHz designs with advanced performance, VSWR of 1.25:1 max. The 3900X terminations are available in SMA male interface configurations.

Coaxial Components Corp.,
www.coaxicom.com.

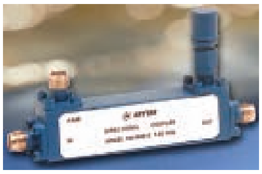
Dual Channel Downconverter

VENDORVIEW

The HMC1190LP6GE is a high linearity dual channel downconverter with integrated PLL/VCO that operates from 700 to 3500 MHz and is designed specifically for multi-standard receiver applications that require a compact and low power solution. It delivers 8 dB conversion gain, with excellent IP3 and input P1dB performance of +24 and +11 dBm respectively. Its RF and LO inputs are single-ended while an enable/disable pin makes it possible to reduce power consumption dynamically as conditions allow.

Hittite Microwave Corp.,
www.hittite.com.

Directional Coupler



KRYTAR's technological advances has extended the frequency range of this single unit, model 101050013, from 1 to 50 GHz with coupling (with respect to output) of 13 dB ±1.0 dB, frequency sensitivity of ±1.0 dB, and directivity of >10 dB. The directional coupler exhibits insertion loss (including coupled power) of less than 1.6 dB across the frequency range of 1 to 26.5 GHz and less than 2.9 dB from 26.5 to 50 GHz. Maximum VSWR (any port) is 1.5 (1 to 26.5 GHz) and 1.8 (26.5 to 50 GHz), input power rating is 20 W average and 3 kW peak.

KRYTAR Inc.,
www.krytar.com.

1 A Buck DC

VENDORVIEW

Linear announces the LTC3375, a highly-integrated general-purpose power management solution for systems requiring multiple low voltage power supplies. The device features eight independent 1 A channels with I²C control, flexible sequencing and fault monitoring in a compact QFN package. Each channel is a high efficiency synchronous step-down regulator with its own independent 2.25 to 5.5 V input supply and an output voltage range of 0.425 V to VIN.

Linear Technology Corp.,
www.linear.com.

Crystal Notch Filter

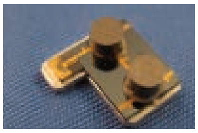
NIC introduces a high performance crystal notch filter operating in the VHF frequency range. This filter offers a narrow band notch attenuation of 25 dB minimum and low passband insertion loss, making it suitable to select closely spaced adjacent channels in receiver applications. Custom designs are available up to 250 MHz.

Networks International Corp.,
www.nickc.com.

Vertical Microstrip Circulator/Isolator

RADITEK's new double junction vertical microstrip circulator/isolator operates from 15.5 to 17.9 GHz, 10 W. It features low loss and high isolation. Typical specifications are: insertion loss (P2-P1) 0.65 dB/(P1-P3) 1.10 dB, isolation (P1-P2, P3-P2, P2-P3) 20 dB/(P3-P1) 35 dB, VSWR 1.30:1 on all ports. It operates at –40° to

New Products

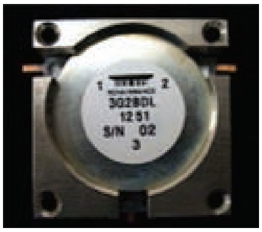


+70°C. Dimensions: 6.0 × 9.0 × 4.0 mm. These units are proven in the field and are fully RoHS compliant.

RADITEK Inc.,
www.raditek.com.

Drop-In Circulator

VENDORVIEW

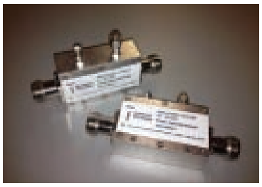


Renaissance's new broadband circulator is ideal for transmitter protection application. Operating over 962 to 1213 MHz, this device can withstand 2000 W peak and 20 W average power levels. It is designed to sustain temperatures from -55° to +120°C while the loss is maintained below 0.5 dB. For the circulator's datasheet, visit www.rec-usa.com.

Renaissance Electronics Corp.,
www.rec-usa.com.

Base Station Coupler

The new RMCO25.5800SNf covers the 5.7 to 5.9 GHz band offering typical electrical performance of 0.3 dB insertion loss, VSWR of 1.15:1 and minimum directivity of 25 dB. Average power handling is 150 W and the unit is operational over the -35° to +85°C range. Mechanical package is 2.30" × 1.42" × 0.79". Connectors used are type N female on the mainline and SMA female on the coupled ports. Optional connectors and coupling values are available on request.



Response Microwave Inc.,
www.responsemicrowave.com.

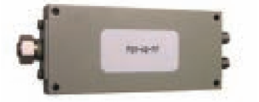
Resistive Power Dividers

VENDORVIEW

RFMW announced design and sales support for Florida RF Labs' RPD Series of broadband resistive power dividers. The RPD0212F is a DC to 12 GHz, two-way divider that handles up to 1 W of CW power in an extremely compact size (0.098" × 0.098"). The new RPD series offers significant advantages over on-board multi-resistor designs by providing excellent broadband frequency response, highly repeatable performance, and streamlined assembly process in a monolithic surface-mountable chip package.

Florida RF Labs,
Distributed by RFMW Ltd.,
www.emc-rflabs.com.

Adjustable Phase Shifter



RLC Electronics' manually adjustable delay line (phase shifter) offers continuous adjustment of electrical delay over the frequency range of DC to 40 GHz. Adjustment is through a multi-turn, locking shaft. Low insertion loss and VSWR are maintained throughout the adjustment range. The unit comes with a choice of male or female 2.92 mm connectors. It has an impedance of 50 Ω, a power rating of 5 W average, and a temperature range of -55° to +85°C.

RLC Electronics Inc.,
www.rlcelectronics.com.

Directional Sensor Module

Model SSP-24303-42-D1 is a low cost, production ready K-Band FMCW ranging and directional sensor module. The center frequency of the module is set at 24.125 GHz with ±150 MHz frequency modulation bandwidth and +3 dBm nominal output power. The sensor operates from a single +5 VDC power supplier and typically draws 250 mA current and requires 0 to +15 V voltage swing for electrical tuning. The sensor incorporates an I/Q mixer to provide target moving direction information.

SAGE Millimeter Inc.,
www.sagemillimeter.com.

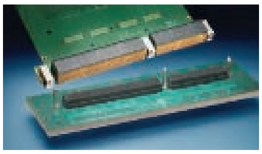
LTE Tx/Rx Switches

VENDORVIEW

Skyworks unveiled five LTE Tx/Rx switches for smartphones and tablets. The SKY13414-485LF, SKY13415-485LF, SKY13416-485LF, SKY13417-485LF and SKY13418-485LF main/diversity antenna switches cover SP4T through SP8T and allow up to eight bands of WCDMA/LTE. The high linearity and low insertion loss achieved by this suite of devices make them ideal for switching applications commonly used in LTE-based handsets, data cards and tablets. Their symmetric design and higher power handling also provide flexibility in signal routing for higher power TD-SCDMA/TDD-LTE, WCDMA/FDD and LTE transmit/receive functions.

Skyworks Solutions Inc.,
www.skyworksinc.com.

Board-to-Board Connector



This rugged, lightweight and high-speed board-to-board interconnect is compliant to VITA 46, in-

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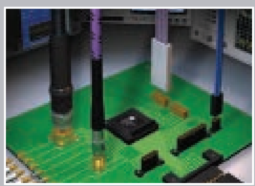
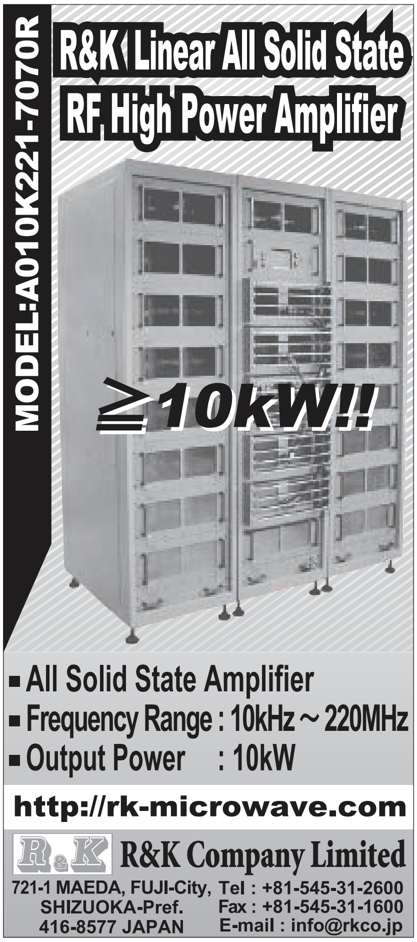




New Products

cluding backward compatibility with all existing VITA 46 daughter cards, and supports OpenVPX architecture. The new connector system features the modularity and flexibility of the field-proven MULTIGIG RT 2 connector products, but with a new quad-redundant contact structure designed for extreme vibration levels. Ruggedized guide hardware is also available for use with the MULTIGIG RT 2-R connectors to increase the stability of the daughtercard-to-backplane interface under shock and vibration.
TE Connectivity,
www.te.com.

Surge Protection Products

Times Microwave Systems introduced the new and unique Times-Protect® LP-18-400-N series of DC pass RF lightning and surge protection products with a frequency operating band from DC to 6000 MHz. This new bidirectional design with either a type N male or type N female connector on one end can be directly attached to an LMR-400 cable via the same standard EZ non-solder interface used on other EZ-400 non-solder style connectors.
Times Microwave Systems,
www.timesmicro.com.

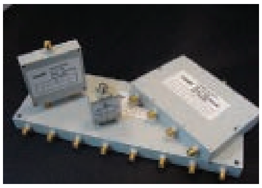
High Power Duplexer

Trilithic introduced a new line of high power duplexers and triplexers designed for 4G LTE build-out. Model FD2001 DIN-R duplexer specifications include: RX: 1710 to 1785 MHz, TX: 1805 to 1880 MHz; impedance: 50 Ω; insertion loss: RX: 0.70 dB max, TX: 0.70 dB max; isolation: 65 dB min, RX to TX; input power: 200 W, single carrier max; VSWR: 1.25:1 max, any port; PIM: <-160 dBc (at 2°43 dBm); temperature: -40° to +60°C; connectors: 7/16 DIN female; dimensions: 7.9" × 7.6" × 1.7".
Trilithic Inc.,
http://rfmicrowave.trilithic.com.

High Power Circulators

CT-849-D is one of a series of 2 KW CW circulators that cover 75 to 125 MHz with 5 percent minimum bandwidths. Peak power options are also available. Typical applications are medical, scientific and FM transmitters. Operating at 80 MHz, the unit provides 20 dB minimum isolation with less than 0.3 dB loss and 1.25 maximum VSWR. Operating temperature is 10° to 60°C case temperature with conduction cooling. The unit size is 9" × 9" × 2". DIN 7/16 connectors are standard with options for 7/8 EIA flanges.
UTE Microwave Inc.,
www.utemicrowave.com.

Power Dividers



VidaRF offers a wide selection of two-way through 16-way power divider/combiners, designed to cover 100 MHz to 20 GHz with average power handling of 30 W for narrow, octave, dual and multi-octave band applications. Standard connector type: SMA female, other connectors available upon request. VidaRF is a North Carolina based company that is focused on being a solutions provider by building to customer specs and offering zero days lead time for custom parts through its stock and ship program.
VidaRF,
www.vidarf.com.

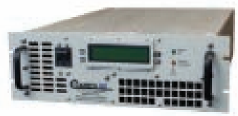
Resistor Networks

Vishay released the new MPMA series of precision matched-pair resistors. Each MPMA network is constructed using moisture-resistant thin film tantalum nitride resistor film with enhanced passivation on a high purity alumina substrate. The MPMA device is resistant to moisture at +85°C, 85 percent relative humidity, and 10 percent rated power per MIL-STD-202, method 202. Offering higher precision matching capability than discrete SMT chips, the AEC-Q200-qualified dividers provide low TCR tracking of ±2 ppm/°C and tight ratio tolerance to ±0.05 percent.
Vishay Intertechnology Inc.,
www.vishay.com.

Amplifiers

Solid State RF Amplifier

Comtech PST introduced its 700 to 2300 MHz, 200 W model BHED78238-200 rack mounted wideband high power solid state RF amplifier.



Comtech has integrated its proven RF GaN PA module designs into a single 19" rack. This amplifier features an internal AC power supply, full Ethernet Interface/GUI control, front panel digital display for forward and reverse power, temperature, current, etc., and separate fault LEDs. Applications include ground mobile or fixed, surface, and airborne platforms.
Comtech PST,
www.comtechpst.com.

High Power Amplifier

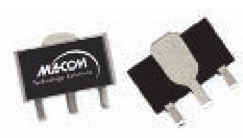
VENDORVIEW

Empower model BBM-5K8CKT is a 2500 to 6000 MHz amplifier which is guaranteed to deliver 100 W output power and related RF performance under all specified temperature and environmental conditions. The amplifier module is 8" × 6.5" × 1" and is suitable

for broadband jamming and high power linear applications in the S/C-Bands. This module utilizes high power GaN on SiC transistors and also features built in control and monitoring, with protection functions.
Empower RF Systems Inc., www.empowerrf.com.

Broadband Amplifier

The MAAM-010373 is a GaAs MMIC amplifier that exhibits low distortion and high gain in a lead-free surface mount package. The amplifier employs a monolithic single stage design, featuring convenient 75 Ω input/output impedance which minimizes the number of external components required. It is fabricated using a PHEMT process to realize low noise and low distortion. Operating between the 50 and 1100 MHz frequency range, the amplifier exhibits a high gain of 22 dB and low noise figure of 2.2 dB.



M/A-COM Technology Solutions Inc., www.macomtech.com.

Silicon Carbide Power Modules

Microsemi's new industrial temperature SiC power modules feature multiple circuit topologies and are integrated into low profile packages. The majority of the new module product family uses aluminum nitride (AIN) substrates to enable isolation from the heat sink, which improves heat transfer to the cooling system. Additional features include high speed switching, low switching losses, low input capacitance, low drive requirements, low profile and minimum parasitic inductance which enable high frequency, high performance, high density and energy-saving power systems.
Microsemi Corp., www.microsemi.com.

Log Video Amplifier

VENDORVIEW

Model SDLVA-0R71R3-75-CD-1 is a 700 to 1300 MHz successive detection log video amplifier. This model has a dynamic range of 75 dB, a log slope of 40 mV/dB and a nominal video bandwidth of 20 MHz. The log linearity is ±1.2 dB typical from -65 to +5 dBm input power levels and a typical TSS of -70 dBm. The limited IF output is +5 dBm typical. This model offers very fast rise times of 9 nsec and fall times of 25 nsec typically.

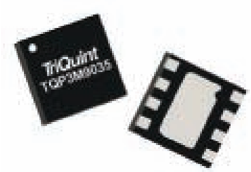
Planar Monolithics Industries, www.pmi-rf.com.

Linear PA Modules

VENDORVIEW

The parts in RFMD's new RF73xx series of high-power, high-efficiency linear power amplifiers are designed for use as the final amplification stage in 3 V, 50 Ω LTE mobile cellular equipment developed for E-UTRAN/LTE band operation. These parts are developed for 5 to 20 MHz LTE channel bandwidths. Each has two digital control pins to select one of three power bias states to optimize performance and current drain at lower power levels. Each also has an integrated directional coupler.
RF Micro Devices Inc., www.rfmd.com.

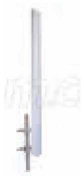
Low Noise Amplifiers



TriQuint introduced two packaged LNA gain blocks that deliver cost-effective high performance over broad bandwidths of 50 MHz to 4 GHz. They combine very high linearity with very low noise figures, making them ideal for use in the transmit and receive chains of high-performance GSM, WCDMA, CDMA, and LTE base transceiver stations and defense applications. In addition to their high performance in wireless infrastructure, the new LNAs can be used in a variety of systems ranging from repeaters and tower-mounted amplifiers to defense communications and general-purpose circuits.
TriQuint Semiconductor Inc., www.triquint.com.

Antenna

Waveguide Antennas



L-com has introduced two new HyperLink® brand horizontal polarized waveguide omnidirectional antennas. These rugged new 2.4 GHz antennas are available in 9 dBi and 13 dBi versions. They feature very low loss which makes them very efficient to operate. The horizontally polarized design is ideal for use in areas susceptible to the affects of interference generated by commonly used vertically polarized wireless LAN equipment. The antennas include rugged UV-resistant PVC radomes designed for all weather operation and come with steel mast mounting brackets.
L-com Inc., www.l-com.com.

Sources

Temperature Compensated Oscillator

Tellurian Technologies announces the development of a highly stable TCXO that has a tight stability in a smaller size (5.0 × 3.2 × 1.65 mm). The TT-VT4000CT is a temperature compensated oscillator with the stability of ±0.14 ppm over -10° to 70°C. The frequency range is 10 to 40 MHz and generates a clipped sine output. The TT-VT4000CT has a low current drain of only 3.5 mA max and achieves a low phase noise of -145 dBc/Hz at 1 kHz bandwidth.
Tellurian Technologies Inc., www.telluriantech.com.

