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March 2015

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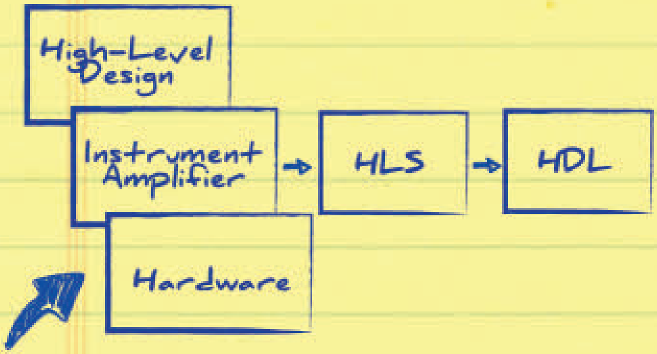

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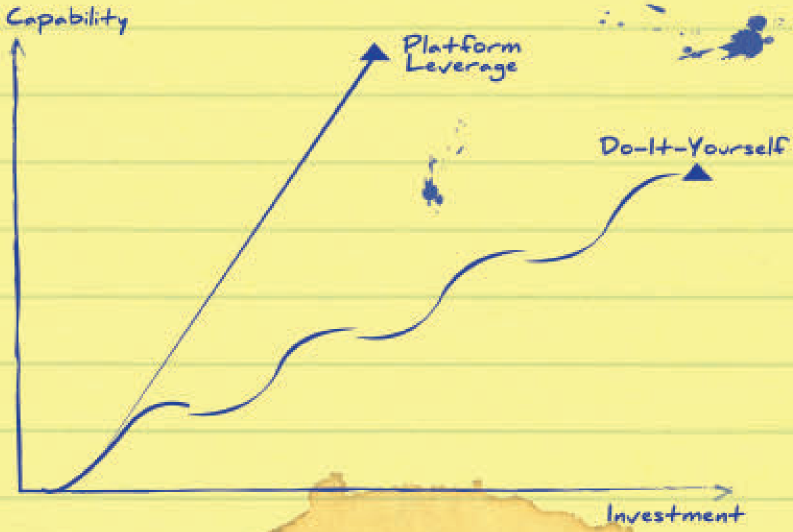

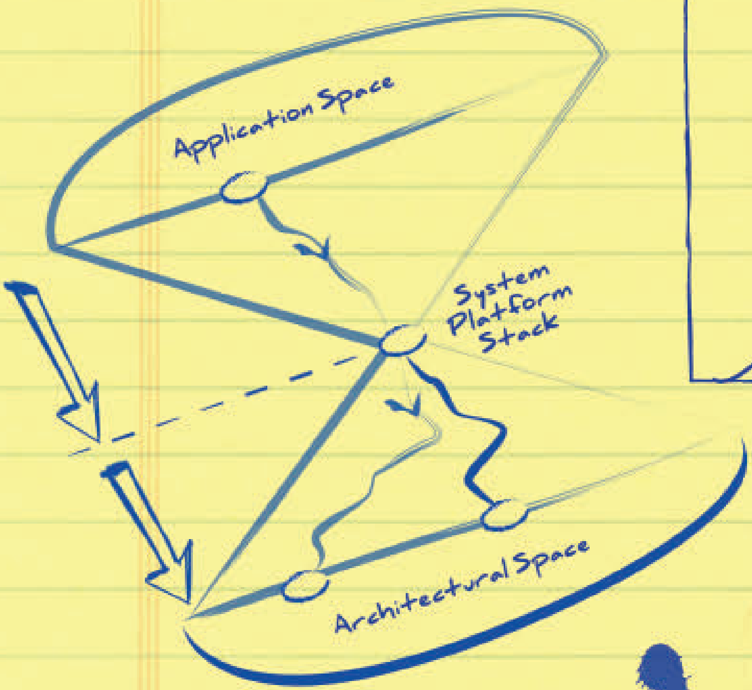

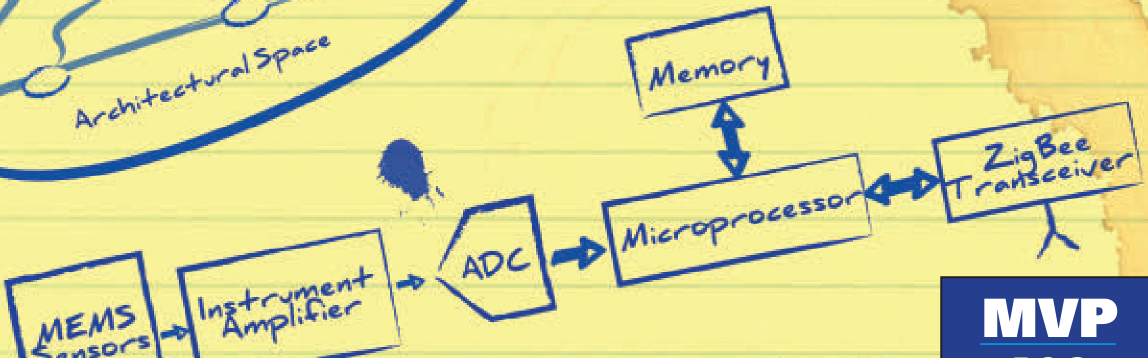

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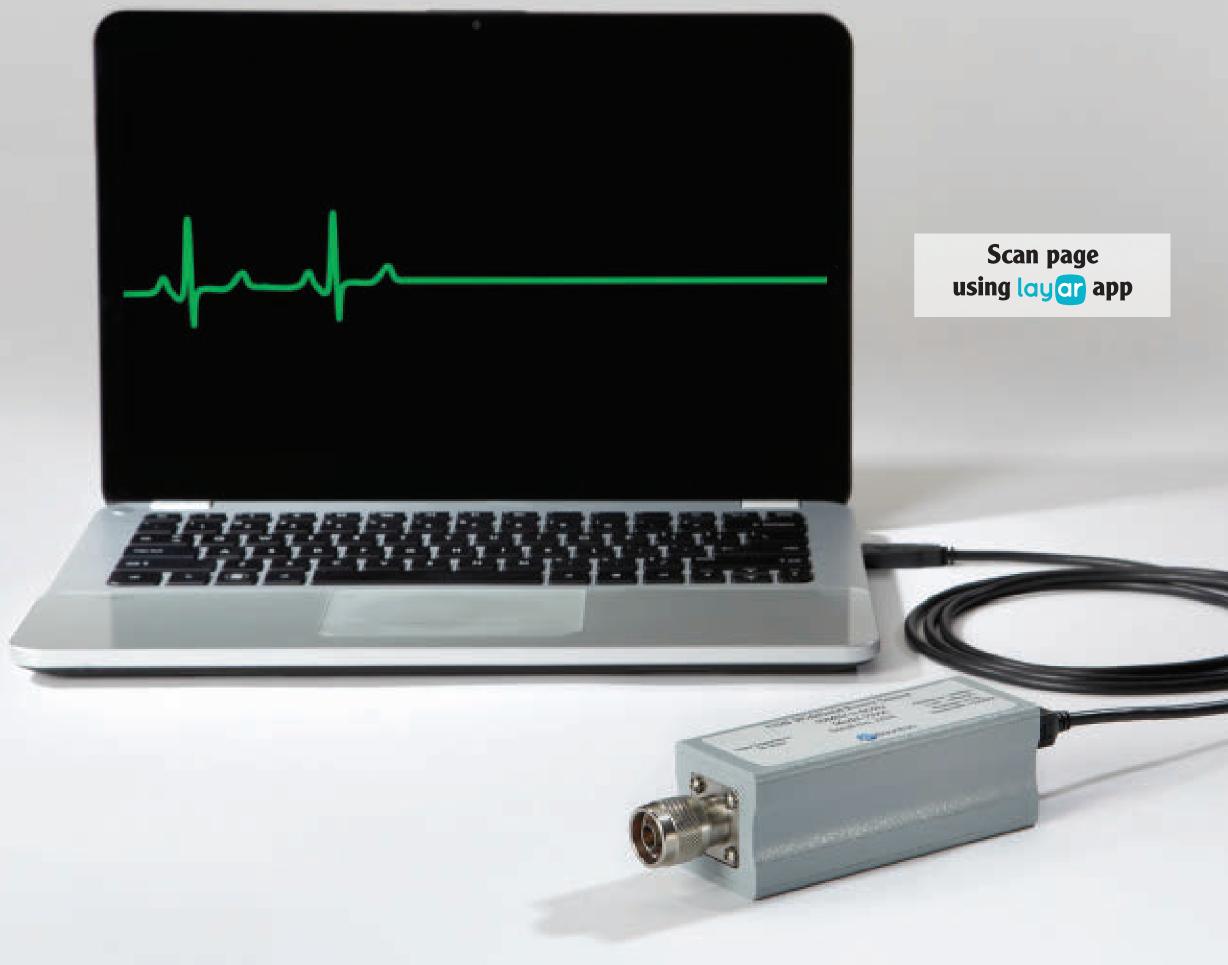

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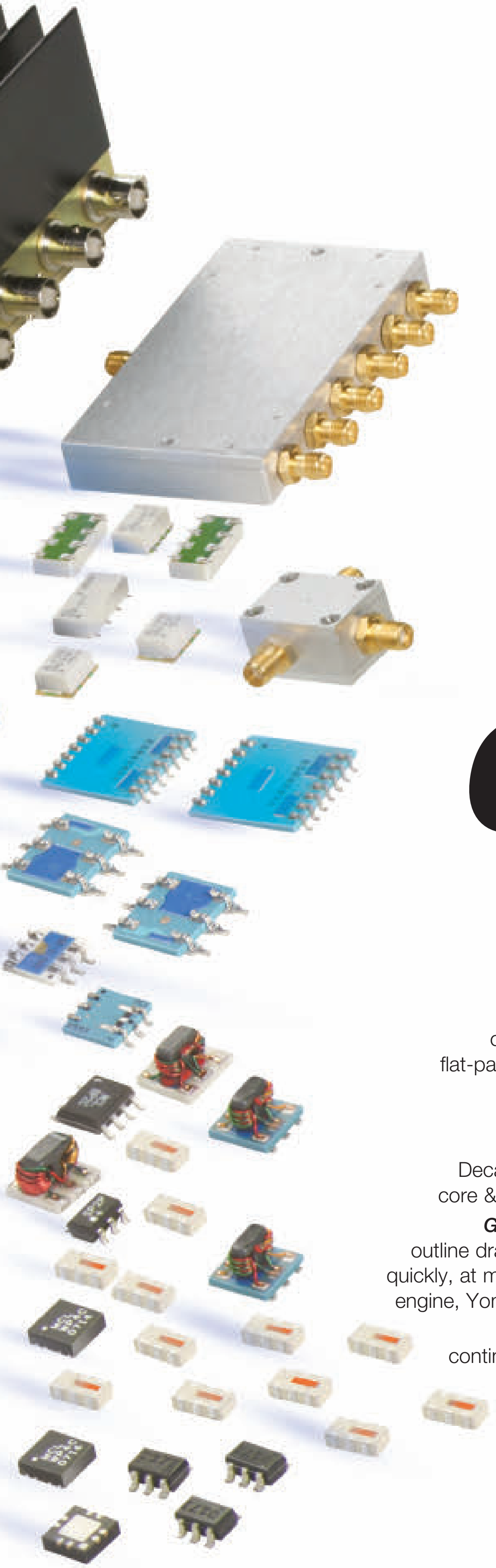

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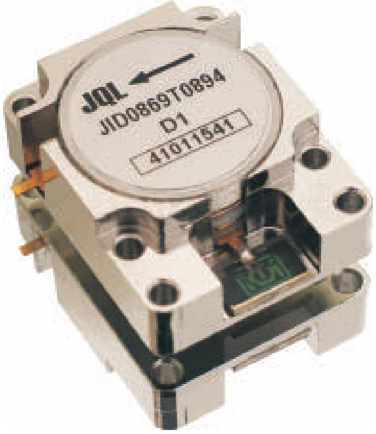

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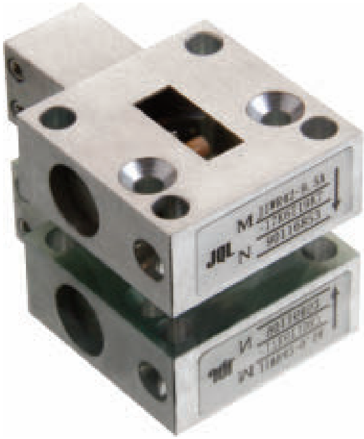