ASB

New, Great!

LNA

Part No.	Freq. (GHz)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package
ASL51T8	0.9	18	0.37	38	TDFN8
ASL41S9	0.9	18	0.55	38	SOT89
ASL52T8	2.0	21	0.65	34	TDFN8

LNA w/o extra component

Part No.	Freq. (GHz)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package
ANM1730	1.7~3.0	25	0.5~0.8	35	MCM3P

Wideband PA

Part No.	Freq. (GHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Package
AWB459	DC~3	19	24	41	SOT89
AWB589	DC~1	20	27	44	SOT89
AWB688	DC~1	21	30	44	SOIC8

GPS LNA

Part No.	Vd/Id (V/mA)	Gain (dB)	NF (dB)	OIP3 (dBm)	Package (mm)
ASL22N	3/8.5	29	1.1	16	UQFN6 (1x1)

CATV

Part No.	Vd/Id (V/mA)	Gain (dB)	Pout (dBuV)	CSO/CTB (dBc)	Package
ASL39D2	5/300	19	105	60/66	SOIC8
ASL59D4	6.5/390	20	108	60/63	TSSOP24
ASL882	12/520	22	110	60/66	TSSOP24

Optical Receiver

Part No.	Vd/Id (V/mA)	Photo.Pin (dBm)	Pout (dBuV)	CSO/CTB (dBc)	Package
ASA306C	4/210	-10~+2	85	60/62	QFN24

※Voltage controlled attenuator included

Digital Attenuator (LSB 0.5 dB, 6 – bit)

Part No.	Freq. (GHz)	Atten. Range(dB)	Typ.IL (dB)	IIP3 (dBm)	Package (mm)
AAT530B6	0.5~3.0	31.5	2.0	45	QFN16 (4x4)

ASB Inc.
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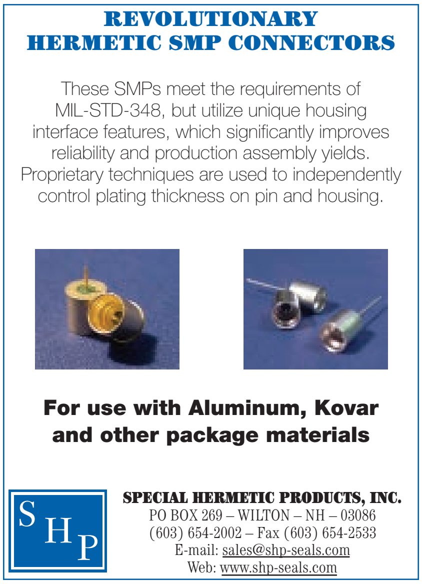
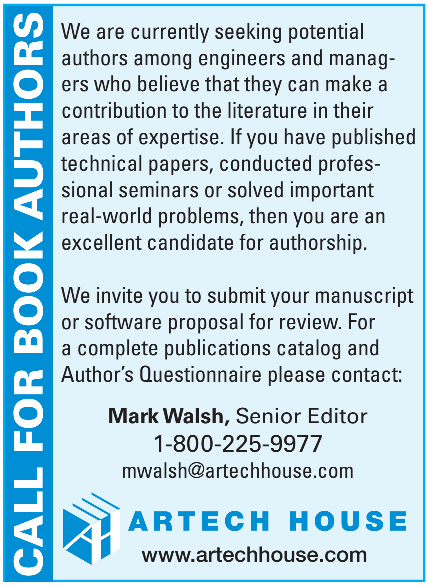
Contact us at sales@asb.co.kr

MICRO-ADS





New Products

Voltage Controlled Oscillator

Z-Communications announced RoHS compliant VCO model V846ME24-LF in the S-Band. It operates at 3100 to 3500 MHz with a tuning voltage range of 1 to 12 V DC and provides better than 1.1:1 tuning linearity. This high performance VCO features a spectrally clean signal of -114 dBc/Hz at 100 kHz offset and a typical tuning sensitivity of 62 MHz/V. It is designed to deliver 3 dBm of output power into a 50 Ω load while operating off a 5 V DC supply and drawing typically 22 mA of current.
Z-Communications Inc.,
www.zcomm.com.

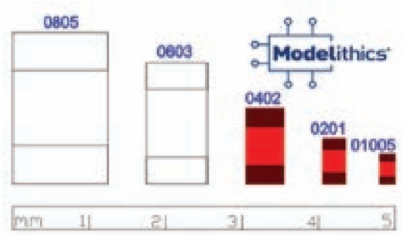
Semiconductors/ICs

Schottky Barrier Rectifier Diodes

AVX introduced a new series of Schottky barrier rectifier diodes uniquely packaged as leadless chips. Eliminating the standard lead frame wire bond provides the chip with top-bottom symmetry, which enables better heat transfer, better current handling capability than SOD devices and fewer mounting problems. Available in several case sizes and a range of current values spanning 0.1 to 8 A, the new leadless chip form Schottky rectifier diodes are ideal for applications including switch mode power supplies, high frequency rectification, portable battery powered devices and reverse bias protection.
AVX Corp.,
www.avx.com.

Software

Enhanced Small Parts Library



The Modelithics Small Parts Library of measurement-based, equivalent circuit models for RF/MW simulation now includes more Global™ models than ever for 0402, 0201 and 01005 (EIA) size passive components from KEMET, AVX and other popular suppliers. Each Global model typically represents an entire component family, accurate from DC to 20 GHz or higher and scale with substrate and pad-geometry and part-value. The Modelithics Small Parts Library now contains 84 Global Models, and more are added with each library release.
Modelithics Inc.,
www.modelithics.com.

MWIE 2013

2013 Microwave Wireless Industry Exhibition in China (MWIE 2013)

2013 National Conference on Microwave and Millimeter Wave

Sponsors: Chinese Institute of Electronics (CIE)

Co-Sponsors: Microwave Society of Chinese Institute of Electronics
Chongqing Acoustic-Optic-Electronic Co., Ltd. of CETC
33rd Research Institute of China Electronics Technology Group Corporation (CETC33)
Kingradio Technology [Shenzhen] Co., Ltd.

Collaborating Media: Journal of Microwaves(China) Mobile Communications (China)
Microwave Journal (USA) Mwrfchina and Rfeda

2013 Microwave Wireless Industry Exhibition（MWIE2013） and 2013 National Conference on Microwave and Millimeter Wave in China (NCMMW2013) will be held in Xuehao Hotel, Chongqing, China, in 21~23 May, 2013.
NCMMW2013 is China's largest conference on microwave and millimeter wave technologies. It is organized by Chinese Institute of Electronics (CIE) and held every two years (every odd year).
MWIE has already been held for over 10 years. It is one of most important events of the National Conference on Microwave and Millimeter Wave in China held every odd year, and the International Conference on Microwave and Millimeter Wave Technology held every even year.

MWIE2013 will be another grand exhibition after "MWIE2012" in Shenzhen, "MWIE2011" in Qingdao, "MWIE2010" in Chengdu, "MWIE2009" in Xi'an, "MWIE2008" in Nanjing China!

Date: May 21~23, 2013 **Venue: Xuehao Hotel, Chongqing, China**

"9th Committee Enlarged Conference of Microwave Society of Chinese Institute of Electronics" will be held during the period of MWIE2013. Nearly 80 Committee members from institutes, universities and companies of all parts of China will attend the conference and visit the exhibition. This is the best chance to let Chinese people know your company and products; exhibit in MWIE2013 is the best choice for your products to enter Chinese market.

Exhibitors to be attended:

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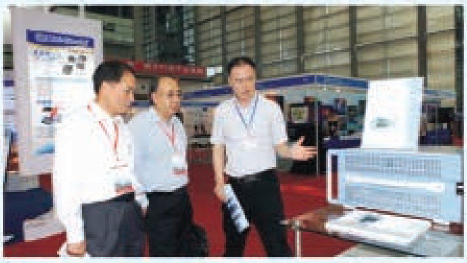

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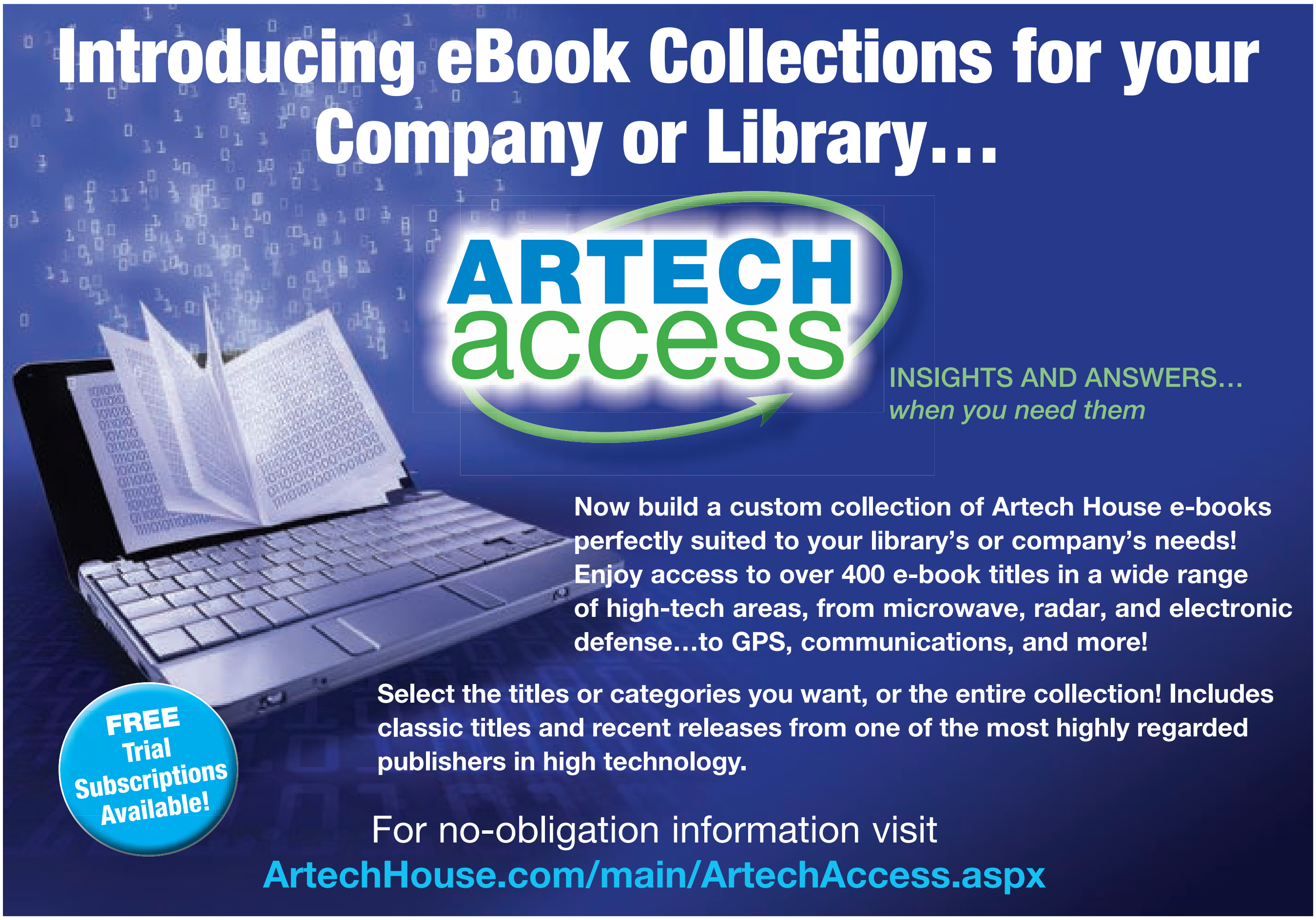

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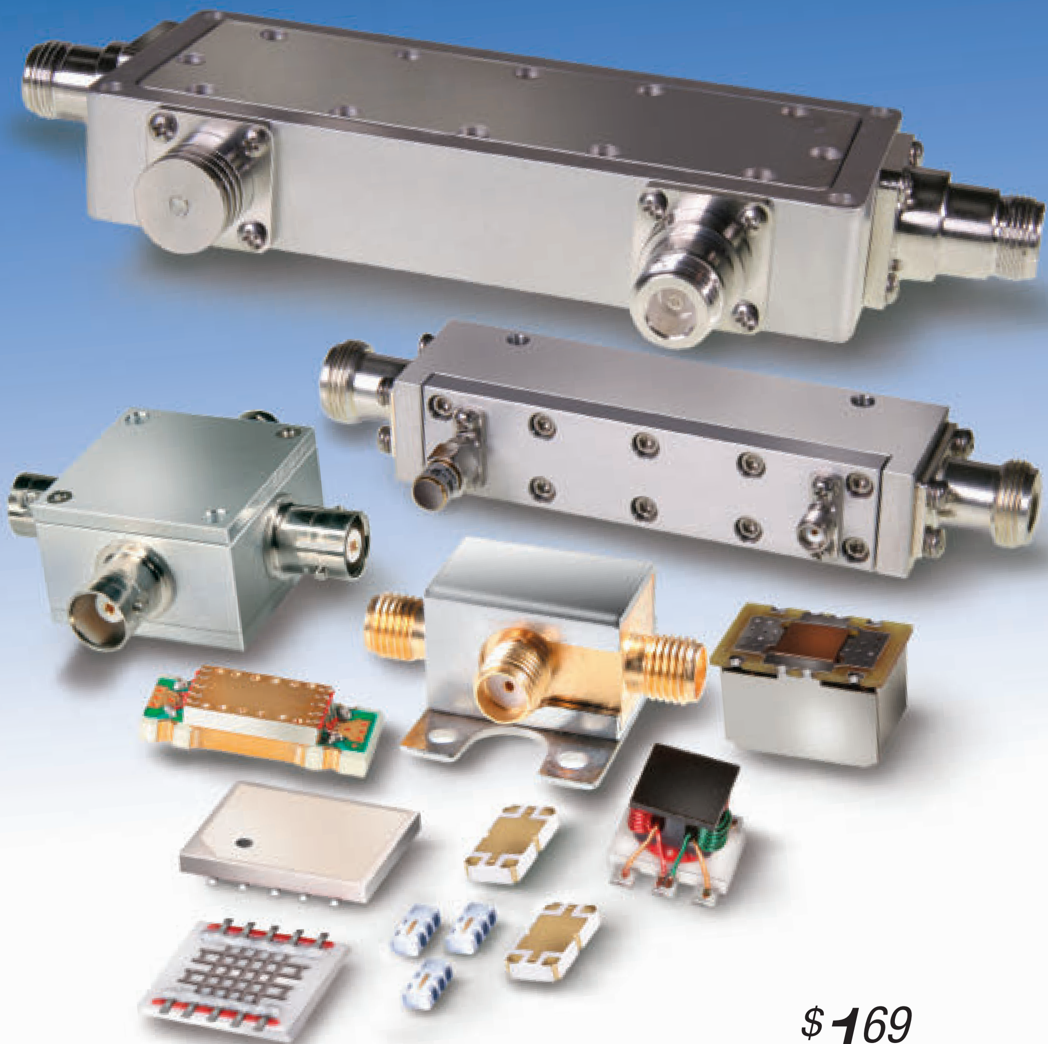

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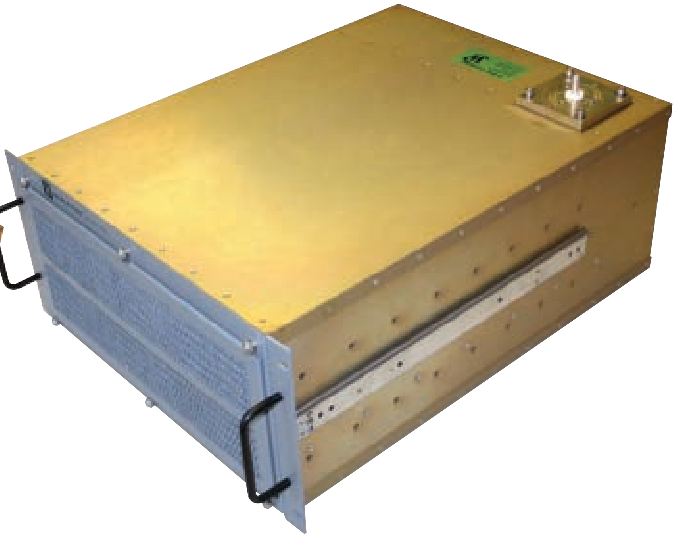