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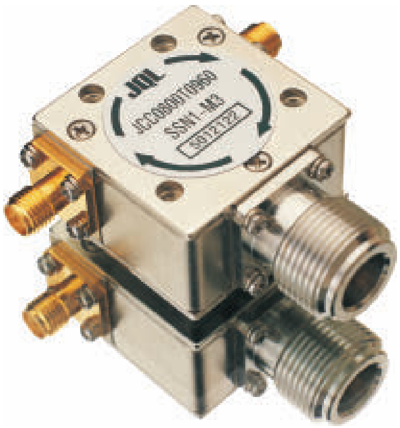

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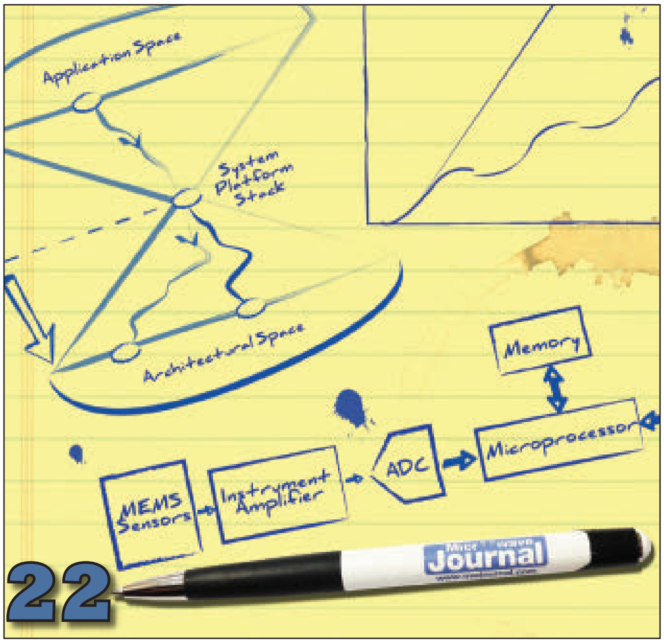

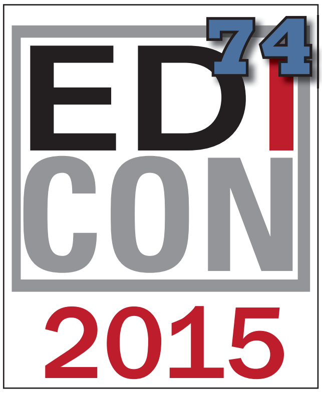

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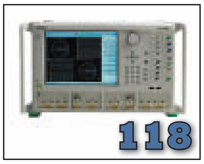

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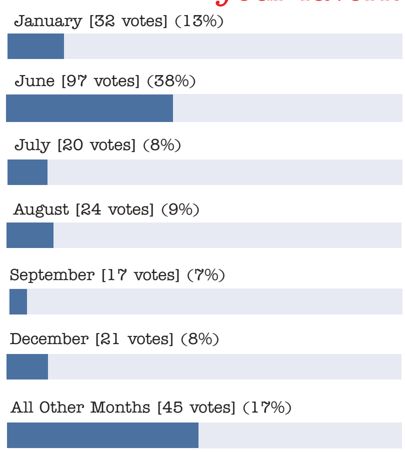

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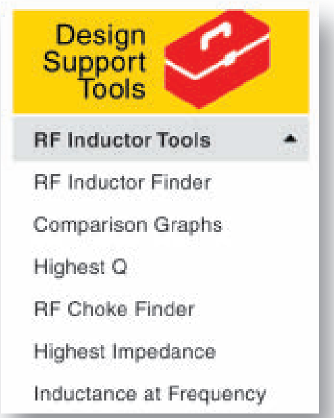

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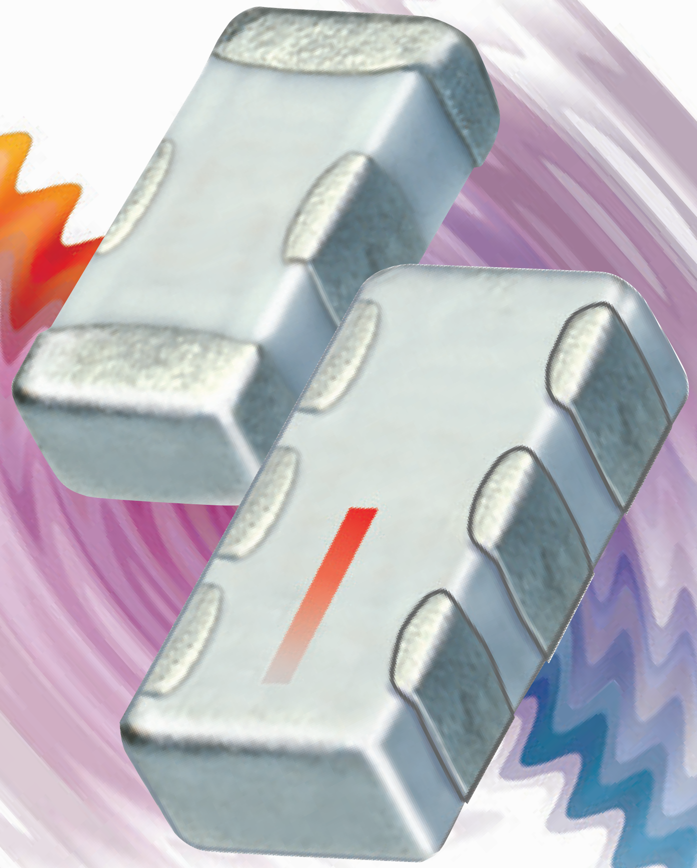

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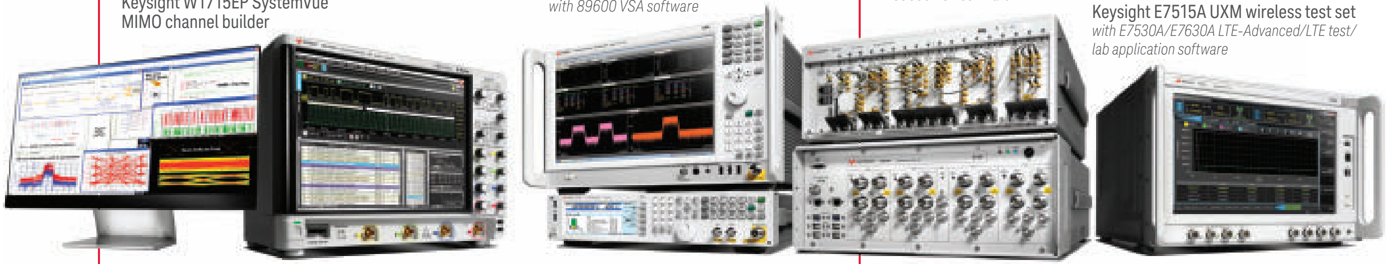

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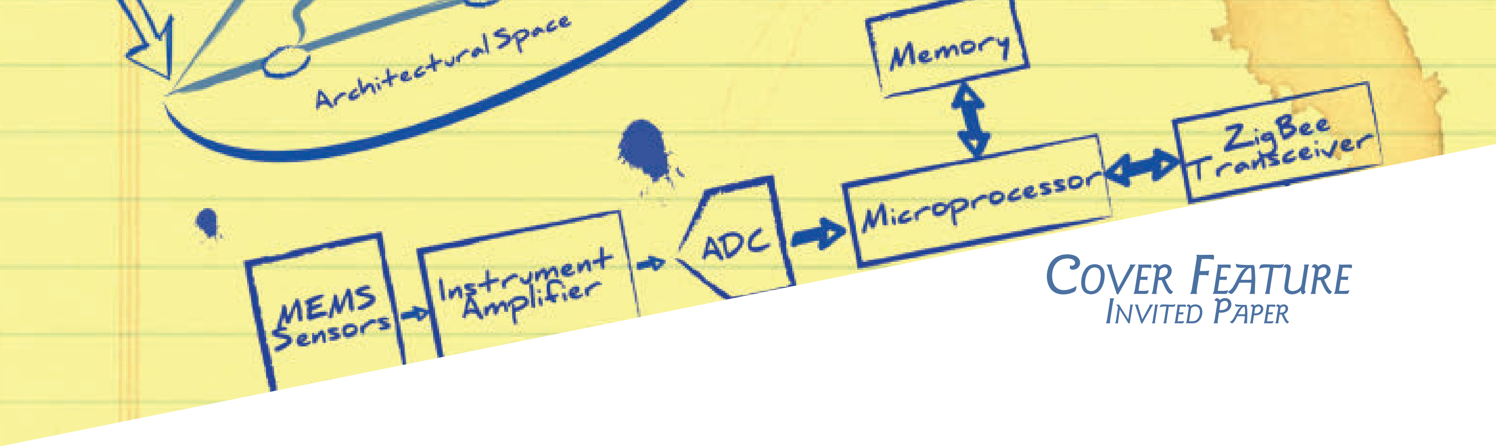


COVER FEATURE
INVITED PAPER

Platforms Drive Innovation in RF and Microwave System Design

James Truchard
National Instruments, Austin, Texas

A few years ago, the concept of an "app" did not exist. Today, iOS hosts over a million apps with more than 85 billion cumulative downloads. The iOS platform delivers leverage to developers around the globe, and its enabling power has fueled its unprecedented success. This concept improves the productivity of innovation and discovery, accelerating the pace of technical advancement.

Ten years ago, consumers used watches, calculators, mp3 players, paper planners and digital cameras. Today, a smartphone replaces all of these and more (including even a bagpipe tuner – one of my personal favorites and a testament to broad app coverage). As a result, we have convenient and useful access to more functionality than ever before.

iOS shows how a platform-based approach drives massive productivity by enabling the collective genius of software experts around the world. They fully exploit the underlying hardware to create applications that cost less, are more capable and are used more than custom-built alternatives.

PLATFORMS FOR DESIGN AND TEST

The transformative impact of platforms applies beyond our mobile devices. In the same way the iOS platform delivered unprecedented results to consumers, the modular platform-based approach is changing the way engineers are meeting industry's most difficult test and design challenges.

The wireless industry presents one such challenge. Demands for bandwidth, capacity, responsiveness and Internet of Things (IoT) connectivity are driving 5G research. Additionally, the defense industry requires new communications technology to meet increasingly sophisticated challenges.

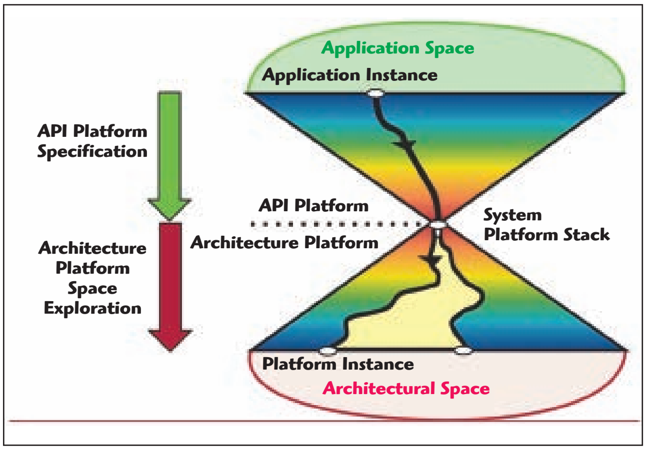
The scale of these challenges strains conventional design approaches because both investment and time are limited. The technical challenges associated with systems for 5G prototyping, radar research and others require a complex set of technologies that includes distributed and heterogeneous systems with real time elements, distributed networks and FPGA computation.

The increasing complexity in these systems drives the need for subsystems. These subsystems are often customized and require even more engineering resources. The higher complexity, longer integration and development time of these subsystems increases the probability of failure. The only hope for success-

fully designing the complex wireless systems of tomorrow, in time to meet the mounting demand, is a highly leveraged platform-based approach.

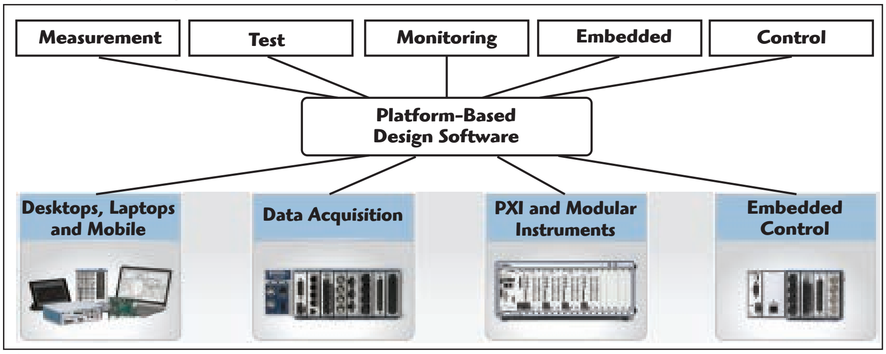
DEFINING PLATFORM-BASED DESIGN

I look to the University of California, Berkeley, to better define the notion of a platform-centric strategy. UC Berkeley has developed a methodology called platform-based design, which supports many of the key requirements needed to meet today's challenges.



▲ *Fig. 1 Sangiovanni-Vincentelli's "hourglass" shows the platform-based design concept.*

Alberto Sangiovanni-Vincentelli's "hourglass" in ***Figure 1*** provides a powerful backdrop to applying platform-based design. He states that "a system can often be usefully presented as the combination of a top-level view, a bottom-level view and a set of tools and methods to map between the views. The platform-based design process is a meet in the middle approach, rather than being top-down or bottom-up, because top-down design often results in unimplementable requirements and bottom-up design often results in a mess. In platform-based design, a successive refinement process is used to determine the abstraction layer." As the hardware and software required to meet these challenges becomes more sophisticated, the benefits of a platform-based approach become more dramatic.

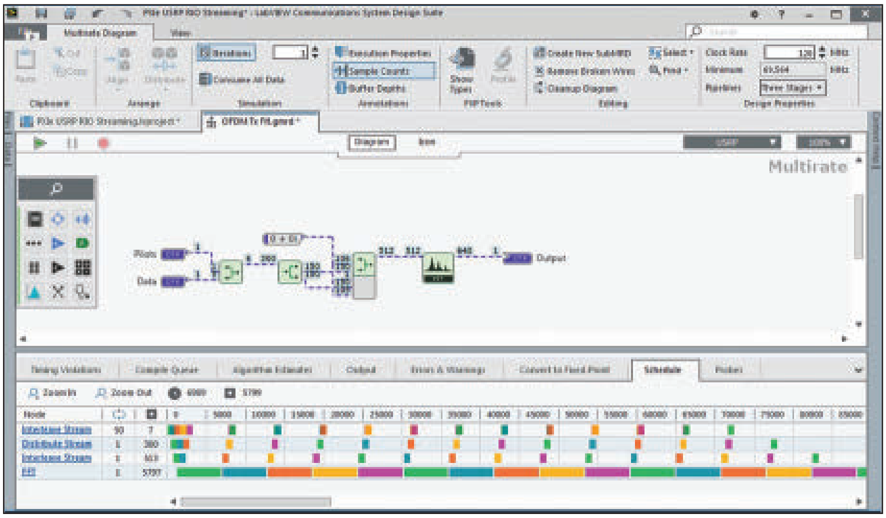


▲ *Fig. 2 A software centric platform targeting multiple hardware footprints shares a reconfigurable architecture and scales to address a variety of applications.*

PLATFORM-BASED DESIGN: A VISION

More than 40 years ago, I had a vision for a platform that would empower engineers and scientists to meet the grand challenges – from fusion experiments to smart energy to advanced wireless research. That vision has evolved to today's productive engineering platforms that tightly integrate hardware and software to allow engineers to innovate faster. Platforms for design must retain backward compatibility while enabling rapid and innovative development. Creating such a platform for design and test requires a strong and correct vision, the discipline to maintain focus and a reinvestment model.

The platform-based approach of graphical system design, shown in ***Figure 2***, combines off-the-shelf, reconfigurable hardware with high-level system design software to enable rapid design iteration. This off-the-shelf hardware allows the platform to stay



▲ *Fig. 3 The LabVIEW Communications multirate diagram makes it easier to convert algorithms from floating-point to fixed-point implementations.*

current and deliver the highest performance and state-of-the-art computing and I/O results possible.

Although system modeling, advanced signal processing and high-level synthesis are all part of the approach, the methodology is uniquely characterized by key software abstractions that tightly integrate hardware. The system design software for enduring and productive platforms must also retain compatibility while enabling rapid and innovative productivity. Along with the need to achieve both flexibility and high performance, this is an essential characteristic of platform-based system design software.

LabVIEW AS A SYSTEM DESIGN LANGUAGE

Platform-based system design software will provide a flexible, highly abstracted and high performance programming environment. LabVIEW, for example, both simplifies typical design and test challenges, such as connecting to hardware I/O, and serves as a complete – actually, Turing complete – programming language. This latter part ensures the extensibility of the language to meet the most demanding engineering system design challenges.

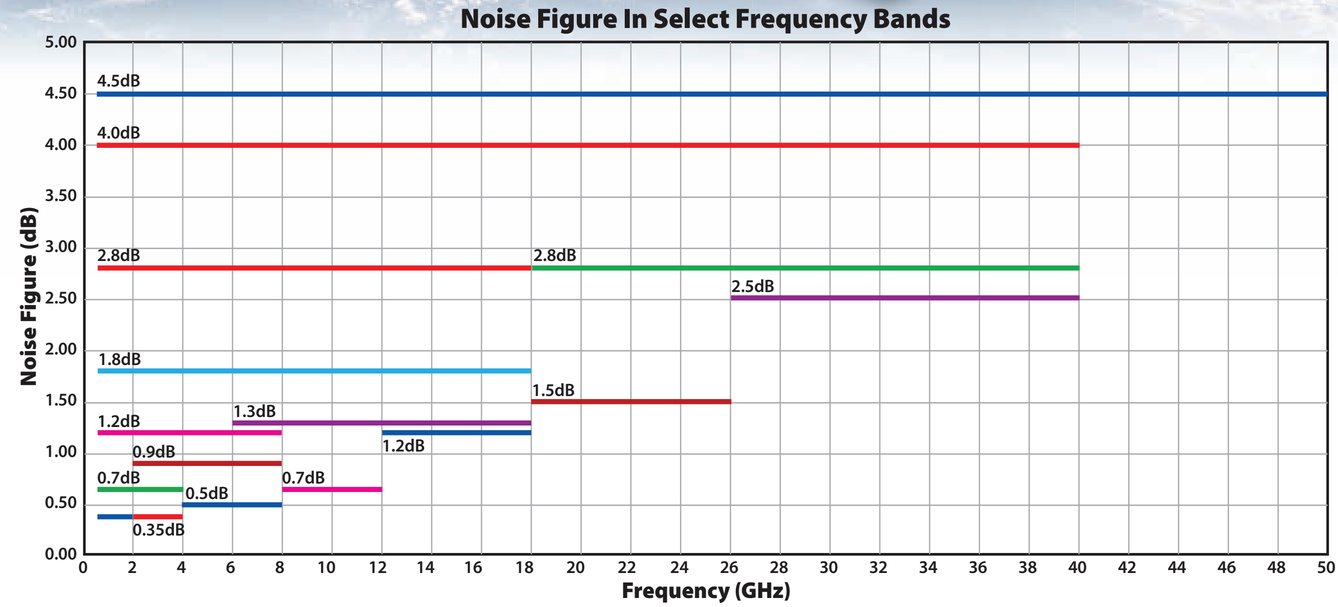
With a platform-based approach, engineers benefit from access to more capable and sophisticated technologies that leads to faster innovation. This approach can turn a previously difficult technology to use, the FPGA, into a flexible, high performance tool that is accessible to more engineers than ever before. High-end sophisticated system design software presents engineering system solutions in understandable, schematic-form programming and converts that view into precise code to program the FPGA.

Platform-based system design software with highly sophisticated compiler technology provides the capability to translate between schematics and complex FPGA code called VHDL. This concept continues to be invested in and expanded, delivering platform-based empowerment to engineers and scientists. An example of advanced compiler technologies is the new multirate diagram (MRD) included in the LabVIEW Communications System Design Suite (see ***Figure 3***). The multirate diagram is an interactive tool for converting floating-point math algorithms to fixed-point implementations designed to execute on an FPGA. The MRD automatically handles typical technical challenges such as handshaking, buffering and queuing data between processes. Here, the benefit of a platform-based approach allows design engineers to use FPGA technology without requiring expertise in floating- to fixed-point algorithm conversion.

INCREASING FPGA ACCESSIBILITY

FPGA chips are critical technologies in advanced wireless research prototypes. They offer the performance of chip-scale solutions in clock rate and processing power with the software reconfigurability required in prototyping new, rapidly changing

Has Amplifier Performance or Delivery Stalled Your Program?



designs. However, the tool flows for FPGA designers have traditionally required very low-level knowledge of these chips and have not connected well with the software and digital signal processing (DSP) tools used by engineers on other design teams. This separation introduces additional complexity and cost in embracing the full use of FPGAs.

The historical complexity of traditional FPGA programming approaches prevents many engineers from incorporating FPGAs in their applications. This is unfortunate because FPGA technology has the ability to enable real time system development by:

- Providing efficient concurrent access to I/O resources with deterministic timing control
- Executing digital signal processing algorithms in real time
- Offering configurability to allow an embedded designer to explore different design trade-offs
- Increasing the reliability of certain applications over traditional processor-oriented implementations (e.g., high-speed streaming for signal intelligence)

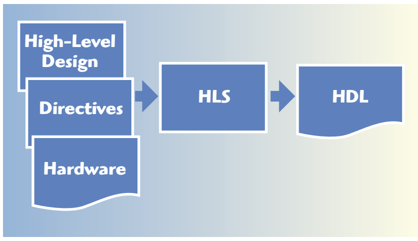


Fig. 4 LabVIEW FPGA incorporates high-level synthesis (HLS) – part of the "magic" of implementing complex systems.

Engineers can use LabVIEW FPGA to simplify FPGA complexity by taking advantage of more approachable software for system design. FPGAs incorporate high-level synthesis, which, in my view, is essential to implement complex systems (see ***Figure 4***).

Filters, encoders/decoders, and analysis functions for machine vision, control and simulation, sound and vibration, digital signal processing, and communication systems are good examples of using FPGAs to abstract various elements of a platform-based design. They can be automatically optimized without requiring knowledge of hardware description languages (HDL) or advanced optimization tricks that reduce the portability and readability of FPGA programming code (see ***Figure 5***).

The simple operation of passing a

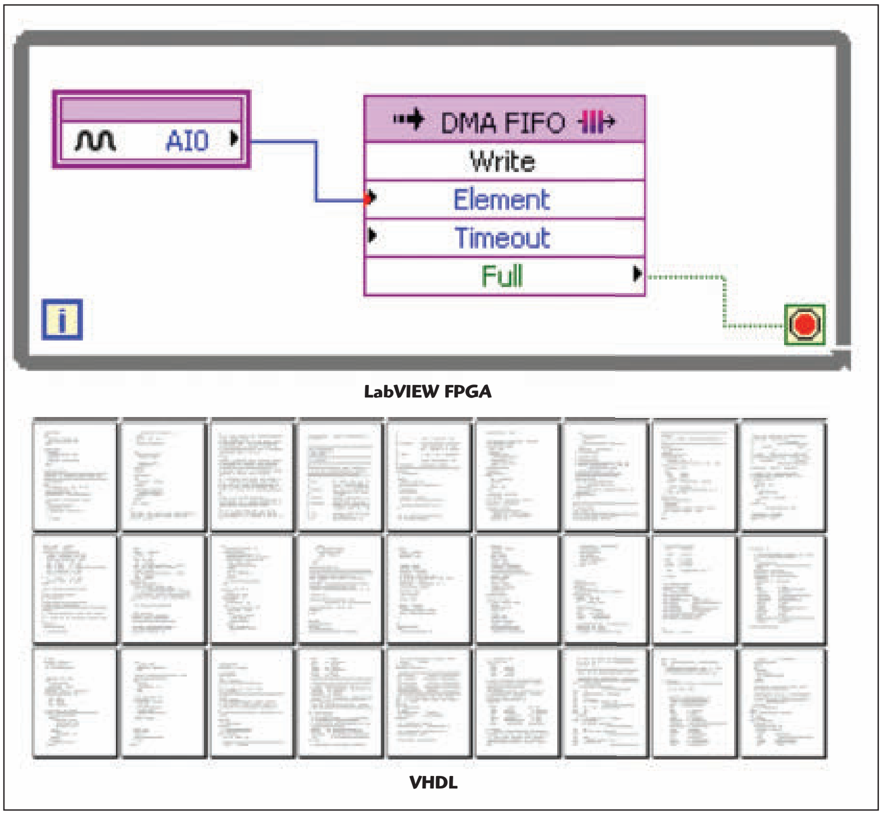


Fig. 5 Modern design tools abstract operations such as connecting an FPGA to a DAC or an ADC.

data point from an analog-to-digital converter (ADC) to a PC requires several pages of VHDL code, but it's expressed as a simple operation in a high-level abstraction software environment. An innovation such as higher-level FPGA synthesis is one of many examples of how platforms enable faster innovation by providing engineers with easier access to powerful technologies.