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D8969	2-Way	1.5-30	12,500	0.2	1.25	20	17 x 17 x 8
D6139	4-Way	1.5-32	5,000	0.25	1.25	20	13 x 11 x 5
D6774	4-Way	1.5-32	20,000	0.3	1.20	20	21 x 17.25 x 11
D6846	6-Way	1.5-30	4,000	0.35	1.35	20	3 U, 19" Rack
D8421	8-Way	1.5-30	12,000	0.3	1.30	20	22.5 x 19.5 x 8.75
D7685	4-Way	2-100	2,500	0.5	1.30	20	14.75 x 13 x 7
D2786	4-Way	20-150	4,000	0.5	1.35	20	18 x 17 x 5
D6078	2-Way	100-500	2,000	0.25	1.20	20	13 x 7 x 2.25
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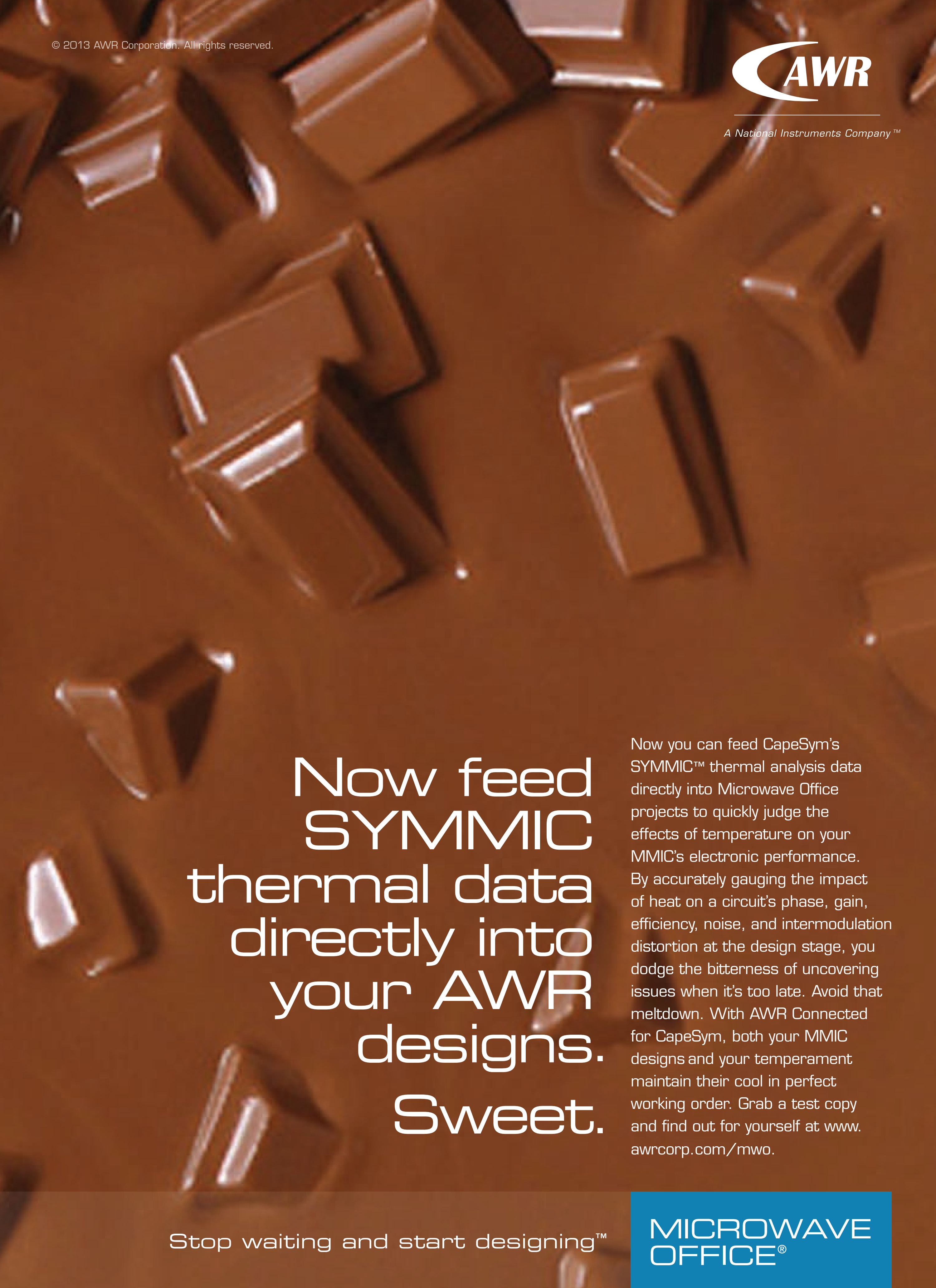
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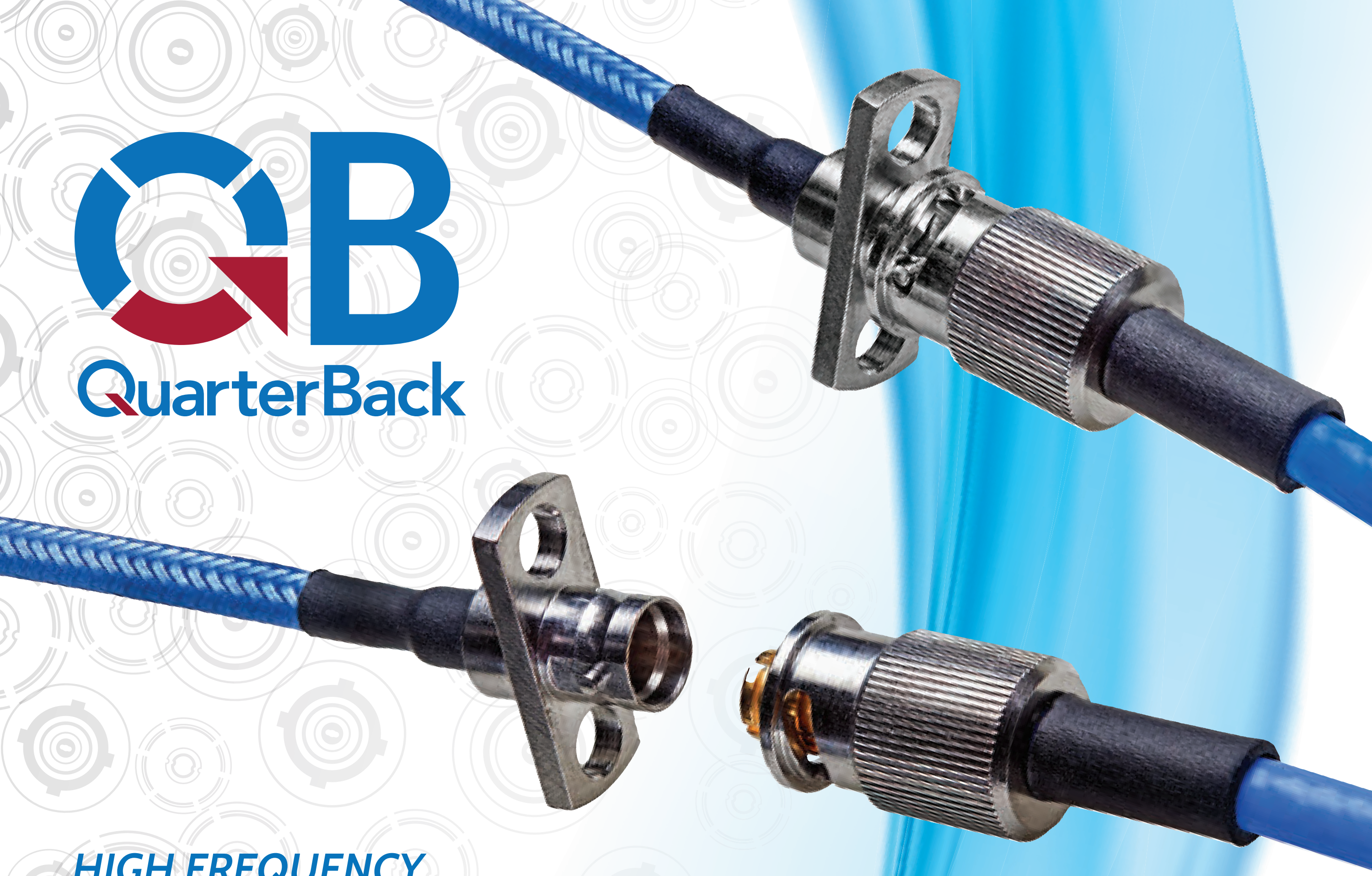

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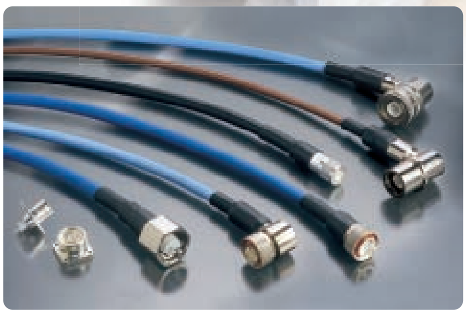

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Simulating Crosstalk and EMI in Cables

Cables not only transfer the power needed to run electrical equipment, but also the data signals needed to operate them. To prevent errors and device failures, the same attention must be paid to the choice and installation of the cabling as is paid to the rest of the system.

Dealing with data means considering signal integrity (SI). Since data signals are modulated electrical pulses, anything that introduces noise into the cable can corrupt the information, causing equipment to lose performance, malfunction or simply fail altogether. Crosstalk and impedance mismatch are common sources of SI problems; cables generally consist of multiple wires travelling together. The fields generated in one wire can, without proper shielding, couple to others and induce currents in them, while signals can be reflected at the interfaces between cables if the impedances do not match. Analyzing these issues uses RF and microwave techniques and expertise.

It is not just interference from other data signals that one needs to worry about, however. Electromagnetic interference (EMI) can come from a range of sources within the system and the wider environment. Switched-mode power supplies generate noise, while lightning strikes and electrostatic discharge (ESD) introduce transients that often cause damaging current surges in devices. Even the interaction between the equipment and its casing can be enough to interfere with data signals. As well as being immune to external radiation, the cables themselves should not radiate either. Electromagnetic compatibility (EMC) is a legal requirement and this means that they must pose little interference risk to other devices.

Every advance in technology pushes cable design requirements further. High-speed devices demand cables capable of handling ever-higher bit-rates. Automotive and aeronautical systems, increasingly reliant on electronic control and communications systems, need cables that are lightweight yet also measure up to stringent safety regulations. Consumer electronics meanwhile are pushing toward standardized multipurpose cables, where one lead might be used for anything from charging a mobile phone to controlling a printer or transferring data to a hard drive.

In light of these developments, designers have turned to cable harnesses, where multiple cables – sometimes a hundred or more – are tied together and travel along the same conduit as well as hybrid cables, which contain both signal and power wires together. The most familiar example of a hybrid cable is probably USB, but custom cables of many configurations are used in industrial applications. For such complex cable designs, traditional design rules to calculate the cable's properties become unwieldy. Simulation offers a way to develop and check an arbitrary cable design and optimize its layout and shielding for better performance.

OVERVIEW OF CABLE SIMULATION

Applying full 3D EM simulation methods to simulate detailed cabling within a large structure such as an automobile is impractical, as shown in ***Figure 1***. Each individual wire might be less than a millimeter in diameter, yet tens of meters long, bending as it carries high frequency signals through an electromagnetically complex environment. A conventional simulation of such a system would need an incredibly fine resolution to capture the fields in the cable, extended over a very large volume, resulting in slow, computationally-intensive calculations. The arbitrary cross sections of cables and changes in the surrounding environment along its path make analytic solutions similarly hard to find.

Specialized cable simulators can model complex cables and cable harnesses far more efficiently. The cable can be divided into segments, each having a constant cross-section. A 2D electromagnetic field solver can then be applied to extract the electrical properties for each segment. The properties of the entire cable may be found by cascading the electrical

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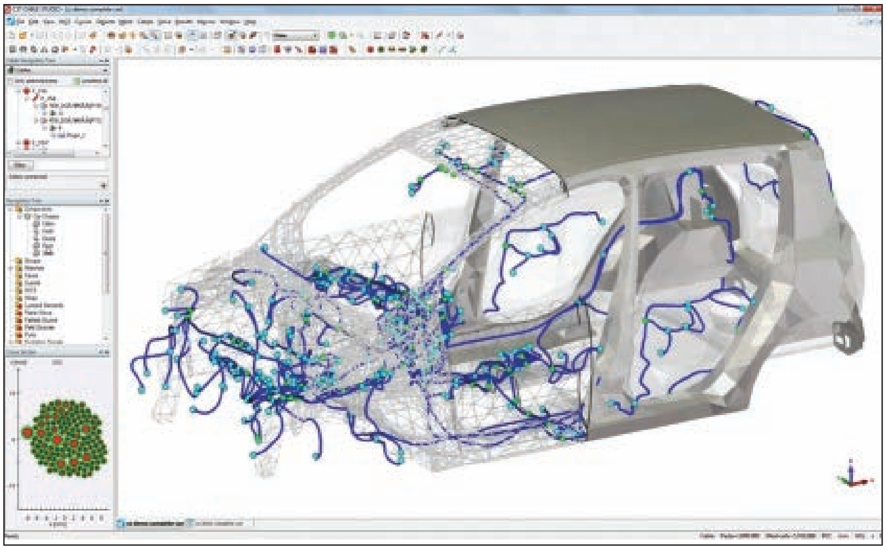

Fig. 1 *The cabling system inside a car.*

TABLE I

VARIOUS APPROACHES TO CABLE SIMULATION

Electrostatic Simulation
Electro- and magneto-static simulations can be used to calculate the L and C contributions to the line impedance. This approach is fast but only accurate at DC.
Full-Wave Simulation
Full-wave 3D simulation lets the frequency dependent effects be taken into account as well, modeling the dispersion of signals as they propagate down the line. This approach is very accurate for broadband signaling, but slower than a specialized cable simulation.
Specialized Cable Simulation
The cable cross-section is analyzed using a 2D field solver and transmission-line network analysis applied to simulate propagation. This approach is both accurate and efficient.

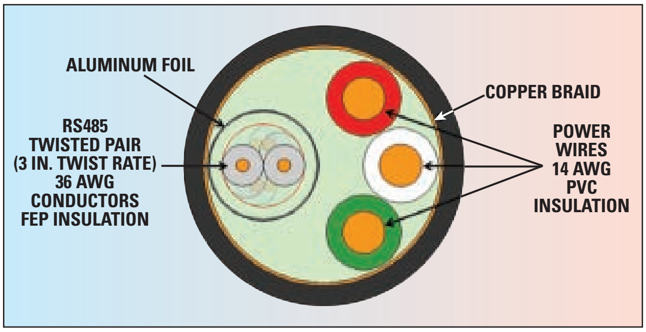

Fig. 2 *A cross section of a hybrid cable carrying five wires.*

models into an equivalent network. The specialized cable solver may also co-simulate with a full 3D field solver to simulate coupling to and radiation from the cable.

The cable shown in ***Figure 2*** carries five wires – two power wires (red and white), two signal wires (gray twisted pair) and a ground (green). The signal wires are shielded from the power wires by foil and the whole cable is shielded by a copper braid. It is an example of a hybrid cable for which an SI and EMI analysis would be important. The signal wires are not only potentially at risk from external interference, they could also pick up noise from the power wires. The shields and the use of twisted pair wires are both meant to reduce noise in the signal; simulation allows the engineer to investigate their performance. The cable is only a few millimeters wide, but could be meters long.

LINE IMPEDANCE SIMULATION

One important property of any data cable is its line impedance. Ideally, the impedance of the data line should match the impedance of the load. If there is a mismatch, signals at the interface between the two will be partially reflected and interfere with the signal, which can lead to SI problems in the connections between the line and components. Reflection is especially problematic for bidirectional cables, where the equipment at both ends acts as both source and receiver.

Calculating the line impedance of a cable is an obvious application of simulation. Multiple approaches exist for impedance calculations: the static approach, a full-wave simulation and a specialized cable simulation. Each has its advantages and disadvantages, as shown in ***Table 1***.

A full-wave simulation also permits one to model the connectors at the end of the cable. Impedance matching and EMI analysis are very important when designing or choosing a connector. This is especially true if the connector differs from the cable in some way – for example, if a twisted wire terminates in a straight pin, or if the connector is shielded in a different manner to the cable. The connectors are critical in impedance matching, since they provide the transition between the cable and the load. Often one wants to know which cable dimensions will give suitable cable characteristics to minimize reflection and improve data transmission. To do this, an optimizer is used. The optimizer simulates multiple possible values for model parameters – for instance, the thickness of an insulator or the position of a wire – using sophisticated algorithms to reduce the amount of guesswork involved in finding the best configuration.

CALCULATING LOSSES

Losses in the cable cause signals to be attenuated, with the degree of attenuation depending on the frequency. High frequencies typically suffer from greater loss, which has the effect of rounding the sharp edges of data pulses, limiting the data transmission rate.

The AC resistance (skin effect) of the wires is one obvious contribution to losses. Another is the loss tangent of the dielectric insulation materials. Signals may also leak through non-

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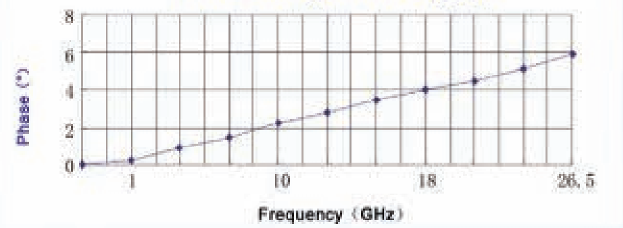
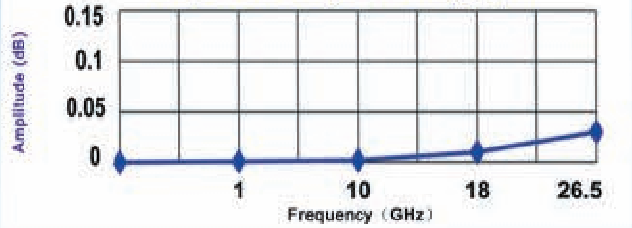
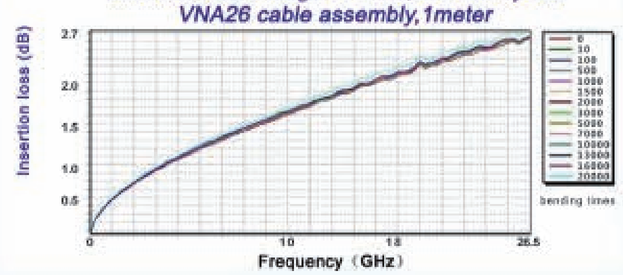
Phase stability vs.flexure graph



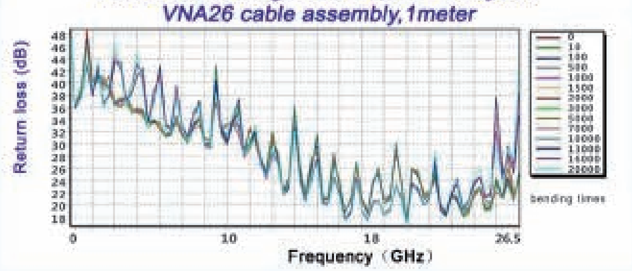
Amplitude stability vs.flexure graph



Insertion loss change over 20,000 flex cycles
VNA26 cable assembly,1meter



Return loss change over 20,000 flex cycles
VNA26 cable assembly,1meter



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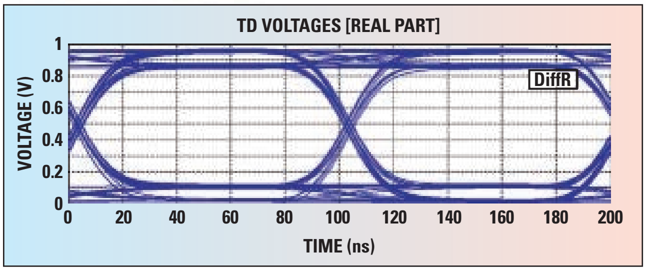
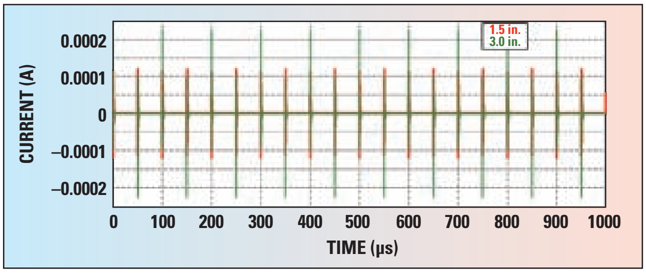


▲ *Fig. 3 Eye pattern of a 20 m long cable carrying a 10 Mb/s signal.*



▲ *Fig. 4 Induced differential mode currents for twist length of 1.5 in. (red) and 3 in. (green) of the hybrid cable, assuming no shielding.*

perfect shields, introducing additional losses into the circuit. Full-wave and specialized cable simulation both allow designers to calculate the losses for a cable. Full-wave simulations of short cable sections can be cascaded, allowing losses over the whole length to be found without having to solve a full model of the structure.

Simulation can also calculate the scattering parameters (S-parameters), which describe the cable's characteristics concisely and show how the losses vary with respect to signal frequency. Standard measurements used in the lab such as the eye diagram, shown in ***Figure 3***, can also be replicated with simulation. To produce an eye diagram, a series of random bits are fed into the cable, and the output at the other end captured and graphed. Layering the output signals gives a useful illustration of the rounding of the pulses caused by attenuation.

CROSSTALK SIMULATION

The potential for crosstalk arises whenever two or more wires are coupled. In the example, the power conductors can couple with the signal lines. This sort of broad spectrum noise may be difficult to filter out of signals. Instead, the best option for reducing crosstalk is to shield the wires well and make sure the coupling is minimized.

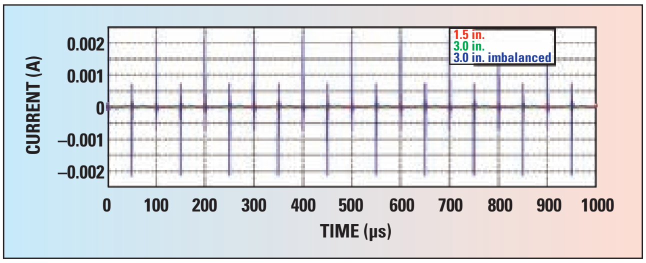
Since the data is carried by differential signaling, it is the difference between the two wires (the differential mode) that matters. If the cable system is perfectly balanced, the noise coupled to each conductor in the differential pair will be equal and the receiver will be able to reject the noise when the voltage signals are subtracted.

Simulating Twisted-Pair Wire

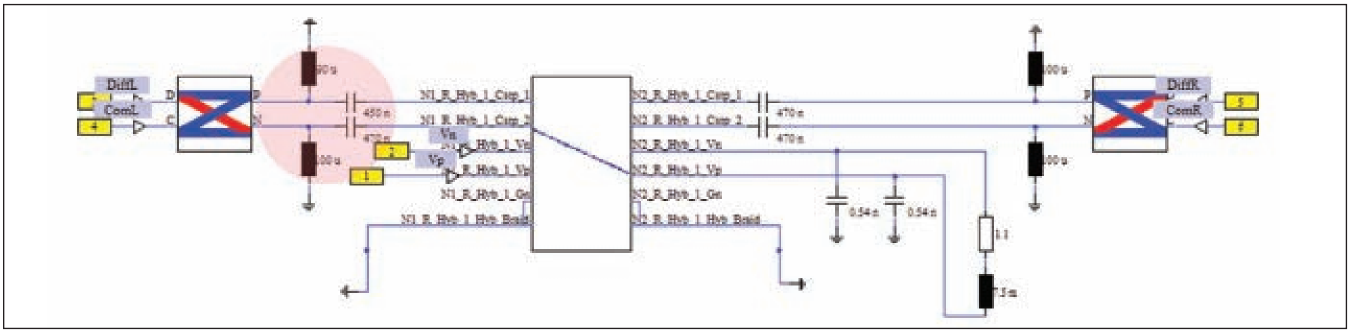
Twisted-pair cabling, commonplace in communication systems for over a century, winds wires around each other in sets of two. This minimizes the loop area between the wires to reduce mutual inductive coupling. It also helps to maintain balance in the line, equalizing the exposure of each conductor to external fields. Coupling is reduced as long as the twist length is small compared to the wavelength of the interference. The precise choice of twist length can make a big difference to how immune the cable is to crosstalk; for cables carrying several pairs of signal wires, such as the ubiquitous Cat-5, giving each set of wires a slightly different number of twists per meter can reduce the crosstalk between them significantly.

With simulation, the cable designer can examine the interference experienced by the wires and test how different wire configurations affect the signal characteristics. Cable simulation lets one easily adjust the distance between twists (twist rate) in the computer model, and simulate the induced currents caused by switching noise in each case (see ***Figure 4***). For this cable, making the twists shorter makes a big improvement to the differential mode noise rejection characteristics of the line. These simulations are performed without a shield around the twisted pair to study the noise rejection due to twisting alone.

Wire twisting is most effective if the two wires are well-balanced. In



▲ *Fig. 6 Differential mode crosstalk in the imbalanced system (blue) massively outweigh the crosstalk in the balanced system.*



▲ *Fig. 5 A length of the cable is attached to a lumped element circuit in CST DESIGN STUDIO™. The imbalanced section is highlighted.*

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a real system, with varying loads and imperfectly manufactured components, this will not always be the case. The cable model can be attached to a circuit made up of lumped elements to replicate the equipment at either end and one can see how well the cable performs when the manufacturing tolerances are taken into account. In this example, shown in ***Figure 5***, a 10 percent imbalance is introduced in the shunt inductance (a drop of 10 µH) and a 4 percent imbalance in the series capacitance (a 20 nF decrease).

This proves to have a huge impact on the coupling. The peak induced current in the imbalanced system is ten times greater than in a perfectly balanced system, leaping from 0.2 to 2 mA – a 20 dB increase in the intensity of the crosstalk (see ***Figure 6***).

Shielding

For an extra layer of protection, which should guard against crosstalk and interference even if the cable terminations are not balanced, the wires can be shielded. Different shield types exist for different applications: the main two are foil shields, consisting of a thin sheet of metal such as aluminum, and braided shields, which are made up of many thin wires woven into a tube. Shields can either go around the entire cable to keep out external interference, or they can be placed within the cable to reduce crosstalk.

However, shielding not only adds bulk and weight to the cable, it can also decrease its flexibility and drive up the manufacturing costs. With many types of shielding available, each with different properties and suited toward different types of interference, it is not always easy to balance a cable's noise characteristics against the design requirements.

The performance of a shield is measured by its transfer impedance, as derived by Schelkunoff.[1] The transfer impedance Z_T is given by:

$$Z_T = \frac{1}{I_0}\frac{dV}{dx}$$

where I_0 is the current flowing on one side of the shield and dV/dx is the voltage per unit length along the opposite side. The transfer impedance effectively provides a measure of to what extent the shield's construction prevents fields passing through. The environment does not affect the transfer impedance – it is solely an intrinsic characteristic of the shield itself. The lower the transfer impedance, the better the shielding.

In a foil shield, the skin effect improves shielding performance at high frequencies as shown in ***Figure 7***. Current diffuses through the shield at low frequencies, but is confined to the surface at high frequencies. This

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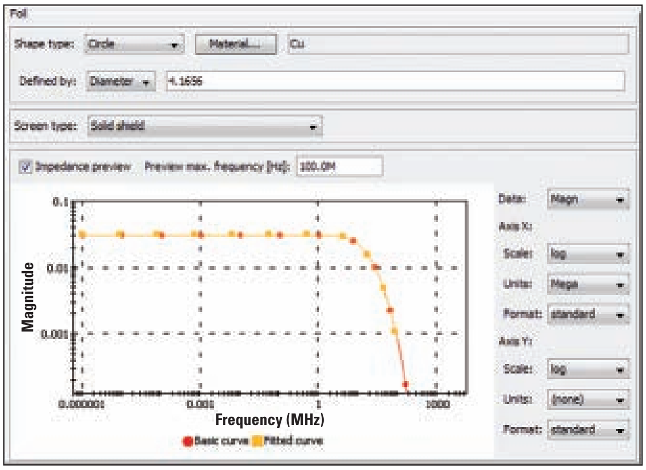
means that external fields cannot penetrate the shield at high frequencies, provided that the shield is perfectly closed and has no apertures. However, in a real shield, fields can also pass through the seam formed where the layers of foil overlap, and for a more accurate simulation, this seam can also be taken into account.

Braided shield, by contrast, behaves the opposite way. The transfer impedance of a braided shield, as described by Kley,[2] depends on a number of effects. The skin effect still plays a role, but more significant at high frequencies are the small apertures between the strands and the mutual inductive coupling, as well as an inductive interaction, known as "porpoising," when strands cross each other. These drive up the transfer impedance, so that a braided shield is most effective at low frequencies. ***Figure 8*** shows the transfer impedance curve for a braided shield across the frequency spectrum.

Because mathematical models exist to describe the behavior of shields based on their properties, they are ideal candidates for designing and testing with cable simulation software. Arbitrary shields, whose properties are found experimentally, can also be used in simulations, simply by importing their transfer impedance profile.

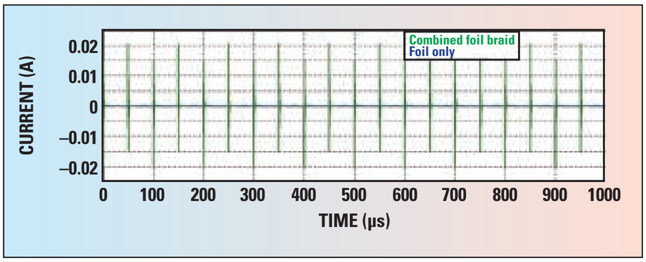
If there are multiple shields, their combined transfer impedance can be found analytically by taking into account the internal impedance of each shield and the inductance between them.[3] Cable simulation software incorporating such calculations is capable of simulating multi-layer shielding arrangements. Because foil and braided shields work best at different frequencies, combining the two in the cable gives it a good broadband noise rejection profile. The crosstalk analysis can now be repeated, but with shields in place – in this case, either a foil shield or a combined foil and braid shield around the signal wires – to see how this affects the noise characteristics of the cable.

The combined two-shield cable has far better coupling rejection than the cable with just a foil shield. In fact, the common mode noise is so low on this cable that it is too small to see in ***Figure 9*** – the peak current is less than 4 μA.

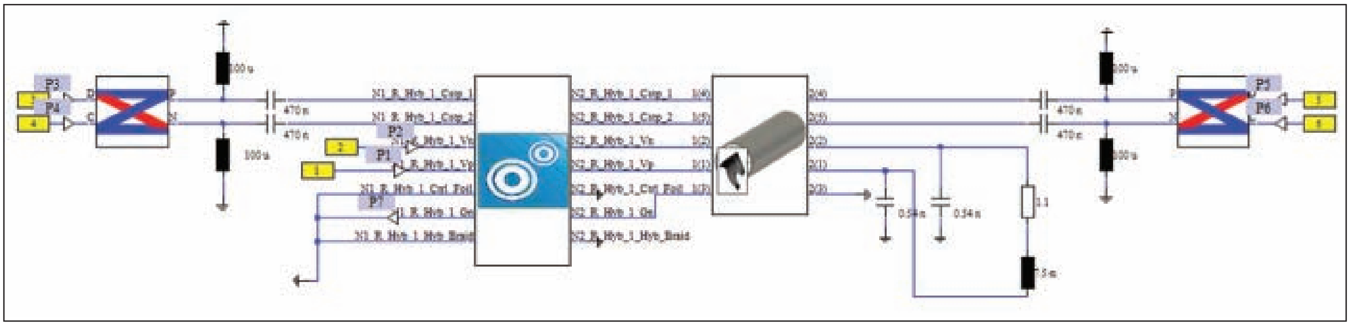


▲ *Fig. 7 Creation tool box for a foil shield in CST CABLE STUDIO™, showing the transfer impedance curve over a range of frequencies.*

▲ *Fig. 8 The same dialog for a braided shield. The transfer impedance rises dramatically at high frequencies.*



▲ *Fig. 9 Common mode noise for different shield arrangements. The induced current when both shields are used is too small to see.*



▲ *Fig. 10 A circuit for testing a cable linked to the load by a shielded connector.*

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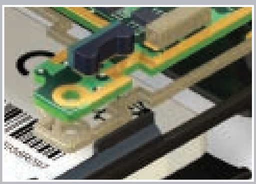


The cable and the connector can also be combined together in one simulation. Circuit co-simulation, combining results from multiple full-wave and cable simulations, connects components so they can be simulated as a system. ***Figure 10*** shows a circuit for one such simulation: the power lines are driven by a periodic switching voltage and the load is modeled by lumped elements. The output from the cable – the blue box on the middle-left – is simply linked to the input of the connector from ***Figure 11*** – the gray tube on the middle-right. Because the S-parameters of the connector have already been calculated, the circuit solver can run very quickly; there is no need to rerun the entire 3D full-wave calculation.

EXPERIMENTAL VERIFICATION

As a demonstration of the effects of grounding and shielding on EMC, and to show the accuracy of cable simulation, multiple cables – standard RG58 coax with a braid, RG6 coax with a combined foil/braid shield, twisted pair with a foil and drain wire, shielded twisted pair (STP) with a braid, and the unshielded versions of the cables – had their EMI properties studied, both experimentally and using computer modeling. These cables were terminated in TNC connectors, which contain a metal shell or shield, enabling an ideal 360° connection between the cable and connector shield. To provide a further comparison, an additional length of twisted pair wire was terminated in a non-shielded connector with a "pigtail" connection from the cable shield to the inside of the enclosure housing (see ***Figure 12***).

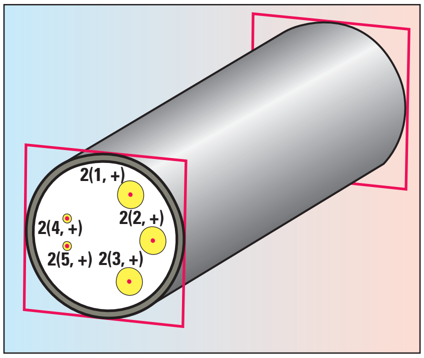


Fig. 11 A shielded connector compatible with the hybrid cable showing the ports for simulation.