PLATFORMS ENABLE FASTER INNOVATION

One way to visualize the effect of platform-based design on engineering productivity is by comparing it with the S-curve approach and observing how each incorporates the many technologies required to complete a design. In the S-curve paradigm, system capability is defined through a series of independently developed functions that are combined to create the greater system.

Consider the example of architecting a system to conduct advanced wireless communications research. Typical systems need multiple computational elements, including DSPs/FPGAs, a CPU, a real time OS, and high performance analog I/O (DACs and ADCs). The use of each of these elements requires a high speed bus (PCI Express) for data movement between elements, as the connective tissue for the system.

Applying the S-curve concept to an unsolved challenge like wireless research means individually developing each of these subsystems and grafting them together. Each technology incurs a learning and integration investment. As a result, system capability is modeled as a series of S-curves, with a unique S-curve for each contributing technology. In some instances, design iterations often lead to reduced capability because migrating to new design tools requires design rework to retain previous functionality (see ***Figure 6***).

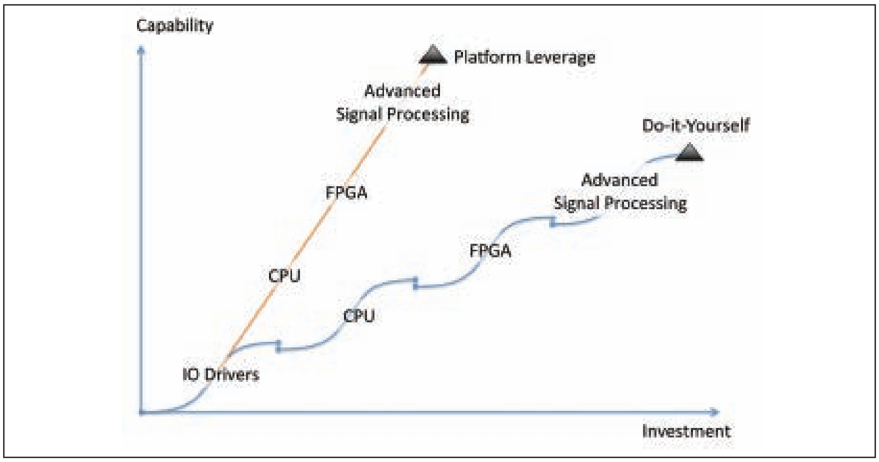
In contrast to the S-curves associated with multiple development tools, a platform approach reduces development cost by providing platform leverage. Designers pay for the learning and/or integration costs associated with using a specific tool only once. In this case, system capability is nearly a linear function of investment; this approach enables system designers to produce more capable designs faster and with a lower investment cost.

PLATFORMS AND ADVANCED WIRELESS RESEARCH

One of the clearest examples of a platform-based approach that meets the toughest engineering challenges is in the field of wireless communications. Researchers are tasked with solving extremely complex challenges – such as 5G – with limited tools. The networks of tomorrow must:

- Offer much higher data rates – up to 1000 of today's 4G networks
- Serve billions of heterogeneous devices – both high and low bandwidth
- Reduce latency to lower, predictable levels – on the order of 1 ms
- Provide more uniform coverage while doing all of the above.

The sheer scale and sophistication of the systems to explore 5G and other advanced concepts require engineers to adopt a platform-based approach to design. In fact, I believe that this approach is the only way to simplify



▲ *Fig. 6 A simple S-curve flow applied to a platform approach makes it clear that building a solution on a platform ensures a competitive advantage.*

immensely complex systems to the extent that engineers can innovate at the speed required to meet industry demands.

Advanced, functional prototypes reveal the power of a platform at work in the real world. Though our customers are researching everything from new waveform technologies to advanced signal intelligence and heterogeneous networks, I believe the research in mmWaves, massive multiple input, multiple output (MIMO) systems and passive radar best highlights the benefits of platform-based design.

mmWAVE RESEARCH

Today, nearly all commercial wireless standards operate at carrier frequencies under 6 GHz. When exploring 5G research, it is clear that the spectrum below 6 GHz cannot support 1000× improvements in data rates – this range simply doesn't offer enough free and unused bandwidth. However, millimeter wavelengths (mmWave) above 6 GHz provide plenty of spectrum that could address 5G data throughput requirements.

Although many engineers once believed mmWaves were impractical for mobile communication, recent research has shown spectrum around 15, 28, 38, 60, and 72 GHz are potentially viable options for 5G mobile deployments. These bands provide up to 2 GHz of bandwidth, which is 100× wider than existing 20 MHz LTE channels. Researchers are investigating new phased-array antenna technologies along with advanced signal processing techniques to overcome the high path loss at these higher frequencies and ensure robust communications.

Nokia Networks is currently prototyping mmWave communications systems for mobile access using a sophisticated combination of hardware and software tools. Nokia has demonstrated a working mmWave prototype capable of processing 1 GHz of real time bandwidth. A prototype of this magnitude requires a platform-based system capable of modulating extremely wide baseband signals, translating them to RF and then demodulating the same signal in real time.

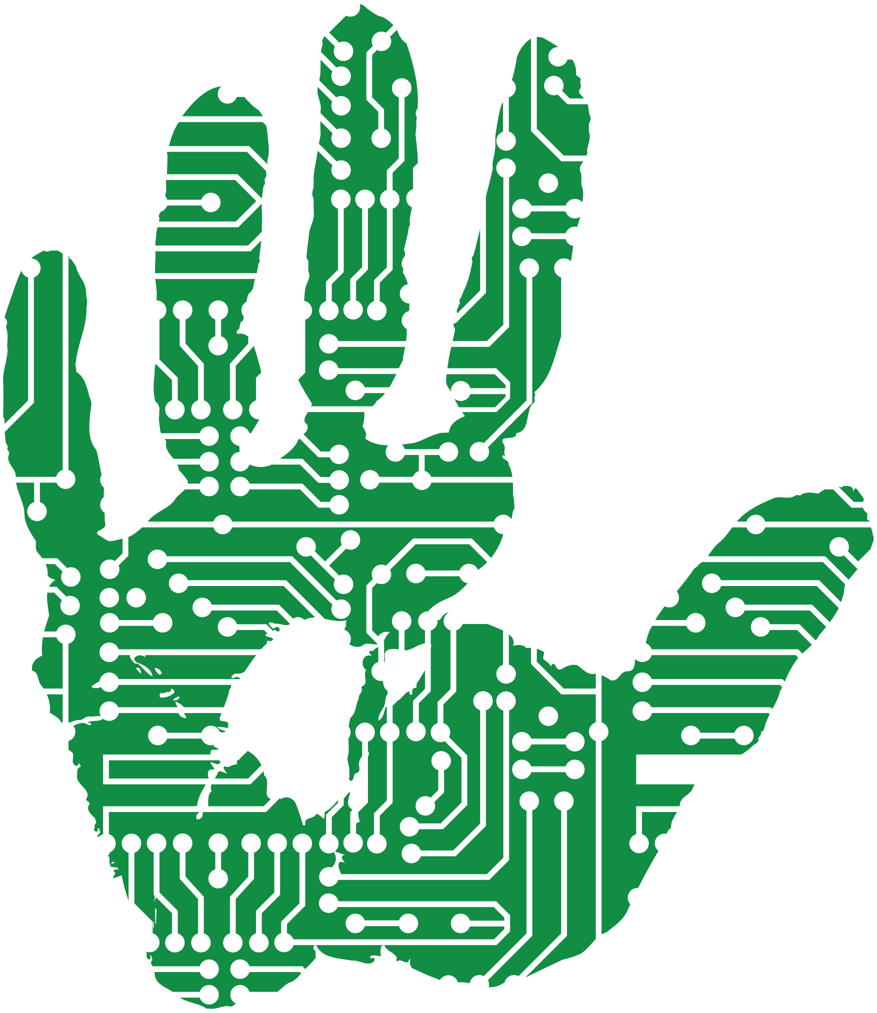
The Nokia system uses multistage up conversion and down conversion in the transmitter and receiver, connected to a multi-beam, phased-array antenna capable of tracking mobile users. The baseband uses a series of FPGAs connected in parallel to process the 1 GHz of bandwidth while controlling the antenna. One of the biggest challenges was to design, develop and deploy the entire signal processing chain for the physical layer. Conventional tools would have taken much longer, but using a platform-based approach dramatically compressed the time to prototype.

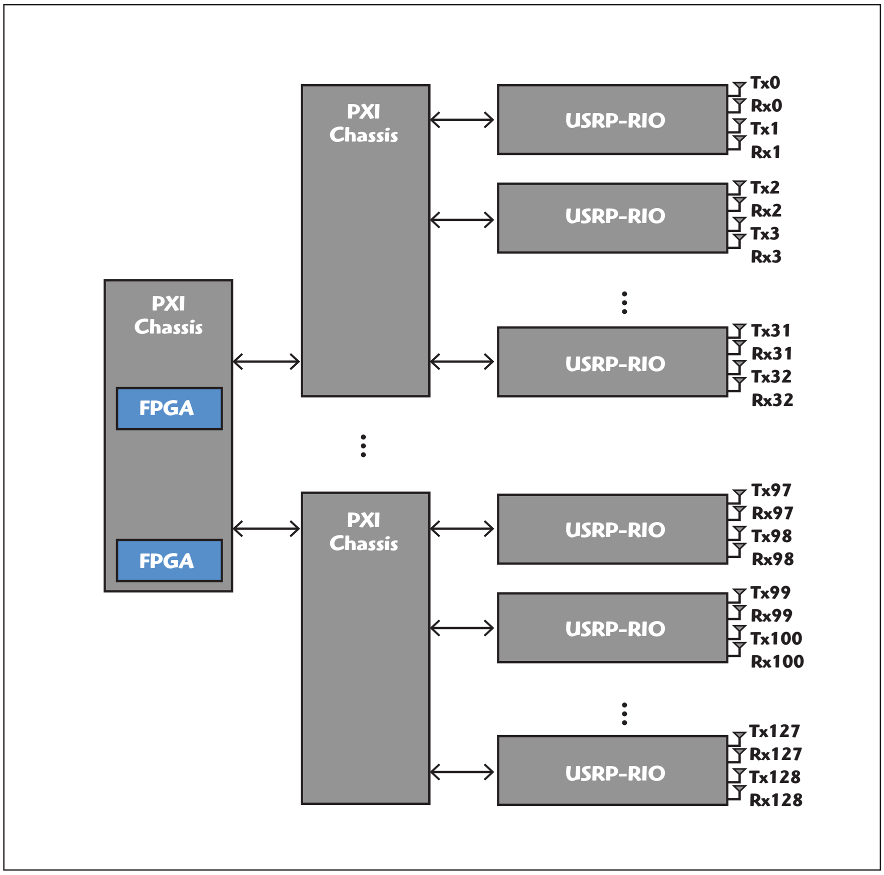
To test and validate this system in a real-world network, the prototype system had to be integrated with a protocol stack (MAC layer and above). Platform-based design makes this integration process more efficient by enabling software reuse – which requires only incremental modifications rather than writing the entire software stack from scratch.

Platform approaches such as NI's graphical system design tools are enabling wireless research labs, like those at Nokia Networks, to prototype mmWave systems more quickly. Although the requirements of these systems forced Nokia researchers to use new technologies at data rates never before prototyped in a mobile communication test scenario, they were able to develop the system in a relatively short timeframe. Dr. Amitava Ghosh, head of broadband wireless innovation at Nokia Networks, estimated that the one year of development time it took to prototype the mmWave system was approximately half the time it would have taken with traditional tools.