The interference source was a wire loop radiating across a range of different frequencies. This loop can couple to the signal wires in the cable – the extent to which the cables reject this interference enables the shielding effectiveness to be assessed. The system would be difficult to solve accurately in full 3D due to the small details in geometry and the specialized cable simulator makes it possible to solve the problem in a fraction of the time (see ***Figure 13***).

Figure 14 shows the results of the study, where increasingly negative coupling corresponds to higher shielding effectiveness. The unshielded results serve as a reference. The spiral/drain cable with a pigtail termination provides an additional 20 dB or so of shielding at low frequencies, but its effectiveness degrades at higher frequencies. The same cable was simulated with a TNC termination (dashed blue line) for comparison, and provides further improvement in shielding, as expected. The STP, RG58 and RG6 cables show good shielding effectiveness at all frequencies. Unlike a 360° shield termination, which provides a low impedance connection from the shield to the ground, the pigtail connection adds inductance and the corresponding frequency-dependent impedance. Furthermore, the aperture in the enclosure is no longer closed and may leak electromagnetic fields to the interior of the load box, coupling noise to the exposed signal wires.

Fig. 12 The experimental setup showing the pigtail connector (left) and the signal cable (right).

The measurements all agree closely with the simulation. With highly shielded cables, the coupling is very small and the induced signals may be below the noise floor of the experimental equipment. This explains some differences for coupling levels below –90 dB. Although it only used a very simple representation of the system, cable simulation was able to model the results very accurately – the simulation even identified a significant resonance at approximately 65 MHz that was subsequently seen in the experiment.

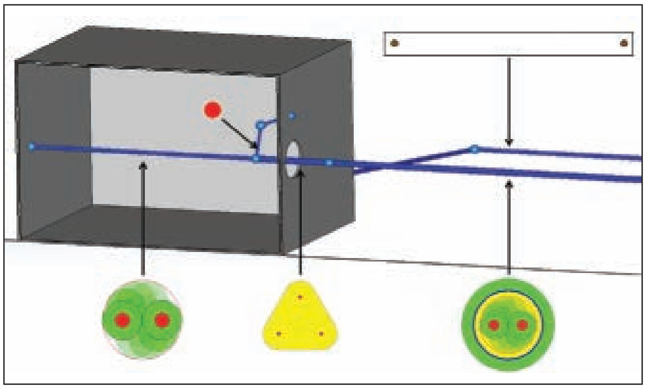
TRANSIENT CO-SIMULATION

Calculating the properties of a cable gives a good idea of its intrinsic characteristics, but in the real world, cables are rarely if ever completely isolated from the environment. Nearby structures, external fields and the route of the cable can all have an effect on signals within the cable. The transient nature of many interference effects, however, means that a full-wave simulation is necessary to model the precise behavior of many potential sources of interference, such as ESD and electromagnetic pulses (EMP).

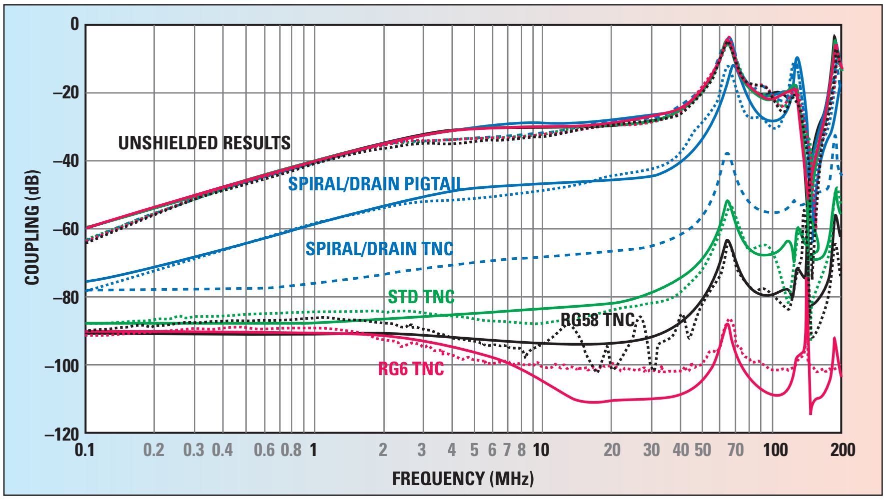
Simulation is therefore a useful tool for full system design, but neither specialized cable simulation nor full 3D simulation alone is ideal for giving a complete picture of how a cable behaves in a complex system. Combining them into a hybrid co-simulation task means that the advantages of both – the fast, accurate cable models and the versatility of full-wave – can be brought to the fore.

Two types of cable co-simulation exist: unidirectional and bidirectional. In unidirectional simulation, the cable is assumed to be either a transmitter or a receiver, while in bidirectional simulation, it is both. Bidirectional simulation is therefore most useful for examining how the coupling between a cable and its surroundings affects signals on the cable itself.

Figure 15 shows a typical application of bidirectional co-simulation. The helicopter contains a number of cables, carrying both power and signals, following complex curved routes. The cables may directly couple if routed too closely together, and radiated



▲ *Fig. 13 Model of the same system in CST CABLE STUDIO™ showing the wire cross section for each segment.*



▲ *Fig. 14 Coupling between the shield and the transmitter for different types of cables, simulated (solid lines) and measured (dotted lines).*

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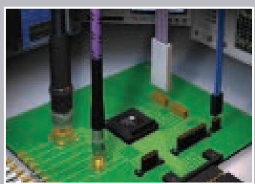

fields may excite resonances inside the vehicle, which can lead to increased coupling. Transient co-simulation allows a number of different scenarios to be modeled. One example would be the potential susceptibility due to an electromagnetic pulse (EMP). A pulse striking the aircraft may couple to the inside through imperfectly conducting panels and seams inducing current in the cabling.

CONCLUSION

Simulating cables requires careful consideration. Specialized cable simulation software can be incorporated into the cable design workflow to speed up the process and give the designer an idea of how the cable will behave once connected to the system. These calculations can give not only the electrical properties of the cable itself, but also permit to observe how fields propagate along the cable and interact with the environment. Properly set-up, cable simulations can replicate real-world situations very accurately, with the results of simulations agreeing very closely with measurements in the laboratory or field. ■

▲ *Fig. 15 A simple wiring system inside a helicopter, showing cables for the control system, antenna (center) and rotor (right).*

ACKNOWLEDGMENTS

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David Johns *is the VP of engineering and support at CST of America and is based in the Framingham, MA office. He holds a Ph.D. in Electrical Engineering from Nottingham University UK, specializing in the development and application of the TLM method. He has been actively involved in the modeling of EMC, EMI and E3 problems for over 20 years.*

Patrick DeRoy *is an application engineer at CST of America and is based in the Framingham, MA office. He recently completed his M.S. degree in Electrical Engineering at the University of Massachusetts, Amherst. His Master's project focused on cable shielding and transfer impedance modeling using CST STUDIO SUITE and validating simulation results by comparison with measurements.*

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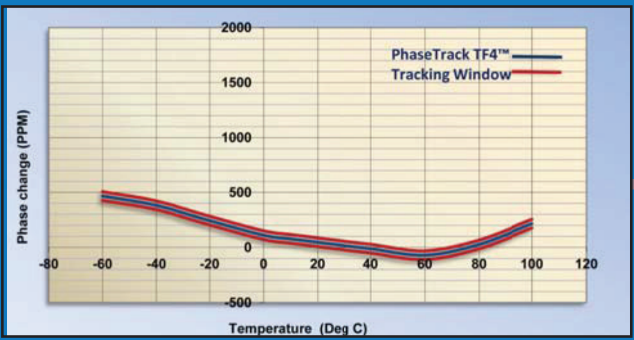

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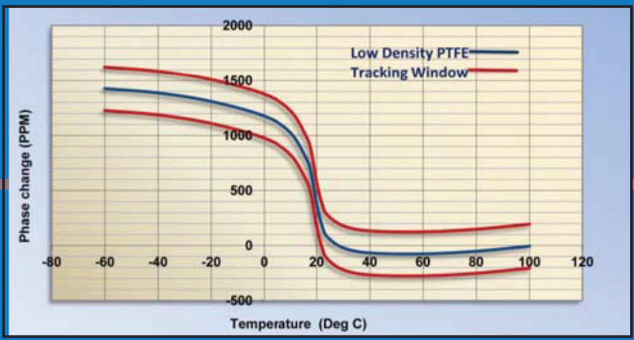

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Making the Connection at EDI CON 2013

The Connectivity Workshop and Expert Panel, to be held as a special event within the Electronic Design Innovation Conference (EDI CON 2013) in Beijing this month, will give Chinese RF/microwave engineers an opportunity to learn about various cable, connector and cable assembly technologies in the context of overall high frequency electronic component design and system integration. The combined workshop and panel session will feature individual presentations from some of the world's leading cable/connector vendors followed by a group panel discussion on the capabilities of today's RF, microwave and high-speed interconnects and the challenges of the systems they support.

Speakers from Mitron, Insulated Wire (IW), Times Microwave, Maury Microwave and Southwest Microwave will present various connector technologies and their corresponding electrical and mechanical characteristics. These talks will concentrate on connector performance, examine how cable/connector attributes align to high-frequency application requirements and guide engineers who require help in selecting the appropriate interconnect solutions for the systems and instrumentation equipment they are developing.

SOME OF THE CHALLENGES

Cables are often the last detail considered during system designs and yet as a ubiquitous component in the signal path of any communication system, their performance is critical to the overall health and performance of the system. The ideal cable system must consider factors such as weight, durability, performance and cost. To avoid being the source of a failure, interconnect systems must be engineered to last the life of the product in any environment. Today's cable systems are increasingly being used in hostile environments, exposed to extreme temperatures, chemicals, abrasion and extensive flexing. Meanwhile, today's high-frequency applications call for smaller, lighter packaging, that last longer and cost less, especially in satellite communications and navigation systems.

To help workshop attendees better understand how to select the best connector/cable for their application, workshop presenters will discuss the constraints that affect performance, including electrical, mechanical, environmental, and application-specific factors. Presenters will share information regarding the materials and construction used in their cable/connector products, emphasizing the engineering and manufacturing technology behind achieving specific performance requirements. Attendees will learn how manufacturers use testing and data analysis to qualify their existing products and enhance future ones.

PERFORMANCE CRITERIA

Electrical performance is often the leading consideration in cable/connector selection. The workshop presenters will discuss the various ways in which cables may impact signal integrity and thus the overall system performance including impedance mismatch (VSWR), which lead to reflections of microwave energy between modules and devices (reducing signal strength and power added efficiency), insertion loss, which ultimately determines the maximum length of a signal cable, electromagnetic interference (EMI) and crosstalk, which results from unwanted coupling of signals between two transmission circuits.

While the electrical performance may be reliable under ideal conditions, environmental factors such as temperature can play a significant role in impacting how connectors behave

DAVID VYE
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in the real-world. For instance, the electrical properties of the material used to support the inner connector of a coaxial cable is subject to change with temperature and mechanical stress. Presenters will discuss this phenomenon, known as the "Teflon-knee," and its impact on phase stability over temperature. The workshop will also consider the impact of mechanical stress when cable systems operating at high speeds in tight spaces are exposed to movement, such as in handheld devices or automation and aerospace applications. Random, rolling and torsion type motion can cause severe damage if not properly managed. Presenters will discuss some of the real-world problems that can degrade performance, how to avoid such mishaps through installment best practices and/or better cable selection.

Environmental stress will have a different impact on performance depending on where cables are used and exposed. Extreme temperatures affect cable materials, with low temperatures making them brittle while high temperatures will cause them to become very soft. Like extreme temperatures, extreme pressures can also have a significant impact on cables. Cables operating in a vacuum may leach oils and additives, which could lead to contamination of a work surface such as a clean manufacturing process for semiconductor chips. Conversely, hydrostatic pressure causes gas or liquids to permeate insulation or cable jackets and can destroy some cable materials. Workshop presenters will look at how these environmental factors and others can significantly shorten the life of a cable, and how to factor such considerations into designing a cable system with the proper technology.

HANDLING TIPS

RF cable assemblies are designed to operate at the highest electrical performance level. High performance cables require special handling procedures to ensure optimum electrical performance. Many of these handling procedures will be discussed by a speaker from Insulated Wire (IW) in the presentation "How to Get the Best Performance Out of Your Cable Assembly." By taking a few basic preventative measures during cable handling, installers and system assembly technicians can significantly extend the life of their assembly and avoid system failures. The expert from IW will provide tips on how to prevent some common problems such as internal damage caused by compression and how to prevent the cable from bending below its minimum bend radius which would cause the cable to kink and also results in internal damage. To maximize connector performance and lifetime, the presenter will discuss proper torque down procedures, connector orientation and how to avoid assembly twisting, proper cable tie down methods, providing adequate drip loops, weather proofing and working with short cable assemblies.

Connector Types

In addition to integrating modules and subsystems, connectors are also used to launch signals from coax to planar substrates where the surface mount ICs and discrete devices that provide radio functionality reside. With pressure to reduce circuit size and increase functionality, engineers are working with thinner PCB materials often at higher frequencies. Design and test engineers need to be aware of the quality of their electrical interface between planar substrate (microstrip, stripline, etc.) and the connector launch. Poor choice in connector size and shape can lead to undesirable parasitics and unacceptable VSWR, resulting in non-optimal performance, power loss and inaccurate device characterization (when being used as part of a test fixture). For example, substrates that are thinner than 8 mil have line widths that are too small to optimize the launch with a taper for even the smallest connector pin. For substrates that are thicker than 30 mil, line structures can be created that achieve a good match and bandwidth to 50 GHz, but the loss of these lines starts to increase significantly at higher frequencies.

In addition to developing better performing products, innovation can also target usability and convenience for the user. Maury Microwave, a leading test solutions provider that also develops interconnect products, will be discussing an innovation that does both. The company's new China country manager, Nian-min Zhang, will present the new ColorConnect™ precision adapters, which are designed for lab and field use addressing the need for quality, performance, ease-of-identification and ease-of-use. New manufacturing techniques have resulted in improved VSWR specifications bridging the gap between calibration-grade metrology adapters and daily-use lab adapters. Following the proposed IEEE high-frequency connector/adapter color convention, the components are the first commercially available products to offer clear indications of compatibility and intermatability. Zhang will discuss how the product 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 adapters.

Addressing Various Applications

Technology trends in circuit miniaturization, wide bandwidths, increased circuit density and functionality, linearity and passive intermodulation requirements are forcing evolution in connector technology. The physical and electrical attributes of connectors are constantly improving, supported by advanced design/analysis capabilities (3D EM simulation such as CST or HFSS) and precision machining.

Cable assemblies and connectors have become specialized for test applications, aircraft, spaceflight, defense and commercial communication applications. Clarifying the specific requirements of these different applications and aligning them to a particular interconnect technology will be a common theme of this special EDI CON workshop/panel. The workshop will allow presenters to educate attendees with regard to some of these advances and the panel session will allow attendees to ask the experts about their own particular needs and challenges. ■

PIM Test Power Levels For Mobile Communication Systems

In 1999, the International Electro-technical Commission (IEC) released Standard 62037 providing the wireless industry a consistent test method for measuring Passive Intermodulation (PIM) in RF components and systems. Over the next 12 years, wireless technology evolved from 2G systems serving primarily voice traffic to 4G systems serving high-speed data users. These 4G systems require new network architectures with broadband modulation schemes to achieve the required increase in network capacity. This article reviews the applicability of IEC 62037 for qualifying components, subsystems and systems used in today's commercial telecommunications infrastructure and specifically addresses whether or not there is technical merit in increasing PIM test power levels from 20 to 40 W.

WHY DO WE MEASURE PIM?

PIM occurs when two or more high power RF signals encounter nonlinear electrical junctions or materials in an RF path. These nonlinear junctions behave like a mixer causing new signals to be generated at mathematical combinations of the original RF inputs. If these signals fall in a network operator's receive band, the noise floor rises causing reduced data rates and decreased service quality.

PIM is often caused by inconsistent metal-to-metal contacts in high current density regions such as inside transmission lines, inside RF components, or outside the system but in the main beam of an antenna. Common sources of PIM are:

- Contaminated or oxidized RF surfaces
- Inadequately torqued RF connectors
- Loose screws or rivets inside RF components caused by transportation shock and vibration
- Metal flakes or shavings inside RF connections
- Poorly prepared RF terminations due to improper tooling, or incorrect assembly procedures
- Metal flashing or rusty vent pipes in front of antennas on roof-top sites

PIM testing identifies the presence of these defects using RF transmission as the stimulus and highly sensitive receivers to detect and measure the response. PIM testing is the ultimate measure of construction quality of RF components, subsystems and systems. It will identify mechanical, as well as material defects in workmanship that may go undetected by more conventional techniques such as visual inspection or S-parameter measurement.

LACK OF STANDARDS

In the early days of commercial telecom, it was understood, based upon experiences of other communications systems and most particularly satellite communications, that PIM could produce interference conditions that were performance impacting. Recognizing this, mobile operators and OEMs impressed upon their component suppliers (manufacturers of antennas, cables, connectors, filters, lightning protectors, etc.) the need to provide "Low PIM" solutions. However, there was very little guidance of what "Low PIM" meant.