MASSIVE MIMO RESEARCH

Wide channel bandwidths make mmWave frequencies compelling candidates for 5G communications, but the challenges of signal propagation at mmWaves introduce another key research vector for 5G: massive MIMO. Massive MIMO is designed to increase data rates by transmitting the base station's power to each user selectively rather than indiscriminately transmitting power over a geographic area. In base stations equipped with hundreds of antennas, the base station transmitters can focus the energy and track the user. In addition, with more antennas, the antenna gain can also be optimized in the downlink to improve communication, even at the cell edges.





▲ *Fig. 7 Massive MIMO prototype systems aggregate gigabytes of data per second into a single CPU.*

Prototyping massive MIMO systems presents a number of challenges – in both hardware and software – from the sheer number of radios integrated into a base station. ***Figure 7*** shows a massive MIMO prototype block diagram with 128 transmit and receive antennas. Each radio's baseband data must be streamed to and from a common CPU, with streams from each radio synchronized in software to ensure that data from all radios can be processed in real time. The radios must be precisely synchronized, and sophisticated beamforming algorithms must be implemented in the PHY to ensure effective communication.

One significant benefit of a platform-based approach is that it simplifies synchronizing large numbers of I/O points (in this case radios). ***Figure 8*** shows a massive MIMO prototype developed by Lund University that is capable of aggregating and distributing data from more than 100 radio channels from 50 universal software radio peripheral reconfigurable I/O (USRP RIO) devices.

▲ *Fig. 8 Massive MIMO prototype developed by Lund University.*

Despite the system's complexity, Lund progressed from system proposal to working system prototype in only six months, which is another tangible platform leverage advantage.

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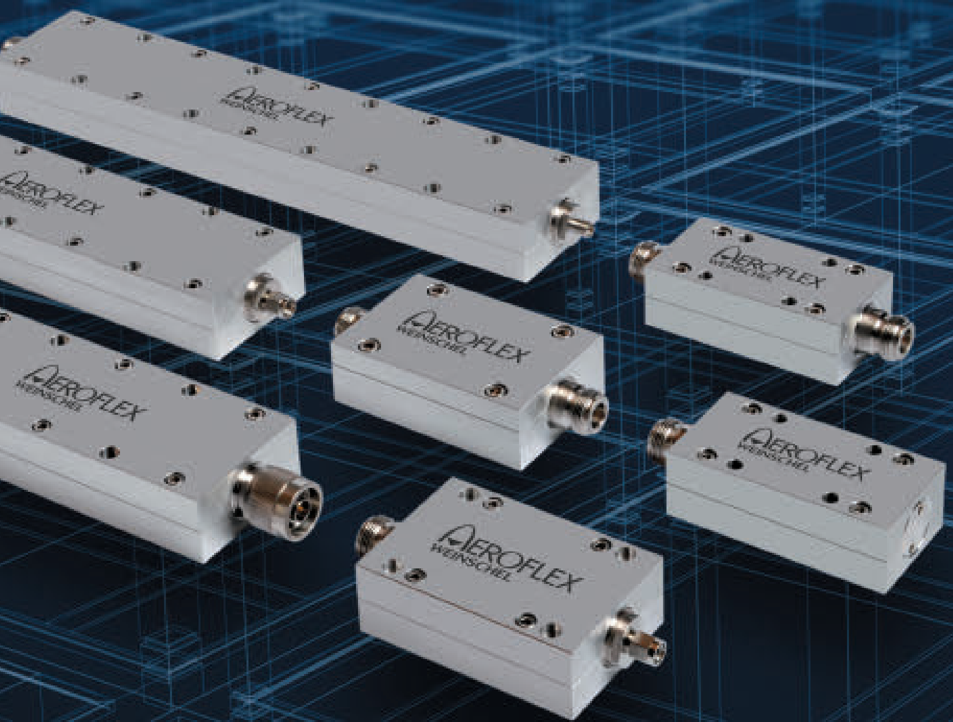

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59	DC to 2.5	100	10	10, 20, 30, 40	1.15	Type N
72	DC to 4.0	50	5	3, 6, 10, 20, 30	1.20	Type N
253	DC to 6.0	550	10	10, 20, 30, 40	1.10 to 1.20*	SMK (2.92mm) or N
257	DC to 6.0	250	10	10, 20, 30, 40	1.10	SMK (2.92mm) or N
258	DC to 6.0	400	10	10, 20, 30, 40	1.10 to 1.25*	SMK (2.92mm) or N
268	DC to 6.0	100	10	6, 10, 20, 30, 40	1.10 to 1.15*	SMK (2.92mm) or N
284	DC to 10.0	50	5	3, 6, 10, 20, 30, 40	1.10 to 1.30*	SMK (2.92mm) or N

Coaxial Terminations

Model	Frequency (GHz)	Avg. Power (W)	Peak Power (kW)	SWR	Connector Type Available
1441	DC to 4.0	50	5	1.20	Type N
1470	DC to 6.0	100	10	1.20	SMK (2.92mm) or N
1471	DC to 6.0	250	10	1.20	SMK (2.92mm) or N
1472	DC to 6.0	400	10	1.20	SMK (2.92mm) or N
1473	DC to 6.0	400	10	1.20	SMK (2.92mm) or N
1476	DC to 10.0	50	5	1.25 to 1.40*	SMK (2.92mm) or N

* Varies with frequency.

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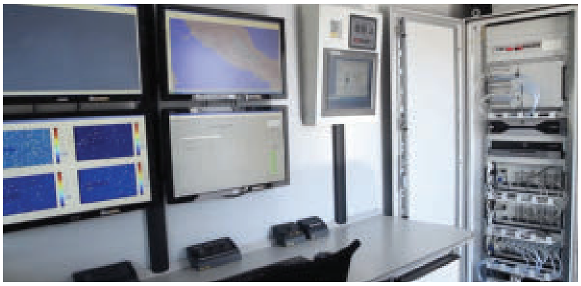


▲ *Fig. 9 Complex systems such as this passive radar are designed and deployed with PXI instruments embedded into the final system.*

PASSIVE RADAR

In addition to wireless research, engineers are applying the platform-based design concept to systems such as radar research. SELEX Sistemi Integrati in Rome, Italy, is using NI's platform-based approach to develop advanced passive radar systems. Unlike traditional radars, which use an onboard "illuminator" to generate a stimulus signal, passive radars rely on environmental illuminators such as cell towers, satellite transmissions and broadcast stations. The principle of passive radar is to measure a signal's direction of arrival by carefully separating the incident signal from the reflection.

Passive radar design challenges include tight phase synchronizing between large numbers of receiver channels, high throughput data movement to a CPU and sophisticated real time signal processing to implement adaptive filtering and cross-correlation algorithms (see ***Figure 9***). In this example, one of the benefits of the platform-based approach is that it simplifies system development by enabling designers to access multiple tools through a single software experience.

BENEFITS OF A PLATFORM

For researchers designing next-generation wireless systems or engineers and scientists exploring any innovation, platforms enable the discovery of new ideas and new designs through leverage and reuse. The design complexity introduced through gigahertz of bandwidth, mmWaves, massive MIMO beamforming, new PHY layers and heterogeneous networks presents increasingly difficult challenges. Given these challenges – and the pressing timelines associated with designing the next generation of communications – using traditional, disparate tools are not an option.

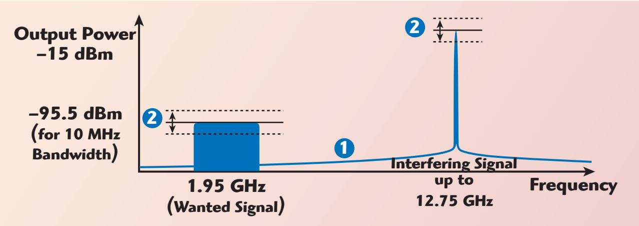
For these challenges, a platform-based approach is the only viable option. As the examples illustrate, industry leaders such as Nokia Networks, Lund University and TU-Dresden know these challenges require highly sophisticated and highly integrated systems that include both hardware and software elements optimized for maximum system capability.

The iOS platform is a proven and highly valuable methodology for creating consumer applications. One example of NI's graphical system design approach is a proven methodology for creating engineering applications. A platform-based approach requires vision, discipline and ultimately enables engineers to design their next-generation systems faster. ■

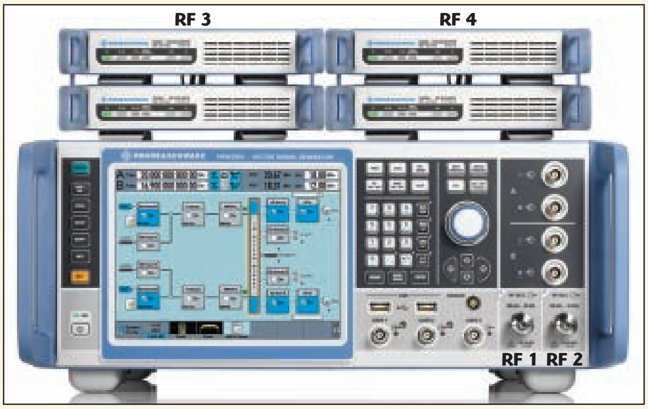
Microwave Vector Signal Generation Up to 40 GHz

Rohde & Schwarz
Munich, Germany

In April 2013, when Rohde & Schwarz launched the R&S SMW200A vector signal generator with up to two 6 GHz RF paths, it was a significant introduction. Not only could it be used for straightforward signal generation, it also simplified the setup of complex measurements. Signals could be internally added with frequency, level and phase offset to easily create scenarios such as wanted signal plus interferer, dual cell and Tx/Rx diversity with real time fading and additional white Gaussian noise (AWGN) – all in just one full-featured vector signal generator.



▲ *Fig. 1 Low wideband noise (1) and the high level accuracy (2) of the R&S SMW200A yield accurate and reproducible measurement results.*



▲ *Fig. 2 Four 20 GHz signals can be obtained using one R&S SMW200A, with two internal 20 GHz RF paths, and two R&S SGS100A/R&S SGU100A 20 GHz combinations.*

Now, with the introduction of four new frequency options that extend the upper frequency limits of the R&S SMW200A to 12.75, 20, 31.8 and 40 GHz, the company has taken this approach into the microwave range. This makes the R&S SMW200A suitable for applications in the area of aerospace and defense (A&D), telecommunications, research and education. The R&S SMW200A is the first and only instrument to integrate two powerful baseband generators with 160 MHz bandwidth and an I/Q modulator with 2 GHz bandwidth in a single instrument and maintain the outstanding characteristics and functions listed above. It allows users to concentrate on the measurement task at hand without the hassle of cabling and calibrating discrete test setups.

BLOCKING TESTS UP TO 12.75 GHz

Telecommunications standards specify comprehensive conformance tests. For example, for LTE tests (Release 11, 3GPP TS 36.141), the wanted signal is around 2 GHz,

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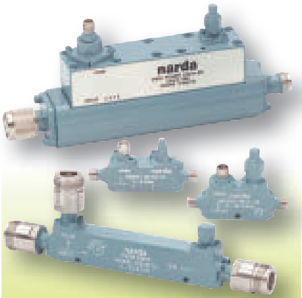

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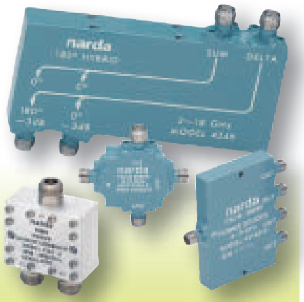

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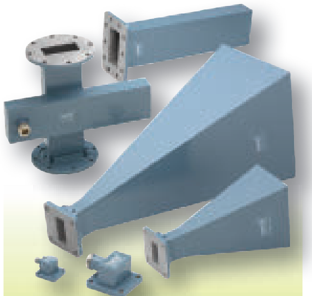

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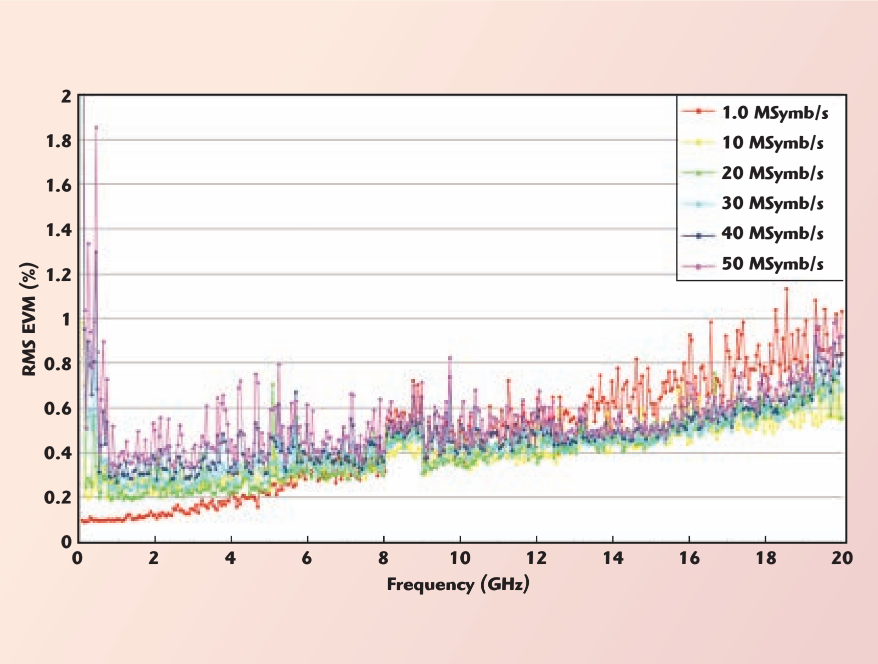

▲ *Fig. 3 EVM vs. frequency for various data rates, measured on a 1024 QAM signal.*

however the interfering signal can be up to 12.75 GHz. This test can be executed with just one R&S SMW200A vector signal generator, since it can be equipped with up to two RF paths.