Left to their own devices, component manufacturers around the world began specifying the PIM performance of their products using varying and inconsistent parameters. Some manufactures only conducted PIM tests in their engineering laboratories claiming that their products were "Low PIM" by design. Others conducted PIM tests on each unit produced to verify not only the design but also assembly workmanship. Some certified higher order PIM products such as IM5 or IM7 depending on the end-user's band of operation. Finally, some manufacturers specified peak PIM while applying mechanical stimulus (dynamic testing) while others measured the best case PIM achieved with the DUT at rest (static testing).

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This arbitrary and haphazard approach made it impossible to compare products and performance. To establish consistency, IEC Technical Committee 46, Working Group 6 was formed to create an industry standard for Passive Intermodulation testing. The PIM Working Group was comprised of OEMs, component manufacturers, universities and national standards organizations.

DEVELOPING THE RECOMMENDED TEST STANDARD

There were many energized debates among the working group constituents that ranged from academic, to practical, to sometimes political. There were arguments about how many carriers should be used, how much power was needed, what IM products to measure, how to define repeatable and meaningful dynamic tests, and whether PIM testing was even necessary since only high order IM products could land in the operator's own receive band.

After considerable analysis, experiments and discussion, IEC Standard 62037 was finalized and released in the fall of 1999. The specification defined technical requirements for PIM testing apparatus as well as provided key recommendations to enable consistency in PIM performance comparisons. Two key recommendations from the original specification were:

- PIM comparisons should be conducted at the same power level: 2 × 20 W recommended for mobile communications applications
- Third order IM products typically represent the worst case condition of unwanted signals; therefore measuring IM3 characterizes the DUT

An update to IEC-62037 was published in May 2012 with more specific instructions for testing of antennas, connectors, cables, cable assemblies and filters. This new revision contains the same fundamental recommendations as the original specification: measure IM3 using 2 × 20 W test tones and adds clarity regarding a third key requirement for PIM tests:

- Devices should be subjected to impact or movement while PIM testing

TESTING AT HIGHER CARRIER POWERS

Some PIM test equipment manufacturers have claimed that PIM testing should be conducted at 40 W rather than the IEC recommended 20 W level in order to "spot problems that cannot be seen on a 20 W PIM tester." Further claims are made that 40 W is the correct power level to use since it is more representative of "real world" BTS operating conditions.

To determine whether or not there is validity to these arguments, first consider the claim that PIM testing should represent "real world" BTS conditions. As seen in ***Table 1***, PIM test parameters have very little to do with the particular air interface, number of carriers, or power level deployed at a site. Rather, the test parameters were selected to define an accurate method to measure the degree of nonlinearity present in an RF path. Presented further in this document, 20 W is more than enough power to accurately measure nonlinearity in RF components as well as in completed feed systems.

If the goal was to simulate the actual BTS environment, the required test equipment would need to transmit hundreds of watts to capture the full range of base station transmit levels. Test equipment would need to transmit multiple carriers rather than just two and would need to transmit GSM, wideband CDMA or LTE waveforms rather than CW test tones. The resulting test equipment would be significantly larger, heavier and more expensive and would pose safety risks to technicians performing the test. In addition, this equipment would need to be replaced every few years to keep up with the ever changing wireless industry (2G, 3G, 4G, etc.). This is not a practical solution for RF equipment manufacturers, or network operators forced to continually invest additional CAPEX to keep up with a continuously changing specification.

These are exactly the same issues that the IEC working group faced back in 1999. Their challenge was to develop a test that was "fit for purpose" and not constantly changing based on individual manufacturer's claims. The IEC team analyzed this problem over several years and produced the test specification that the industry has relied on ever since.

To address the claim that higher test power will unveil PIM problems that cannot be seen using the industry standard 20 W test, one must understand how PIM behaves with increasing test power as well as consider the test as a whole rather than by its individual components. The magnitude of PIM produced by a given defect is dependent on the physical characteristics of that defect. Looking at the data in ***Figure 1***, one can conclude that the Spinner PIM standard (produced using a diode in its construction) creates the highest level of PIM and that the corrugated jumper cable (constructed with solid copper conductors with soldered connections) produces the lowest level of PIM at any given test power. Some observations from Figure 1 are the more severe the defect, the higher the PIM for a given test power, the PIM level increases linearly on a dB scale with increasing test power and the rate of PIM level increase versus test power is different for each PIM source. One will also notice that as the test power changes over the range of 2 to 40 W, the magnitude of the PIM produced

TABLE I
COMPARISON OF PIM MEASUREMENTS AND ACTUAL BASE STATION OPERATING PARAMETERS

	PIM Measurement	Typical BTS
Carrier Modulation	CW	Various: GSM, UMTS, CDMA, LTE
Number of Carriers	2	1, 2, 3, 4 or more
Bandwidth per Carrier	5 kHz	> 5 MHz for LTE
Carrier Power	20 W	20, 40, 60, 80 W and higher
IM Product of Concern	IM3	IM5, IM7, IM9 and higher


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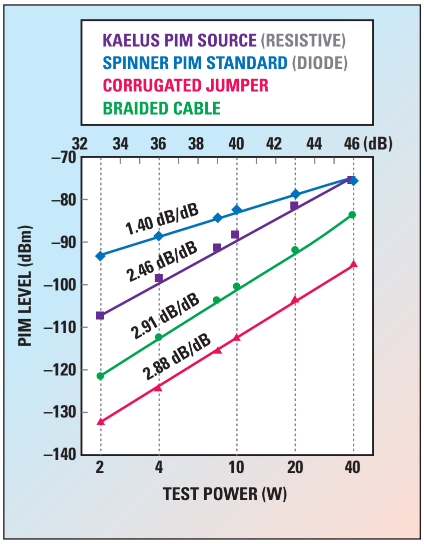


▲ *Fig. 1 IM3 change vs. test power.*

by each defect also changes. In theory, IM3 is expected to change 3 dB for every 1 dB change in test power and is expected to be linear over a wide range of test powers. In practice, this rate of change is typically lower and varies based on the physical characteristics of the defect causing the PIM. In the example, the "PIM slope" varies between 1.4 and 2.9 dB/dB for the components tested and, as expected, remains very consistent over the full range of powers tested.

This means that if we know the magnitude of PIM produced by a defect at one test power level and we know the PIM slope, we can accurately estimate the magnitude of the PIM that will be generated at a different test power. Using this knowledge, we can see that nothing new or unexpected is revealed by increasing the test power. The PIM magnitude is higher at 40 W than it is at 20 W, but it is higher by a predictable amount.

In order for the claim to be true that 40 W PIM testing will "spot problems that cannot be seen on a 20 W PIM tester," either the test instrument does not have sufficient receiver sensitivity to yield a 10 dB signal to noise ratio for the PIM signal being measured or the PIM level increases in a nonlinear fashion (on a dB scale) as the test power level increases. High quality PIM test instruments manufactured today typically achieve a receiver noise floor level on the order of –130 dBm. Since the IM3 level that is required to measure is on the order of –150 dBc (–107 dBm) for factory tests and –140 dBc –97 dBm) for field tests, the typical signal-to-noise ratio achieved is between 23 and 33 dB. This means the PIM signal level is already 20 to 200 times stronger than the 10 dB minimum signal to noise ratio required for an accurate measurement. Increasing the test power does not create a useful benefit in measurement accuracy and may increase the personal safety risk to test personnel.

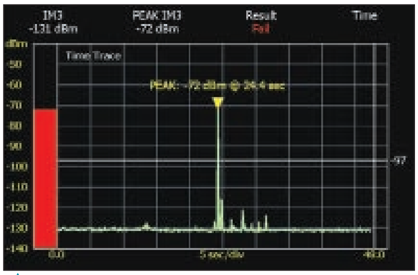
The data presented in this paper shows that IM3 increases linearly on a dB scale with increasing test power. This is true for the vast majority of defects found in RF components and in typical cell site installations. Similar results have been demonstrated across a wide range of test powers and test frequencies by other investigators.[1,2]

THE IMPORTANCE OF DYNAMIC TESTING

It is important to emphasize that all elements of a PIM test are important and must be used together to ensure the quality of the system under test. Accurately controlling the test power alone does not ensure a trouble free system, regardless of the test power level used.

To demonstrate the importance of dynamic testing, metal flakes (see ***Figure 2***) were inserted inside an RF connection and the system was

▲ *Fig. 2 Metal flakes used to demonstrate the need for dynamic testing.*



▲ *Fig. 3 Results of dynamic testing showing jump in PIM level.*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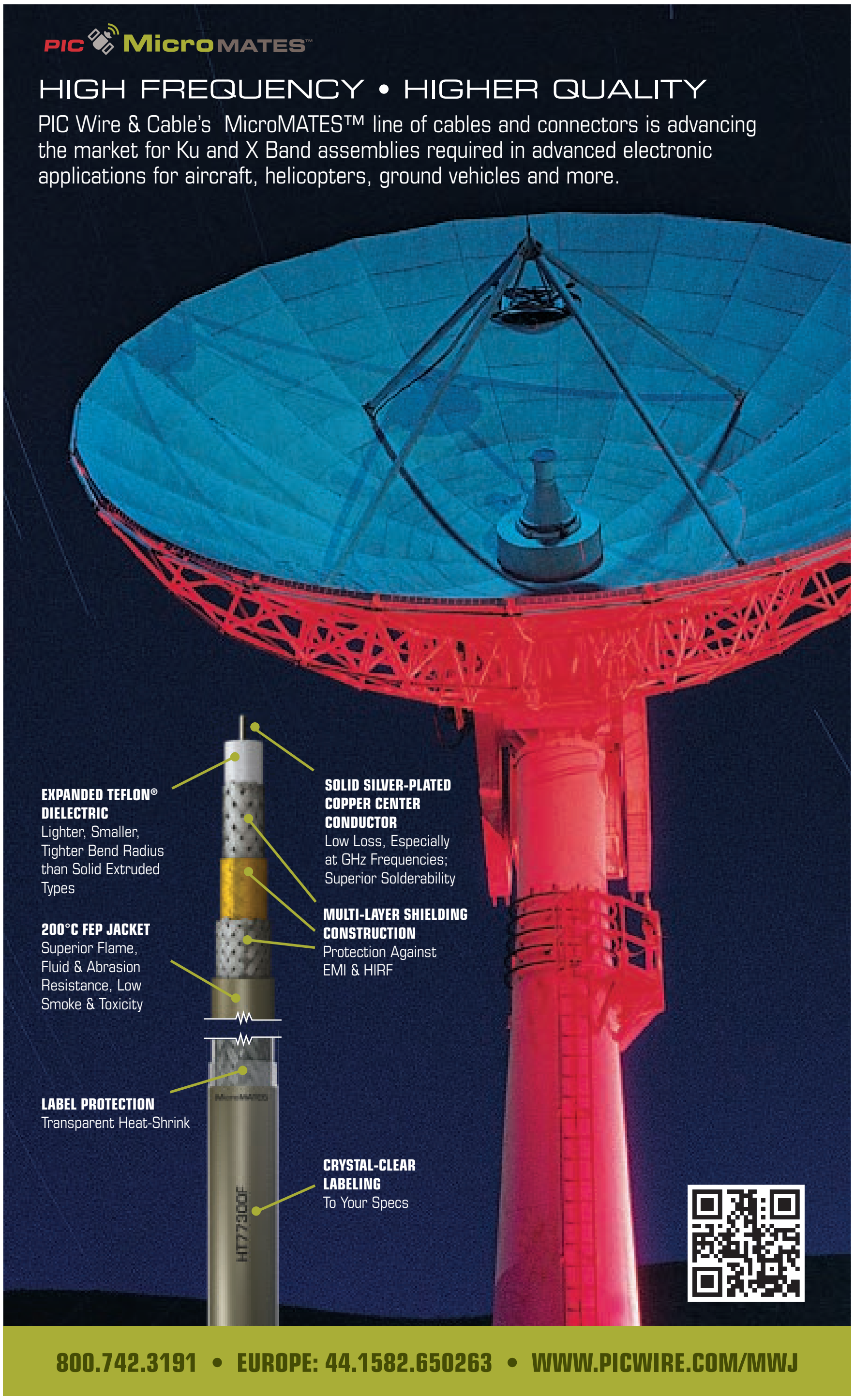
tested using the required 20 W power level. Without mechanical movement (static testing) the PIM performance appeared to be very good. When the connection was lightly tapped (dynamic testing) the PIM level jumped more than 50 dB clearly indicating that a problem exists (see ***Figure 3***).

Dynamic testing identifies loose metal-to-metal connections as well as contact surface defects that might cause arcing at higher power levels. Without dynamic testing, these defects could go unnoticed until activated by wind loading, tower vibration or stresses caused by temperature changes.



Claims have been made by test equipment manufacturers that using 40 W of power rather than 20 W eliminates the need for dynamic testing. There is no single test power that by itself will sufficiently stress a system to identify defects. Applying mechanical stress while the PIM test is in process is the only way to ensure that the system is robust. If simply increasing the test power would have eliminated the need for dynamic testing, the IEC working group would not have spent the last 10 years fine tuning dynamic PIM test requirements for RF components such as jumper cable assemblies, RF connectors, filters and antennas. Details of this work can be found in the newly released versions of the IEC 62037 PIM test specification.

CONCLUSION

The existing PIM test standard was developed through a lengthy process of analysis, measurement and debate by a respected group of engineers, scientists and managers from the commercial telecommunications market: OEMs, component manufacturers and standards organizations. The test standard produced has been used globally for more than a decade. Component manufacturers, OEMs and network operators have built their quality procedures and performance requirements around measuring IM3 with 2 × 20 W test tones while applying dynamic stimulus. As shown by the example of the metal flakes inside a connector, dynamic stimulus is a critical component of the PIM testing process for identifying faults that are not visible under static conditions. There is no technical justification for changing the power level used for PIM tests to 40 W or any other power level (higher or lower). Nothing has changed since the specification was first released in 1999 to invalidate the IEC's original, well considered recommendations. ■

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1. P.L. Lui, "Passive Intermodulation Interference in Communication Systems," *Electronics & Communication Engineering Journal*, Vol. 2, June 1990, pp. 109-118.
2. M. Bayrak and F. A. Benson, "Intermodulation Products from Nonlinearities in Transmission Lines and Connectors at Microwave Frequencies," *Proceedings of IEEE*, Vol. 122, April 1975, pp. 361-367.

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200	1.22	1.3
225	1.28	1.3

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Connect with Confidence: Color-Coded Interconnects

We all know of engineers and technicians who have at times been unsure whether two adapters mated, whether cable assemblies could be connected and what torque wrench to use. With this uncertainty comes an underlying fear of damaging equipment, reducing measurement accuracy and wasting precious time. If only these interconnects, which are so similar, could be easily labeled and identified.

John Bies of Redstone Arsenal certainly did; he lobbied for the establishment of a "standardized method to rapidly identify high frequency coaxial connectors." His report included a short list of possible results from misidentifying connectors and attempting to mate two incompatible connectors, including damaged equipment, degraded equipment reliability, degraded performance, degraded mission readiness, increased maintenance time, increased maintenance actions and lost efficiency. Additionally, even if two connectors could mate, their operational frequencies might differ, as is the case with mechanically compatible 3.5mm and 2.92mm connectors where the highest common operational frequency may only be 26.5 GHz.

Bies went on to state that the benefits of color-coding high frequency coaxial connectors would include the elimination of damage to equipment, a greater confidence in connector identification and use, a financial saving in training time and costs (he estimated $5.8 million and 5000 man-hours per year in the U.S. military/government agencies alone), an increase in efficiency, reliability and readiness, and an improvement in personnel safety.

An Institute of Electrical and Electronics Engineers (IEEE) Coaxial Connector Rapid ID Working Group was established in June 2008 and a proposed color code scheme was developed in August 2008. The IEEE project authorization request P1802 was submitted for review in January 2009 and approved in May 2009. The working group is now referred to as IEEE P287 with mandate to review the 287-2007 standards for coaxial connectors. With no other reason than selecting a familiar color scheme known to engineers across the globe, the standard resistor color-code BBROYGBVGW was proposed for high frequency coaxial connectors (increasing resistor value compared to increasing frequency) and is shown in ***Figure 1***.

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COLORCONNECT™ PRECISION ADAPTERS

ColorConnect Precision Adapters are currently the only commercially available adapters to employ the IEEE working group color-coding scheme. These adapters offer improved VSWR specifications bridging the gap between calibration-grade metrology adapters and daily-use lab adapters. Compensated beads maintain an accurate 50 Ω transmission line for improved VSWR performance. Compensated female contacts extend the usable lifetime to more than 500 matings. Critical pin-depth and position-tolerance prevents performance degradation (due to "gap-fit") and component damage (due to "interference-fit"). Inner and outer conductor's finish and materials ensure high conductivity with reduced signal loss. Mating surface flatness and finish minimizes signal loss. Orbital consistency and concentricity ensure proper alignment and best repeatability. ColorConnect Precision Adapters are available in SMA, Type N, 3.5mm, 2.92mm, 2.4mm and 1.85mm in-series and between-series and are selectively shown in ***Figure 2***.

STABILITY™ CABLE ASSEMBLIES

Cable assemblies are used in a wide range of applications and by a user-base with varying degrees of experience and training. As with the adapters, how can one be certain that the cable assembly about to be connected is in fact compatible, and that damage to both the assembly and system will not occur? Listening to its customers, Maury implemented its ColorConnect color-coding to its Stability line of cable assemblies.

BLACK	— DC–18 GHz —	Type N Connector
Brown	— DC–18 GHz —	SMA Connector
Red	— DC–20 GHz —	Precision Type N Connector
Orange	— DC–26.5 GHz—	3.5mm Connector
Yellow	— DC–40 GHz —	2.92mm (K) Connector
Green	— DC–50 GHz —	2.4mm Connector
Blue	— DC–67 GHz —	1.85mm (V) Connector
Violet	— DC–18 GHz —	GPC-7 Connector
Gray	— DC– <Reserved for future use>	
White	— DC–110 GHz	— 1.0mm (W) Connector

▲ *Fig. 1 Proposed color coding scheme.*

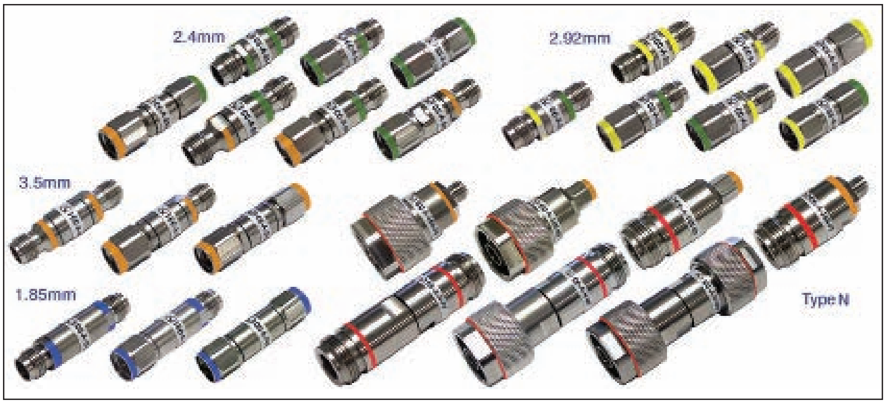
Designed specifically for phase-stable and amplitude-stable applications, Stability offers excellent measurement repeatability even after cable flexure. With a ruggedized, durable construction, Stability will outperform other typical assemblies resulting in a reduced total cost-of-test. Stability's light weight, flexibility and small form factor make it ideal for daily use with VNAs, test instruments, bench-top testing and ATE systems.

Stability assemblies are offered with 2.92mm connectors to 40 GHz, 3.5mm connectors to 26.5 GHz and Type N connectors to 18 GHz, and have respectable insertion losses of 0.84, 0.67 and 0.54 dB/foot, respectively (at F_{max}). Designed specifically for phase- and amplitude-stability, these assemblies offer a typical phase-stability after bending of 5, 3.5 and 2 degrees, respectively, and an amplitude-stability after bending of 0.05, 0.02 and 0.0015 dB, respectively. Phase stability with temperature is less than 4°/m/GHz between –55° and +125°C. Stability achieves a crush resistance of > 260 lb/inch (44 kN/m) by employing additional ruggedizing layers, including a crush protection layer, a braided strength member and braided outer jacket.

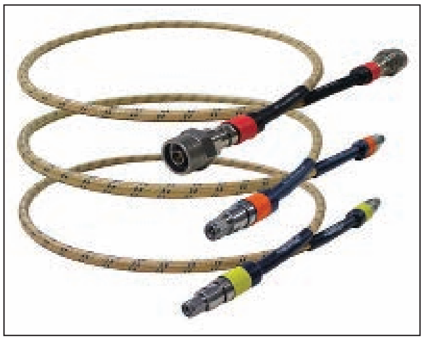
The assemblies have a minimum bend radius of 1 in (25.4 mm) making it flexible and versatile. With a flex life-cycle over 20,000, Stability offers one of the lowest cost-of-ownership of most any phase-stable assembly. 2.92mm, 3.5mm and Type N color-coded Stability Cable Assemblies are shown in ***Figure 3***. ColorConnect Precision Adapters and Stability cable assemblies have been specifically designed so that the color identification bands are visible when connected, making identification and verification simple without the need to disconnect any piece of the interconnect chain.

TW-SERIES TORQUE WRENCHES

Most, if not all, 5/16"-hex high-frequency connecters look similar from the outside but vary greatly in performance and design. Sub-Miniature version A (SMA) connectors use a polytetrafluoroethylene (PTFE) dielectric which contacts along the mating plane, that along with the



▲ *Fig. 2 Assortment of in-series and between-series color-coded adapters.*



▲ *Fig. 3 2.92mm, 3.5mm and Type N color-coded cable assemblies.*

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variances in design and construction can cause mating uncertainties and introduce a possible air gap. Because of the possible variances in materials used (i.e., brass versus stainless steel) and the possibility of the thin outer wall (conventional SMA design), it is generally accepted that SMA connectors require a torque value of 5 in-lb in order to limit possible damage.

Other 5/16" hex high-frequency connecters implement an air-dielectric and are named after the diameter of said dielectric; 3.5mm, 2.92mm, 2.4mm and 1.85mm. 3.5mm and 2.92mm employ center pins of equal size and are thereby mechanically mateable, along with the SMA. However, due to the design and specifications of the connector which includes a stronger wall (0.021 inches in the case of the male versions), 8 in-lb torquing is recommended.

With a common 5/16" hex interface, how does one tell the difference between 5 in-lb torque wrenches designed for SMA connectors, and 8 in-lb wrenches designed for the rest? Maury offered a color-coded handle, black for 5 in-lb and blue for 8 in-lb, but it was often confusing to remember which was which. Maury's new line of TW-series torque wrenches employ color-banded handles, with the 5 in-lb handle striped with a brown band, and the 8 in-lb handle striped with orange, yellow, green and blue stripes, as shown in ***Figure 4***. TW-series wrenches employ a "break" design making it difficult to over-torque a coupled junction. Each torque wrench is factory preset to the proper in-lbs value and have a variance of ± 10 percent. With its high quality, low cost and color code, engineers can match up the paint stripes on the wrench handle with the color bands on the ColorConnect adapters and Stability cable assemblies and be guaranteed a proper torque each and every time.

▲ *Fig. 4 Color-coded torque wrenches.*

Color-coded connectors, cable assemblies and torque wrenches give engineers and technicians the confidence that the proper interconnections are being made. No more doubt or concerns about damaging equipment or inaccurate measurements due to mis-matched connections or improper torquing. They reduce costs, improve testing relibility and reduce setup time. ■

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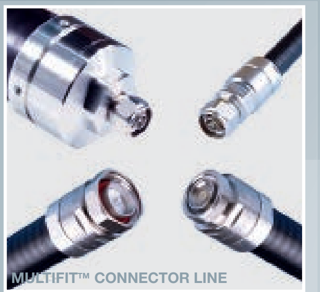

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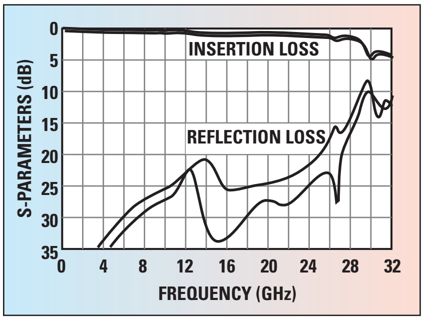
A significant trend is the ever-increasing bandwidth requirements of high frequency electronics and modern data-transmission circuits, alongside a strong push toward integrated modules, is cost and performance. This means that classical coax connectors do not have an important role to play in large volume assemblies at high frequencies. However, connectivity solutions for test and measurement applications are required for frequencies up to 110 GHz and beyond in the design phase. To address these issues, the Solderless PCB Mount Rosenberger Precision Connectors (RPC) were developed.

Surface mount connectors are typically realized as right angle or edge mount types. Both of these types are used throughout the communication industry where impedance control and good shielding properties are required. They are reliable, exhibiting excellent and reproducible results. However, with the move to very high frequencies, where the wavelength of the transmitted signals is comparable to the dimensions of the connector, care has to be taken not to couple resonant structures to the signal path.



▲ *Fig. 1 Calculated insertion (S_{12}, S_{21}) and reflection loss (S_{11}, S_{22}).*

This means that careful control of potential resonances and radiation at the interface from the connector to the circuit board is essential for a predictable performance. The wavelength in vacuum is 3 mm at 100 GHz and quarter (0.75 mm) and half wave (1.5 mm) resonances have to be managed. Voids and gaps have to be small compared to these dimensions, keeping in mind that the wavelength is much smaller in the PCB dielectric.

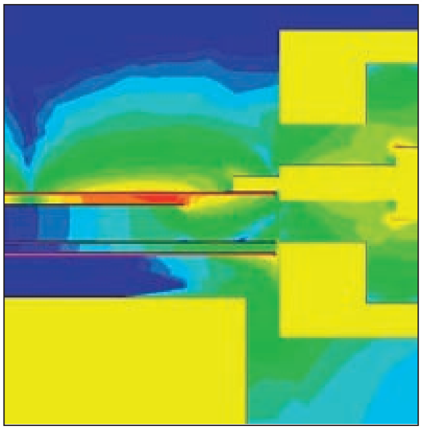
SUBSTRATE THICKNESS

The substrate thickness also has to be kept well below a quarter wavelength for mode-free operation. The ratio of the width of a microstrip line and the substrate thickness is constant for a given substrate material. The sizes of millimeter-wave circuits are thus no more than a few tenths of a millimeter and have to be connected electrically by the center pin of the surface mount connector.

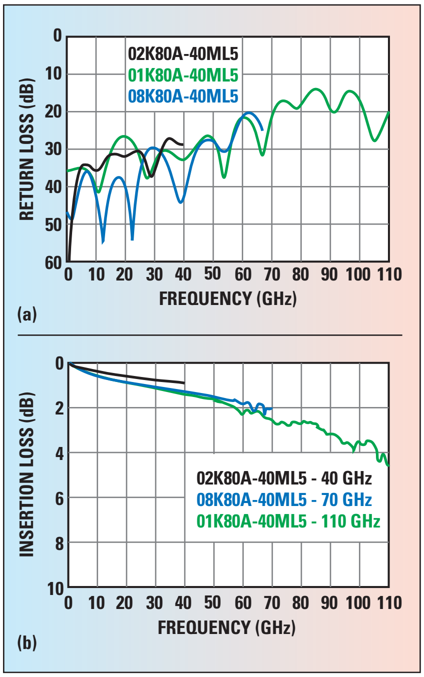
For illustration, we calculated the S-parameters of an edge mount connector that is shown in ***Figure 1***. It shows excellent signal properties up to 25 GHz. However, a very strong resonance is observed at 30 GHz. This is caused by a parasitic resonant structure that is coupled to the transmission line via the gap between the connector body and the PCB ground. It sucks out a significant part of the signal, causing a deep narrowband dip in the order of several dBs in the insertion loss while causing a spike in the reflection loss.

A significant part of the signal is radiated into free space where it may potentially interfere with adjacent circuits. The logarithmic field plot of ***Figure 2*** illustrates the resonant fringing field as it escapes through the void in the ground plane. Stressing a physical model, it

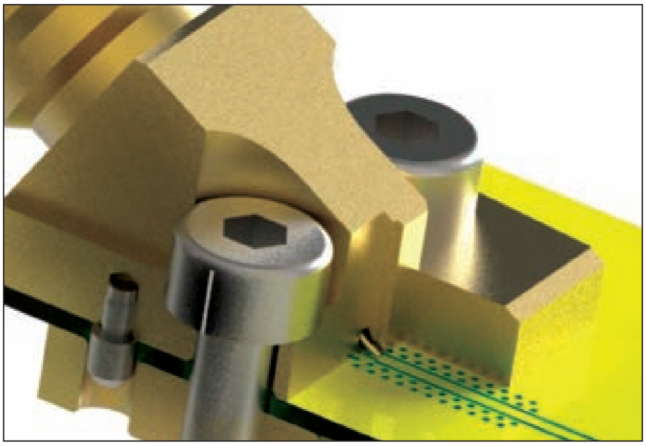
Rosenberger Hochfrequenztechnik GmbH
Fridolfing, Germany



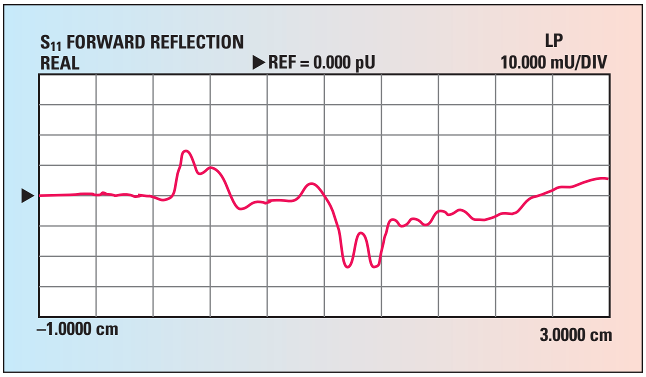
▲ *Fig. 2 Field plot of the resonant fringing fields at 30 GHz.*



▲ *Fig. 4 Measured reflection loss of solderless PCB mount connectors (a) and measured insertion loss (b).*



▲ *Fig. 3 Detailed view of the PCB contact area with cut-out.*



▲ *Fig. 5 Gated S_{11} in TD of the 110 GHz connectors 01K80A-40ML5.*

behaves similarly to a waveguide transition with the signal pin acting like an inductive post. Let us consider how we mastered the challenges.

TECHNICAL FEATURES

The structure of the connector topology that was chosen is depicted in ***Figure 3***. The RF-ground plane and the top ground are connected by many vias that keep the PCB mode-free. The connector block is placed on top of the ground plane. This helps keep the footprint for this connector very simple and easy to design while no resonances may be excited in the transition.

The 'pencil point'-like signal contact causes only a very low capacitive loading to the stripline, which is essential for minimum reflections at high frequencies. No voids are required in the ground plane that would otherwise make the design cumbersome. As the signal pin protrudes from the mounting face of the connector, a spring force is applied to the signal pad once the connector is mounted, providing a stable and vibration-proof connection.

FEATURES

- Connectors are available in: RPC-2.92 (40 GHz) 02K80A-40ML5, RPC-1.85 (70 GHz) 08K80A-40ML5 and RPC-1.00 (110 GHz) 01K80A-40ML5
- No soldering required
- Prepositioning enforced by dowel pins
- Clamping mechanism accommodates a wide range of board thicknesses while providing a continuous ground connection between contact area and circuit board
- Universal, robust and reusable

As expected from the simulations, test results confirm the excellent RF-properties of the new connector series with connectors available up to 40, 70 and 110 GHz. Reflection loss and insertion loss of the three products are plotted in ***Figures 4a*** and ***4b***, respectively. The frequency response is mode-free up to 110 GHz. The insertion loss represents 50 percent of the GCPW-losses on the PCB. The actual insertion loss of the connectors is considerably lower. The 70 and 110 GHz versions have been tested on the same substrate. A separate design was chosen for the 40 GHz version.

This explains the lower loss of the 02K80A-40M at lower frequencies. It may be attributed exclusively to the different PCB layouts. The TDR response of the 110 GHz type of connector is shown in ***Figure 5***. The coaxial interface is on the left. It confirms the excellent impedance control along the signal path. There is a wide field for the application of this connector family in the ultra high frequency test and measurement applications and also in situations where minimum radiation and coupling to adjacent circuitry is mandatory.

Rosenberger Hochfrequenztechnik GmbH & Co. KG,
Fridolfing, Germany
+49 (0) 86 84 180,
info@rosenberger.de,
www.rosenberger.com.

Locking Push-On RF Connector for Harsh Environments

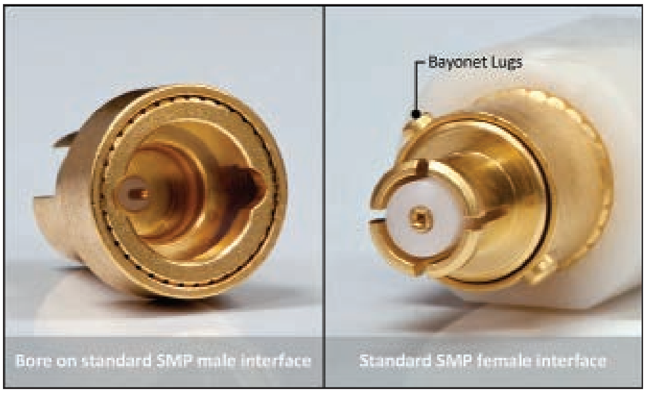
Carlisle Interconnect Technologies has advanced the design of traditional push-on RF connectors with a new line of locking push-on connectors, the SMP-L™ series. This new series of connectors addresses the needs of RF system designers who are looking for a blindmate interconnect solution that can withstand harsh mechanical stress, primarily in rugged military/defense applications such as radars, missiles, handheld radios, avionics and UAVs, as well as for a growing number of commercial uses. The SMP-L connectors are available in cable, PC board or panel configurations for use within microwave modules and subsystems.