The signal quality is just as important as the multitude of functions. An excellent adjacent channel leakage ratio (ACLR) is vital for a vector-modulated interfering signal whose frequency is close to the wanted signal. Extremely low wideband noise (region 1 in ***Figure 1***) is required for a continuous wave (CW) interferer at 12.75 GHz. At the same time, the level accuracy of the wanted and interfering signals must be high (region 2 in Figure 1), and the signal content must be precisely specified. These are signal scenarios where the correct configuration and signal quality will have a decisive impact on the accuracy and reproducibility of measurement results.

PHASE-COHERENT SIGNALS

Measurements on active antenna systems for beam forming applications require high quality, phase-coherent test signals. One common reference is usually not sufficient to ensure that the relative phases remain stable over a long period of time. LO coupling, such as offered by the R&S SMW200A, is required. LO coupling enables extremely precise and long-term stable

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SATCOM	DM-HPL-35-101	1.625	1.85	20	40	40%	CW	28	4.0 x 4.00 x 1.00
	DM-HPS-35-101	2.2	2.5	20	40	35%	CW	28	4.0 x 4.00 x 1.00
	DM-HPC-60-101	5.5	8.5	50	50	25%	CW	28	2.5 x 2.75 x 0.45
	DM-HPX-100-105	9.75	10.25	50	100	30%	CW	28	7.4 x 4.30 x 1.65
	DM-HPKU-40-105	13.75	14.5	45	50	20%	CW	24	4.5 x 4.00 x 0.78
	DM-HPKU-40-101	14.4	15.5	45	30	15%	CW	28	2.5 x 2.75 x 0.45
	DM-HPKA-10-102	29	31	50	12	15%	CW	20	3.1 x 3.00 x 0.78
	DM-HPKA-20-102	29	31	50	20	15%	CW	20	3.5 x 4.50 x 0.78
RADAR	DM-HPL-1K-101	1.2	1.4	50	1000	40%	100 µs, 10% d.c.	50	6.0 x 6.00 x 1.50
	DM-HPS-1K-102	2.9	3.1	45	1300	35%	100 µs, 10% d.c.	32	14.0 x 8.00 x 1.75
	DM-HPS-1K-103	2.9	3.3	45	1500	35%	100 µs, 10% d.c.	50	9.5 x 9.50 x 1.50
	DM-HPS-1K-104	3.1	3.5	45	1300	35%	100 µs, 10% d.c.	50	9.5 x 9.50 x 1.50
	DM-HPC-50-105	5.2	5.8	50	50	35%	100 µs, 10% d.c.	32	3.0 x 3.00 x 0.60
	DM-HPC-200-101	5.2	5.9	50	200	40%	100 µs, 10% d.c.	50	4.5 x 4.50 x 0.78
	DM-HPX-140-101	7.8	9.6	50	140	40%	100 µs, 10% d.c.	40	3.6 x 3.40 x 0.67
	DM-HPX-400-102	8.8	9.8	50	450	35%	100 µs, 10% d.c.	50	7.0 x 4.50 x 1.65
	DM-HPX-800-102	8.8	9.8	50	900	35%	100 µs, 10% d.c.	50	9.0 x 6.00 x 1.65
	DM-HPX-250-101	9.4	10.1	50	250	40%	100 µs, 10% d.c.	50	3.6 x 3.40 x 0.67
	DM-HPX-800-101	9.4	10.1	50	900	35%	100 µs, 10% d.c.	50	9.0 x 6.00 x 1.65
	DM-HPX-20-101	9.9	10.7	46	20	30%	100 µs, 10% d.c.	32	3.6 x 3.40 x 0.67
	DM-HPX-50-101	9.9	10.7	50	50	30%	100 µs, 10% d.c.	40	3.6 x 3.40 x 0.67
ELECTRONIC WARFARE	DM-HPMB-10-103	0.1	6	55	10	20%	CW	28	2.5 x 2.75 x 0.45
	DM-HPLS-50-101	1	3	50	50	30%	CW	45	4.3 x 3.50 x 0.45
	DM-HPLS-160-101	1	3	16	160	25%	CW	45	6.3 x 6.00 x 0.78
	DM-HPSC-50-101	2	6	50	50	30%	CW	28	2.5 x 2.75 x 0.45
	DM-HPSC-80-101	2	6	50	80	25%	CW	28	4.5 x 4.00 x 0.78
	DM-HPSC-150-101	2	6	60	150	25%	CW	28	6.5 x 6.50 x 0.78
	DM-HPMB-10-101	2	18	45	10	15%	CW	32	2.5 x 2.75 x 0.45
	DM-HPMB-40-101	6	18	50	30	15%	CW	28	2.5 x 2.75 x 0.45
	DM-HPX-25-101	8	11	45	25	30%	CW	28	2.5 x 2.75 x 0.45
	DM-HPX-50-102	8	11	50	50	30%	CW	28	2.5 x 2.75 x 0.45

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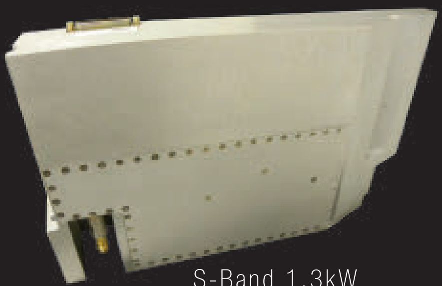

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www.deltamicrowave.com | sales@deltamicrowave.com | (805) 751-1142 phase synchronization of both generator paths – internally in a single instrument, without additional cabling. If additional phase-coherent signals are required, the LO signal of the R&S SMW200A master signal generator can be forwarded to R&S SMW200A slave signal generators.

In phase-coherent applications, a cost efficient alternative to an additional signal generator is to use the R&S SGS100A RF source and R&S SGU100A up-converter combination (see ***Figure 2***). This hardware enables the generation of RF or I/Q vector modulated signals up to 40 GHz.

A very powerful mini-system combines one R&S SMW200A with two internal 20 GHz paths plus two additional R&S SGS100A/R&S SGU100A 20 GHz combinations. This setup provides a total of four 20 GHz signals. When necessary, fading and/or AWGN can be added. The complete setup is controlled by the master signal generator.

TESTING DIRECT MICROWAVE LINKS

One of the many applications for direct microwave links (point-to-point communications) is the networking of base stations via the air interface instead of wired connections. These connections require high data rates, which are achieved via an appropriately high order of modulation (128 QAM and higher) and wide bandwidths.

This obviously places high demands on the signal quality. Due to its outstanding EVM, the R&S SMW200A is ideal for these types of measurements, even for high orders of modulation and wide bandwidths (see ***Figure 3***). For a 10 GHz carrier frequency, the measured EVM is 0.36 percent with 128 QAM and 0.37 percent with 1024 QAM (each with 20 MHz bandwidth).

COMPLEX PULSE SCENARIOS

When it comes to sophisticated pulse generation, enhanced sequencing capabilities, antenna diagrams, antenna scans and scenario simulation for single and multiple emitters, the ideal tool is the R&S SMW200A together with the new pulse sequencer software. The signal calculated by the pulse sequencer (installed on a PC) can be uploaded to the R&S SMW200A, which generates the desired scenario up to 40 GHz. This solution covers automotive radar applications, radar applications, coexistence testing of radar and telecommunications signals and also a wide range of A&D applications.

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Channel Models Key to 5G Development

Tommi Jämsä
Anite

Device testing and measurement firm Anite has been at the centre of establishing the first radio channel models[1] for 5G with the European working group METIS.[2] Here, the company's senior manager of channel emulation research and technology, Tommi Jämsä, discusses some of the technical challenges which must be overcome before 5G communications can become a reality.

5G, the next generation mobile and wireless communications system, represents a fundamental transformation in the development of device and network infrastructure technology. The ultra-broadband architecture will address the huge surge in mobile data consumption and the advanced capabilities of mobile wireless devices by combining new, complementary technologies with existing ones.

It will be designed to address a much broader range of applications, services and types of wireless mobile connectivity compared to previous generations, enabling new types, including HD and ultra-HD video streaming and virtual and augmented reality. 5G technology will also support the development of the Internet of Things (IoT) including machine-to-machine (M2M) connections for applications such as smart grid, car-to-car, emergency communication, eBanking and eHealth.

To ensure that these applications are enabled to their full potential, there needs to be an industry-wide focus on how to deliver these high-bandwidth critical applications. The end user's experience will depend on a number of factors, including data rate, latency, reliability and ubiquitous coverage.

MOVING FROM MAXIMIZING CAPACITY TO INCREASING DENSITY

The mobile industry has used 4G technologies to maximize capacity, targeting peak data rates of 1 Gbps for low mobility and 100 Mbps for high mobility, as specified by the ITU's Radio Communication Sector (ITU-R).[3] 5G will steer the focus more towards capacity density, offering a high number of simultaneous mobile users data rates of several Gbps – significantly higher than those currently available in 4G. A combination of higher data rates and number of devices contributes to a much greater requirement for the overall wireless capacity per square kilometre – as much as 1000 times higher than the capacity of LTE. Some delay-critical industrial

M2M applications and tactile communications will demand very low latency. Low-powered devices will need to provide very long battery life – up to many years.

5G is expected to make use of massive multiple-input-multiple-output (MIMO),[4] as it offers very high spectral efficiency and system capacity. Massive MIMO will utilize tens – or even hundreds – of antenna elements within the base station and dozens in the mobile device. The high number of devices in use, due to the forecasted rise in M2M applications, is expected to cause increased network interference. However, this is compensated to some degree by the fact that propagation losses at higher frequencies naturally reduce interference levels.

Higher frequencies bring other advantages as available spectrum below 6 GHz is very limited and a 1000-fold increase in capacity is very difficult – or even impossible – to achieve at current frequency bands. As a result, 5G is likely to operate on much higher frequencies (possibly millimeter waves) and adopt new air interface technologies such as filter bank multicarrier (FBMC) and non-orthogonal multiple access (NOMA). The frequency bands discussed among key industry players include cellular bands below 6 GHz as well as higher frequency bands such as 10, 28, 32, 43, 46 to 50, 56 to 76 and 81 to 86 GHz. However, these bands are currently just speculative. RF bandwidths are assumed to be around 100 MHz below 6 GHz but may be up to a few GHz at millimeter bands (i.e., frequencies from 30 to 300 GHz).

PAVING THE WAY TO 5G DEPLOYMENTS IN THE 2020s

To accelerate 5G technology development and testing, key industry players have formed a number of organizations and research bodies including Wireless World Research Forum (WWRF), METIS, EU Horizon 2020, Virtuoso and 5G Public-Private Partnership (5G PPP). The industry is currently in the research phase, which will be followed by system design, standardization and finally commercialization in the early 2020s.

ITU-R plans to finalize its vision of the 5G mobile broadband connected society later this year. ITU-R's World Radio Communication Conference 2015 is expected to discuss additional spectrum in support of the future growth of international mobile telecommunication (IMT) systems. The ITU will further evaluate 5G technologies and will hopefully publish IMT-2020 specifications around year 2020.

The 3rd Generation Partnership Project (3GPP) is presently working on Release 13, which includes technology features for small cells, Wi-Fi offload, indoor positioning, device-to-device (D2D), massive MIMO (elevation beamforming), carrier aggregation with a higher number of carriers, machine-type communications and license assisted Access (LAA). The following release (Release 14) is expected to come out in 2016 and coincide with the system design phase of 5G development. Some 5G study items might be started in Release 14.

Subsequent 3GPP releases – 15 and 16 – are expected to concur with

the standardization and commercialization phases, respectively. Technology features in 3GPP Releases 14, 15 and 16 will pave the way to 5G deployments in the early 2020s.

THE IMPORTANCE OF CHANNEL MODEL DEVELOPMENT

Many industry players have emphasized the importance of defining a channel model in early 5G research and development, since existing channel models are not deemed adequate. New channel models need to be developed to reflect radio wave propagation at very high frequencies, which are mostly new to the cellular development community.

5G will need to adapt to various radio channel conditions in a more efficient way, utilizing all dimensions of the radio channel: delay, frequency, time, location, polarization, azimuth and elevation angles. To do so, 5G channel models need to support a number of requirements, including:

- Wide frequency range (1 to 100 GHz)
- Wide bandwidth (hundreds of megahertz)
- Wide range of channel models for many 5G service applications
- An accurate 3D channel model with spherical waves for massive MIMO
- A mobility model for direct D2D and car-to-car communications
- Multi-link models for mobile ad hoc networks
- Models for special scenarios such as emergency calls and ultra-dense networks

Channel model evaluation for 5G technologies is essential as new standards are developed and new products are researched, developed and finally approved. New channel models need to be developed in the research phase to assess link, system and network performance in realistic propagation conditions as well as to compare different algorithms and technologies. The various channel model proposals are then assessed in terms of their performance in the standardization phase.

Research and development teams within chipset, device and network infrastructure manufacturers need the channel models to design device mechanics, antenna, radio and signal processing elements according to 5G market requirements. The same channel models are also used by test and measurement manufacturers, typically in channel emulators, to create a way of validating the 5G performance in a realistic, repeatable and reproducible manner (see ***Figure 1***).

The METIS project task group led by Anite has published the world's first channel models for 5G, an essential step towards further development of candidate 5G technologies. Co-funded by the European Commission, METIS is a consortium of 29 key wireless industry players and the first international and large-scale research activity on 5G.

Several channel measurement campaigns at various frequencies (2, 5, 26, 37, and 60 GHz) have been conducted within the METIS project. METIS' final deliverable, due to be published in early 2015, will in-

troduce updated 5G channel models. Because the proposed 5G requirements are quite challenging from a channel model development point of view, the suggested METIS channel models combine deterministic and stochastic (non-deterministic) models. On the deterministic side, a simplified environment based model – a "map-based model" – is consistent in space but isn't ideal due to its location specific nature. The stochastic model is based on a widely accepted geometry-based stochastic channel model (GSCM), which has been standardized by 3GPP and ITU-R. The GSCM model developed for 5G supports three-dimensionality of the channel (3D), direct D2D links, higher frequencies, massive-MIMO as well as frequency dependent path loss models. However, GSCM alone is viewed as insufficient for 5G due to its lack of spatial consistency.

5G DEVELOPMENT UNDERLINES CHANNEL MEASUREMENT MODELING AND TESTING

There are many revolutionary aspects to 5G development as discussed above. 5G will utilize advanced technologies that set new requirements for testing, such as massive MIMO, D2D, millimeter wave, cognitive radio and cloud radio access network (C-RAN). The extremely challenging technical and performance requirements of 5G highlight the significance of radio channel testing compared to previous cellular technologies.

Conventional conductive testing of 5G devices is expected to be more difficult compared to 4G, because 5G is predicted to make use of a greater number of antenna elements (massive MIMO) in devices and infrastructure, adaptive antennas and operate on much higher frequencies. over-the-air (OTA) testing is therefore expected to play an even larger role in device or infrastructure performance verification.

Channel measurement and modeling is an essential part of 5G development due to more comprehensive performance requirements and use of new frequency bands (many of which are yet to be thoroughly investigated). This complexity is likely to put a greater emphasis on testing, as new devices and infrastructure are developed for 5G technology. ■

End Notes

1. A channel model allows the propagation of a wireless signal between the transmitter and receiver to be predicted, including such factors as attenuation, multipath, interference and noise.
2. METIS (Mobile and Wireless Communications Enablers for Twenty-Twenty Information Society) is a project under the Seventh Framework Programme for research and development (FP7).
3. Requirements related to technical performance for IMT-Advanced radio interface(s), Report ITU-R M.2134 (2008), available online http://www.itu.int/.
4. MIMO refers to system architectures where both the base station and the user's device are equipped with multiple transmit and receive antennas.

Cliff Drubin, Associate Technical Editor

U.S. to Account for More Than 50 Percent of Global C4ISR Market in Next Decade

Due to the emergence of asymmetric warfare and an increasing focus on counterterrorism efforts, the U.S. has a strong demand for highly sophisticated and advanced intelligence, surveillance and reconnaissance (ISR) capabilities.

According to Strategic Defense Intelligence's (SDI) latest report, the U.S. C4ISR market is estimated to value $65 billion in 2014, and is anticipated to increase at a CAGR of 1.34 percent, reaching $74.3 billion by 2024. The U.S. will maintain the current level of investment into C4ISR – platforms which enable network centricity – as countries such as China and Russia make rapid progress in closing the technological gap with the U.S. and extremist groups learn to operate against advanced technologies.

"The efficacy of these systems has already been tested in Afghanistan and Iraq, and the fresh challenges posed by IS in the Middle East means that IT and cybersecurity, electronic warfare, 24/7 airborne surveillance and information collation for command centers are now vital points of differentiation for the U.S. military," says Saktishree D. Majhi, analyst at SDI. "All of these capabilities are facilitated by C4ISR equipment such as UAVs, radars, electro-optic and infrared systems, target acquisition and fire-control sensors, IP based radio and satellite communication devices."

Although the U.S. is still the largest defense spender globally, the defense budget will only increase marginally in the next few years, which means the U.S needs to look to channel their resources towards certain areas of military spending. Saktishree adds, "The U.S. is phasing out tanks and other key weapons programs and is diverting its spending on IT and other C4ISR programs despite the significant research and development costs. Due to a change in combat strategies, the U.S. military is presently more oriented towards carrying out precision strikes using the least possible amount of weaponry and manpower, and this is made possible only by technologically advanced C4ISR systems."

"The U.S. is phasing out tanks and other key weapons programs and is diverting its spending on IT and other C4ISR programs despite the significant research and development costs..."

The Global UAV Market 2015-2025

According to ASDReports' new sector report on the global UAV market, the global economic slowdown has reduced the defense budgets of most leading spenders in the world, including the U.S., France, Germany and the UK. Cuts to military expenditures have led to the cancellation and indefinite delays of various UAV projects, resulting in a detrimental impact on the growth of the UAV industry. For example, in 2010 the U.S. army indefinitely postponed the upgrade of its Shadow RQ-7B aircraft to the new RQ-7C model, in order to reduce costs. The French government may also scrap the Talarion UAV development project to save development costs. High UAV accident rates, as a consequence of unfavorable weather conditions or system failure, also hinder the deployment of UAVs in critical missions such as combat roles.

Accidents are more frequent for UAVs, mainly because manned aircraft have trained pilots capable of diagnosing or overriding system problems. However, if a UAV encounters difficult weather conditions or a system failure, the remote pilot is often unable to access important information such as wind speed and take evasive action.

The global UAV industry is highly fragmented due to the presence of a large number of established manufacturers and a significant number of small and medium-scale enterprises. However, many of these established firms acquire small UAV manufacturers possessing niche capabilities in order to enhance their own technological capabilities and increase their overall product portfolios. For instance, in 2013, Selex Galileo, a part of Italian-based Finmeccanica, acquired Unmanned Technology Research Institute (UTRI), an Italian developer of MUAVs for defense and homeland security.

Source: U.S. Army

Boeing Receives Contract to Modernize B-52 with Digital Communications

VIEW VIDEO

The B-52 Stratofortress bomber was built during the Cold War, but its digital capabilities have entered the 21st century thanks to Boeing's ongoing Combat Network Communications Technology (CONECT) upgrade.

The U.S. Air Force recently awarded Boeing a full rate production contract to deliver 10 CONECT kits that mod-

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Source: U.S. Air Force

ernize communication systems for the B-52 bombers today and into the future. Those technology enhancements include full-color LCD displays with real time intelligence feeds overlaid on moving maps, several communication data links that connect via satellite to platforms and troops in the field and an onboard, high speed network that enables aircrew to respond quickly to a mission change or identify and engage new targets with their weapons.

"CONECT gives the B-52 the agility and flexibility needed for the modern battlefield while also providing greater situational awareness for the aircrew," said Scot Oathout, Boeing's B-52 program director.

U.S. Air Force personnel install CONECT at Tinker Air Force Base, Okla., in conjunction with the B-52's regularly scheduled programmed depot maintenance. Under previous contracts, Boeing is currently supplying 20 CONECT kits to the Air Force. This new full rate production award will bring the total number of upgraded B-52s to 30.

With Inmarsat-5 Launch, Global Broadband Network Closer to Reality

The second Boeing-built Inmarsat-5 satellite has sent its first signals from orbit, an essential step toward establishing Inmarsat's Global Xpress network, the first global, high-speed mobile broadband service.

"This second satellite brings us one step closer to providing global, mobile broadband service to commercial and government customers around the world," said Mark Spiwak, president, Boeing Satellite Systems International. "The Global Xpress network will change the way people communicate. Its success to date is a testament to our team's dedication and the solid relationship between Boeing and Inmarsat."

The Inmarsat-5 satellite series will enable services that include worldwide mobile broadband communications for ships; in-flight connectivity for airline passengers and high-resolution video, voice and data streaming.

A third Inmarsat-5 satellite is scheduled for launch in the first half of this year, completing the Global Xpress constellation. A fourth Inmarsat-5 satellite, scheduled for delivery in 2016, is in production in El Segundo, Calif. Inmarsat also has contracted Boeing Commercial Satellite Services to provide L- and Ka-Band payload capacity and managed services to potential government customers.

GSA Confirms Rise of 300 Mbps Cat 6 LTE-Advanced Systems

In a paper titled, "LTE-Advanced Carrier Aggregation Deployments: Peak Speeds," the Global mobile Suppliers Association (GSA) confirmed that 20 operators have commercially launched 300 Mbps Category 6 LTE-Advanced service in 15 countries: Australia, Austria, Estonia, Finland, Germany, Hong Kong, Portugal, Romania, Russia, Singapore, Slovenia, South Korea, Spain, Switzerland and the UK. 3GPP defines a Category 6 system within its Release 10 specifications as having a theoretical peak downlink speed capability of 300 Mbps, and 50 Mbps on the uplink.

Alan Hadden, president of GSA, said, "Further 22 Category 6 LTE-Advanced systems are also being deployed or are in a trial phase. It means that 42 operators in total are investing in 300 Mbps LTE-Advanced deployments in 24 countries."

This follows on from a recent GSA announcement that 107 operators, i.e., almost 30 percent of all LTE operators, have launched, are deploying or are trailing LTE-Advanced technologies. Carrier aggregation is the first LTE-Advanced feature to be commercialised and facilitates higher data throughput rates, the most efficient use of spectrum assets for network operators, and an enhanced user experience of mobile broadband. 49 operators have commercially launched LTE-Advanced carrier aggregation in 31 countries, with theoretical peak downlink speeds between 110 and 300 Mbps.

Nine Category 9 systems are in deployment, trial or test phase in Australia, Japan, Portugal, Qatar, Turkey, South Korea, Switzerland, UAE and the UK. 3GPP defines a Category 9 system as part of Release 11, and is capable of a theoretical peak downlink speed of 450 Mbps, and 50 Mbps for the uplink direction. Capabilities well beyond Cat 9 have already been demonstrated in a number of multiband multimode LTE-Advanced trials.

£100 Million to Propel Future of UK Aerospace Industry

The UK has ambitious plans with a £100 million boost for UK aerospace that includes £20 million of investment in the skills that will take the sector to new heights. The £20 million funding will provide a vital boost to industry skills at all levels, with the creation of new high-tech masters courses, apprenticeships and career opportunities for young people and graduates alike.