DESIGN

The introduction of push-on blindmateable connectors, such as the Sub Miniature Push-on (SMP), galvanized the RF/microwave industry as their use enabled designers to increase package density by stacking PC boards and thus reducing their form factor, while also simplifying the assembly and test of these designs. Since then, SMP and other push-on connector types have become the interconnect system of choice within RF/microwave systems.

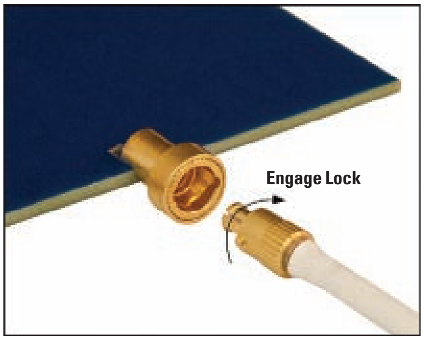
Generally, push-on connectors utilize a push-on or friction-fit mating, or sometimes a snap-on mating to ensure a suitable connection. While a number of factors contribute to the overall performance of these systems, signal integrity issues at the connector level typically arise from any coupling or de-mating problems at the interface, including any alignment issues with respect to the socket (female)/pin (male) components. Under somewhat vigorous use, including harsh environments that are subject to significant movement or vibration at the connector interface, such conventional push-on architectures may not perform well. Furthermore, there are certain applications where push-on connectors are required to remain mated even under the tensile strain of the cable coupled to the connector.

The SMP-L series adds a patent pending positive-locking mechanism referred to as Secure-Lok™ onto a standard SMP interface

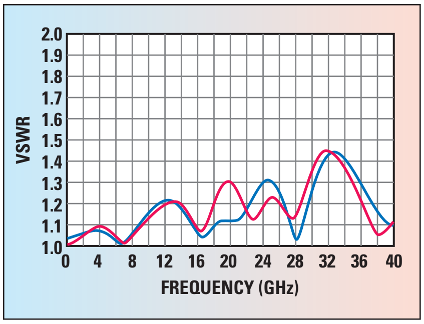


▲ *Fig. 1 Secure-Lok connectors.*

Carlisle Interconnect Technologies
Cerritos, CA



▲ *Fig. 2 SMP-L locking mechanism.*



▲ *Fig. 3 Typical performance of P657SL-3CC (cable connectors) measured on Accuphase TLL40-1111A flexible cable.*

to improve upon the ruggedness and repeatability. The female SMP-L connector interface adds a movable collar onto and rearward of the push-on socket, which includes a pair of bayonet pins. The male SMP-L connector interface adds a second bore onto and in front of the push-on plug, which includes a latch to accept the bayonet pins of the female interface (see ***Figure 1***).

When the female interface is inserted in the male interface and rotated clockwise, the bayonet pins slide along the inclined latch surfaces to axially drive the collar into the receiving bore to secure the female connector onto the male connector (see ***Figure 2***). To disengage the locking mechanism, the collar on the female interface must be pressed in and rotated anti-clockwise to de-mate the connectors. Consequently, the retention mechanism of this design improves upon a push-on connector's ability to resist unintentional de-mating forces, and to maintain signal integrity under adverse operational conditions such as heavy vibration.

PERFORMANCE

The SMP-L connectors retain the electrical performance characteristics of their SMP equivalents, and thus are an excellent fit for RF/microwave systems operating up to 40 GHz. The coupling retention mechanism, Secure-Lok, improves the retention force to > 100 lbs when measured on a 0.085" cable. This ensures that a reliable connection is maintained between the male and female interfaces even in harsh environments where a standard SMP interface with detent can possibly lose mating. The SMP-L interface specifications are listed in ***Table 1*** and typical VSWR performance to 40 GHz is shown in ***Figure 3***. In addition, durability tests were performed during the qualification phase to ensure that repeatability is maintained over 500 mate/de-mate cycles.

TABLE I

SMP-L SPECIFICATIONS

Parameter	*Specification*
Impedance	50 Ω
Frequency Range	DC to 40 GHz
VSWR	1.3:1 (DC to 26 GHz) 1.5:1 (26 to 40 GHz)
Insertion Loss	$.06 \times \sqrt{f}$ GHz
DWV @ Sea Level	500 Vrms
Insulation Resistance	1000 MΩ min
RF High Pot. @ 5MHz	325 Vrms
Corona Level @ 70,000'	190 Vrms
Inner Conductor Resistance	6.0 MΩ
RF Leakage	–80 dB (DC to 3 GHz) –65 dB (3 to 18 GHz)
Force to Engage	
Smooth Bore	1.5 lbs
Force to Disengage	
Smooth Bore	1.0 lbs
Coupling Nut Retention Force	>100 lbs
Temperature Range	-55° to +165°C
Environmental	
Thermal Shock	MIL-STD-202, Method 107, Cond B
Moisture Resistance	MIL-STD-202, Method 106, except step 7b
Corrosion	MIL-STD-202, Method 101, Cond B
Vibration	MIL-STD-202, Method 204, Cond D
Shock	MIL-STD-202, Method 213, Cond I

COMPATIBILITY

The SMP-L family comprises of female cable connectors and their male PCB and panel receptacles. These SMP-L connectors are fully compatible with the standard SMP connector line, which includes bullets, adapters, panel mounts and field replaceables. Thus, a complete interconnect system is available for new designs that also maintains compatibility with the existing SMP standard interface that is commonly employed in RF/microwave systems. Additionally, Carlisle has designed a variety of SMP-L connectors, including IP67 compliant configurations, specifically for its customers' application needs.

Hence, SMP-L connectors are an ideal solution for applications that require the performance and density of a push-on connector with the ruggedness of a locking feature. Their superior performance under vibration and other harsh environmental factors allows designers to overcome the historical limitation of using only threaded connectors such as the SMA or Type N in their designs. Moreover, the compatibility of the SMP-L connectors with the standard SMP interface enables the use of a single interconnect system throughout the design.

Carlisle Interconnect Technologies, Cerritos, CA (562) 498-0901, www.CarlisleIT.com.

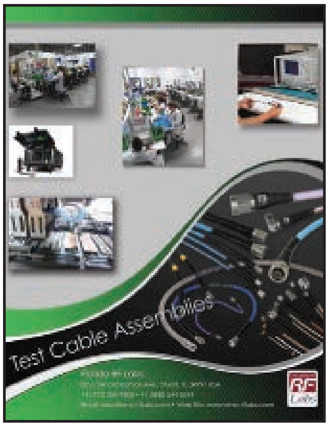
Cables & Connectors Supplement

LITERATURE SHOWCASE

Locking Push-On Connectors

CarlisleIT advances the design of traditional push-on connectors with its new line of SMP-L™ connectors by adding a patent-pending locking mechanism called Secure-Lok™ to the standard SMP interface. SMP-L connectors are ideal for rugged military and commercial applications where susceptibility to vibration and other environmental factors is an issue.

Carlisle Interconnect Technologies, www.CarlisleIT.com.

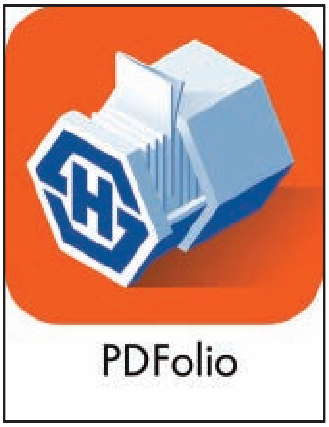


Test Cable Assembly Brochure

VENDORVIEW

Continuing its commitment to "Excellence in Interconnect Solutions," Florida RF Labs has released a brochure highlighting its dedication to providing durable, high-performance test cable assemblies for lab, production and test equipment applications. The brochure features Lab-Flex®, Lab-Flex S, ASR and Mini-Flex product families and introduces the new Titan-Flex test assemblies.

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



App for iPads

As of now Huber+Suhner provides the "PDFolio" app for the iPad showing all brochures and catalogues. The documents are arranged according to technologies and markets and can be downloaded as and when required. All content of the app is always updated. This app is available for free in the iTunes Store.

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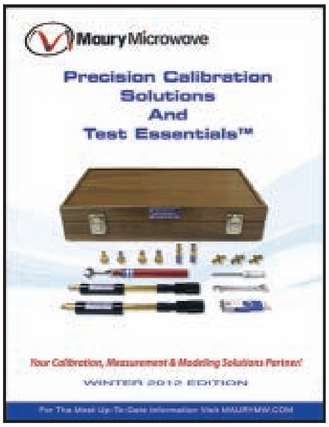


Precision Calibration Solutions and TestEssentials Catalog

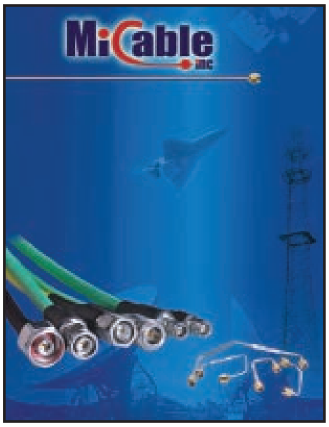
A complete listing of Maury's cal kits/cal standards for accurate calibration of Agilent, Anritsu, Rohde & Schwarz and other network analyzers (DC to 110 GHz). Maury's cal kit configurations include all popular coax and waveguide connector types. Other items include Maury's metrology-grade adapters, TestEssentials™ lab adapters, and ColorConnect™ precision adapters, Stability™ microwave/RF cable assemblies, connector gage kits and much more, with a full section on Maury's complete line of thermal/cryogenic noise calibration systems and equipment.

Maury Microwave Corp., www.maurymw.com.

Connectors, Cable Assemblies and Components Catalog

Mesa Microwave since 1995 has been manufacturing connectors, cable assemblies and components for the RF and microwave industry in frequency ranges from DC to 110 GHz for commercial and military applications. Mesa is the source for standard and custom designs for unique applications. Contact the company at (480) 890-1612 or sales@mesamicrowave.com. "Live chat" is available. Request a catalog online at www.mesamicrowave.com.

Mesa Microwave, www.mesamicrowave.com.

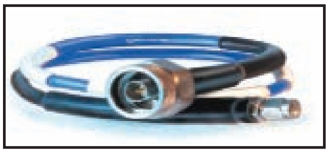


Coaxial Cable Assemblies

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 test cable assemblies, hand-flex cable assemblies, and semi-rigid cable assemblies. In addition, the company also designs and produces various precise coaxial stainless and copper connectors and adapters. Custom designed cable assemblies are also available. MIcable Inc. is your quality fast and low cost solution. Please email sales@micable.cn.

MIcable Inc., www.micable.cn.

LITERATURE SHOWCASE

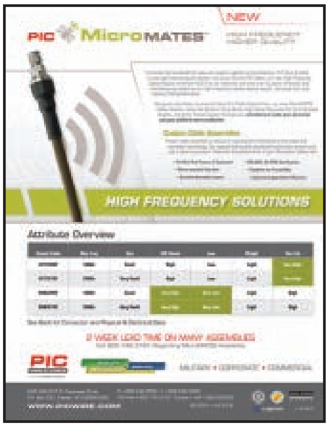


Six-Month Cable Guarantee

VENDORVIEW

Mini-Circuits offers a six-month product guarantee for CBL series RF cable. Test cables traditionally undergo tremendous strain due to many connections which are a normal part of nearly every test lab application. Furthermore, a test environment often results in stress on the cable and cable-to-connector interface due to the high number of bends and flexures required during testing processes. Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within six months of shipment.

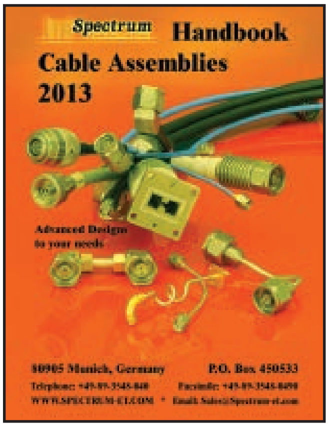
Mini-Circuits,
www.minicircuits.com.



MicroMATES Assemblies

PIC Wire & Cable's MicroMATES™ were introduced in 2012 for Ku- and X-Band assemblies. Learn more about these 50 Ω 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.

PIC Wire & Cable,
www.picwire.com.



Cable Assembly Handbook 2013

Spectrum Elektrotechnik GmbH has a new comprehensive handbook with detailed information on such products as high performance cable assemblies, operating to 65 GHz; phase matched cable assemblies, showing also phase adjustable connectors to 40 GHz; multipin/multiport cable assemblies: circular connectors with up to 12 coaxial cable assemblies, operating to 18, 26 and 40 GHz, and rectangular connectors with 23 coaxial connectors and 26 DC lines; phase king assemblies with limited phase shift over temperature; phase stable assemblies to 26 GHz; and many more.

Spectrum Elektrotechnik GmbH,
www.spectrum-et.com.

Connector Series Application Note

SV Microwave has released a new application note for the QuarterBack™ connector series. The line utilizes a quarter turn bayonet style coupling nut with a locking feature for standard SMP/SMPM interfaces. The QuarterBack connectors are ideal for high vibration and test applications that require a large number of mating cycles.

SV Microwave,
www.svmicrowave.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.

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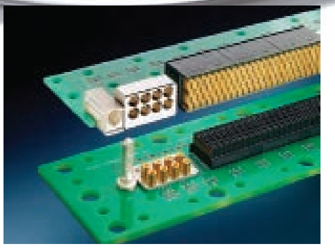

VITA 67 Standards for Connector Modules

The VITA 67.0, 67.1 and 67.2 standards, which define the RF connector modules for implementation within the OpenVPX™ architecture, have been ratified by the American National Standards Institute (ANSI). TE Connectivity's RF connector modules, which meet these new standards, have been designed for high-reliability, high-density aerospace and defense applications that meet the vibration, environmental and corrosion resistance requirements of VITA 47.

The new VITA 67 standards enhance the ability to add RF capabilities in VITA 46 VPX board-to-board connections. The modules provide a convenient and standardized microwave interface and also meet the needs of C4ISR applications such as ground base stations and communication systems, land and sea antiballistic signal processing, avionics and ground-based radar systems, and electronic countermeasures.

The modular design allows application-specific configurations with high contact counts in VPX systems. The RF connector modules are compatible with VITA 65 OpenVPX specification, which defines standard profiles for various configurations at the chassis, backplane, slot and module levels.

RF modules are available with standard 4 positions (VITA 67.1) or 8 positions (VITA 67.2) of high-frequency coaxial contacts for blind-mate daughtercard to backplane applications. The SMPM based contacts are on a 0.240" centerline, and the module interface is designed to maintain excellent channel-to-channel isolation, over 100 dB at 30 GHz.

The jacks are designed with float on the daughter-card side to accommodate mating tolerances and confirm that the RF interface is bottomed through the full board-to-board tolerance range, maintaining a positive RF ground and supporting frequencies up to 40 GHz. The modules offer a contact float of 0.079", radial misalignment of ±0.010", and a design that provides reliable blind-mating. Contacts are available for a wide range of flexible and semi-rigid cable.

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(800) 522-6752, www.te.com.

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Germany, Austria, and Switzerland (German-speaking)
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Brigitte Beranek
Gerhart-Hauptmann-Street 33,
D-72574 Bad Urach
Germany
Tel: +49 7125 407 31 18
FAX: +49 7125 407 31 08
bberanek@horizonhouse.com

Israel
Oreet Ben Yaacov
Oreet International Media
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FAX: +82 2 481-3414
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Ace Media Service Inc.
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Nishiiko, Adachi-Ku
Tokyo 121-0824, Japan
Tel: +81 3 5691 3335
FAX: +81 3 5691 3336
amskatsu@dream.com

China
Michael Tsui
ACT International
Tel: 86-755-25988571
Tel: 86-21-62511200
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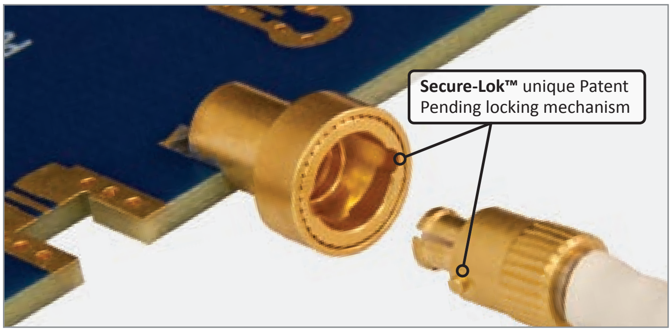
The **SMP-L** connectors provide a secure connection similar to threaded connectors while retaining the advantages of a push-on blindmate interface. Consequently, they are ideal for use in RF & Microwave systems designed for rugged military and commercial applications.



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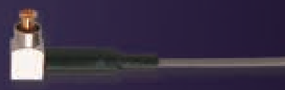

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