Led by global aircraft manufacturer Airbus through the Aerospace Growth Partnership, the skills project also sees leading employers including Augusta Westland in Yeovil, BAE in Hook and GKN in South Gloucestershire joining together to develop existing and future aerospace talent.

Additionally, six projects will share £80 million for aerospace research to help deliver growth and innovation in key areas of technology. This funding comes from a £2 billion pot committed jointly by industry and government as part of the UK government's industrial strategy, through the Aerospace Technology Institute (ATI). The projects involve 18 companies, 11 academic or research institutions and five Catapult centres from across the UK.

One such project provides £10 million for five companies, led by GE Aviation Systems, to develop advanced printed circuit board test equipment, to improve the manufacture of high quality electronics that can operate in harsh environments.

Chief executive of the ATI Gary Elliott said, "These investments, as part of a broader industrial strategy, are recognised elements of the UK's Aerospace Technology Strategy which is securing the UK's position in a highly competitive, global aerospace manufacturing sector."

UK business secretary Vince Cable said, "The UK's aerospace industry has been propelled to a position of global excellence by a combination of winning ideas, innovation and talent. This has created new ways to manufacture, new skills and a flexible chain of supplying businesses that will secure the industry's long term profitability."

"This has created new ways to manufacture, new skills and a flexible chain of supplying businesses that will secure the industry's long term profitability."

"Government is working in partnership with big businesses like Airbus, GKN and Bombardier on an aerospace industrial strategy to give business the confidence to invest and create long-term jobs in the UK."

ESA and Airbus DS Confirm Partnership to Complete Full EDRS

Following the successful test campaign of the first multigigabit optical intersatellite link between the Copernicus Sentinel-1A and Alphasat satellites, ESA and Airbus DS have confirmed their partnership to complete the full European Data Relay System (EDRS). This campaign paved the way for an entirely new approach of delivering data, with space systems becoming part of the global Big Data challenge.

This campaign paved the way for an entirely new approach of delivering data, with space systems becoming part of the global Big Data challenge.

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The EDRS system consists of the first payload, EDRS-A, to be launched by mid-2015 on the Eutelsat-9B satellite, followed by a satellite, EDRS-C. The EDRS-C satellite, based on a SmallGEO platform from OHB Systems AG, will also carry Avanti's HYLAS-3 telecommunications payload.

EDRS' unique features include a bidirectional optical intersatellite link operating at 1.8 Gbit/s, based on the Laser Communication Terminal developed by TESAT in Germany under funding from DLR German Aerospace Centre, a bidirectional Ka-Band link offering a bandwidth of 300 MHz, on EDRS-A, as well as a 1.8 Gbit/s feeder link to the ground.

The positioning of the two EDRS payloads on the geostationary arc offers near-real time transmission of, for example, Earth observation images to the ground at unprecedented speeds.

EU Initiative to Build Capacity for Technology Transfer

The launch of the Public Research Organisation GRowing Europe through best practice SolutionS for Technology Transfer (PROGRESS-TT) project marks the beginning of a European Commission initiative to improve the capacity of public research organisations to convert investment in research into commercial returns through innovation.

The aim of this Horizon 2020 project is to share the experiences of Europe's leading Public Research Organisations (PRO) with those PROs with the greatest potential to commercialise their research results. It will do this by gathering best practices and developing a suite of technology transfer (TT) tools, methods and insights.

The project consortium, led by Pera Consulting (UK) Ltd., brings together nine highly qualified international partners, representing the complete value chain of TT practitioners.

"Innovation is at the heart of Europe's growth strategy. Over the next three years, PROGRESS-TT will bring together consortium partners with vast experience of technology transfer, capacity building and creating business solutions, skills invaluable in overcoming the barriers PROs face in transferring their technology to industry and commercial success," said Célia Gavaud, international business manager for Pera Consulting and project coordinator of PROGRESS-TT.

"Innovation is at the heart of Europe's growth strategy."

Market for IoT Analytics to Reach $5.7 Billion in 2015, with Startups Driving the Innovation

A new market analysis by ABI Research finds that the revenues from integrating, storing, analyzing and presenting Internet of Things (IoT) data will reach $5.7 billion in 2015. In the next five years, the market will expand dramatically, to an extent that in 2020 it is estimated to account for nearly one-third of all big data and analytics revenues.

Principal analyst Aapo Markkanen says, "About 60 percent of this year's revenue comes from three key areas: energy management, security management, and monitoring and status applications. Within these segments, we can generally find analytic applications that reduce the cost base of asset-intensive operations (condition-based maintenance), automate routine workflows (surveillance), or even enable new business models (usage-based insurance). These early growth drivers also have in common the fact that the economics of IoT connectivity align easily enough with the requirements of analytic modeling."

Making sense of IoT data from machines and sensors often comes with unique challenges, such as the need for time-series databases in storage, and for relatively deep domain expertise in analysis. These kinds of factors create a certain mismatch with many leading technologies that have been designed for more traditional, "digital-first" analytic environments. This, in turn, is attracting a flurry of startup-level activity aimed at filling the gaps.

> "What is remarkable about this market is how much of the innovation actually comes from startups..."

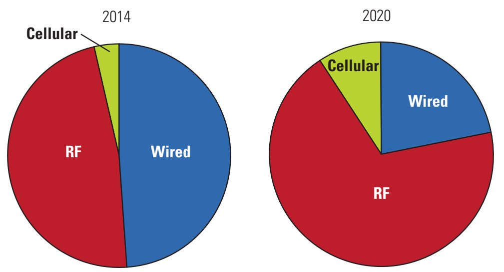
According to practice director Dan Shey, "What is remarkable about this market is how much of the innovation actually comes from startups. Take, for instance, ParStream's geo-distributed architecture, CyberLightning's 3D visualization technology, or Peaxy's work on software-defined data access. All three address some of the problems that usually come up in discussions with end-users. Meanwhile, more incumbent vendors like Datawatch, Informatica, Software AG and Splunk seem well-positioned to seize the IoT opportunity."

Installed Base of Smart Street Lights to Reach 40 M by 2019; RF Mesh Networking Solutions to Lead the Way

The installed base for 'smart' street light luminaires is set to grow rapidly, with network controlled nodes set to rise from 2 to 40 million by 2019, finds ABI Research. "Alongside the energy savings, lifespan and quality of light improvements that LEDs offer, the enhanced controllability of this technology through the adoption of intelligent networking solutions has the ability to revolutionize the way cities utilize their street lighting infrastructure in order to deliver an attractive, sustainable and safer living space," comments Andrew Zignani, research analyst.

Power Line Communication (PLC) networking solutions are currently dominant but will face increasing challenges from both radio frequency (RF) and cellular technologies over the forecasted period. By 2020, RF solutions will make up over two-thirds of installed smart street light luminaires. While cellular implementations are currently very limited, the independence from the electrical distribution network and the lack of additional gateways required can enable smaller business cases down to the single luminaire level. However, most municipalities will require a combination of technologies to achieve their ambitions. "Though each connectivity solution has its own advantages and disadvantages, due to the vast structural and regional complexities in street lighting infrastructures, a hybrid approach that incorporates a combination of PLC, RF and cellular technologies, depending on various circumstances and project scale, will need to be adopted in order to ensure the most widespread, reliable, and cost-effective coverage," adds Zignani.

Smart Street Light Installed Base by Connectivity
World Market Forecast: 2014 and 2020



Source: ABI Research

Vehicle-to-Vehicle Communication Technology Industry Awareness Driven by Driverless Cars

While early implementations of V2V-equipped vehicles will start appearing in the next years—partially driven by Europe's C2C-CC consortium—widescale deployments should not be expected before 2020.

"Industry awareness about the importance of V2V and V2I is clearly gaining momentum, largely driven by its expected key role in enabling driverless vehicles, as stated by NHTSA in its Advance Notice of Proposed Rulemaking to Begin Implementation of Vehicle-to-Vehicle Communications Technology. It has prompted car OEMs such as GM announcing a 2017 Cadillac CTS model to be equipped with V2V technology from Delphi, in conjunction with the

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Super Cruise ADAS solution. Other OEMs such as Toyota and Audi are also committed to V2V," says VP and practice director Dominique Bonte.

Cellular will have a role to play as well. 4G has already been trialed by the likes of Volvo and PSA for emulating non-safety critical V2V applications such as exchanging non-time critical information including hyperlocal weather, road condition and traffic data directly between vehicles.

Global Smartphone Shipments Exceeded 1.2 Billion in 2014

Juniper Research estimates that the number of smartphone shipments exceeded 375 million in Q4 2014, with an annual total of over 1.2 billion smartphones shipped for 2014, representing a 29 percent Y-O-Y growth.

Samsung shipped an estimated 315 million smartphones in 2014 accounting for 25 percent of all smartphone shipments, however the company reported its first annual earnings decline in 3 years. The company witnessed another quarterly fall in shipments and market share, to just over 76 million in Q4 2014, representing a 3 percent decline.

Apple Breaks iPhone Sales Record

Meanwhile, Apple posted a record quarter of 74.5 million iPhone sales, representing Q-O-Q growth of 90 percent and Y-O-Y growth of 46 percent compared to Q4 2013. With the demand for iPhones driven by the 6 and 6 Plus models, the company for the first time ever, sold more iPhones in China than in the U.S. Despite closing in on Samsung in Q4, Apple had a market share of 15 percent for the full year in 2014.

> Apple closes in on Samsung in Q4 2014

The reception of the iPhone 6 Plus indicates a large potential for Apple phablets and is expected to further accelerate the 'Bigger Screen' trend. However, potential releases from budget vendors could outpace their expansion and reduce Apple's overall market share in the category over time. Juniper estimates Apple to account for 30 percent of the Phablets (5.5" to 6.9" screen) market in 2015.

Lumia Sales Up, Lenovo Takes Third

Lenovo-Motorola combined is estimated to have shipped over 90 million smartphones in 2014, managing to improve market share to just over 7 percent. Microsoft, meanwhile, reported 10.5 million Lumia shipments in Q4 2014, driven by low-cost models, and Huawei improved its market share Y-O-Y, shipping over 70 million smartphones in 2014, with its Honor line of devices accounting for nearly 28 percent of the total.


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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Harris Corp. and **Exelis, Inc.** announced a definitive agreement under which Harris will acquire Exelis in a cash and stock transaction valued at $23.75 per share, or an approximately $4.75 billion enterprise value. The transaction is expected to close in June 2015 and is subject to customary closing conditions, including regulatory and Exelis shareholder approval. Upon closing, Harris shareholders will own approximately 85 percent of the combined company, and Exelis shareholders will own approximately 15 percent.

Cobham Wireless, formerly the Wireless Test Business of Aeroflex, and **National Instruments (NI)**, the provider of platform-based systems that enable engineers and scientists to solve the world's greatest engineering challenges, announced a worldwide partnership to service applications in cellular and connectivity with solutions based on PXI technology. Under the terms of the agreement, NI acquires the existing Cobham PXI modular instruments hardware product line and becomes Cobham's primary provider of PXI technology. The acquired PXI modular instruments will be manufactured by NI and supplied exclusively to Cobham for sale through the Cobham Wireless business unit's direct sales channels and brand, which will ensure continuity and continued support for existing PXI-based customers. The companies will also collaborate to incorporate the latest NI PXI modular instruments, including the NI vector signal transceiver with LabVIEW FPGA, into Cobham's next-generation cellular and connectivity test systems. With the agreement, Cobham Wireless will become the NI Global Preferred Partner for cellular and connectivity applications, part of the NI Alliance Partner Network.

Raytheon Co. has acquired privately-held **Sensintel, Inc.**, a leading provider of unmanned aircraft systems (UAS) solutions to the intelligence and special operations markets. Located in Tucson, Ariz. with approximately 50 employees, Sensintel will become part of Raytheon Co.'s Missile Systems business. The transaction is not expected to materially impact Raytheon's sales or earnings in the first quarter or full year 2015. Terms of the agreement were not disclosed.

Focus Microwaves of Montreal, Quebec announced it has acquired the **Pulsed IV** and **Bias-Tee** lines of **AURIGA Microwave** of Chelmsford, Mass. Focus also hired key Auriga personnel, in order to support customers, fulfill existing and pending Pulse System orders and to push further product development. Focus operates the Auriga PIV and BT lines out of its new location in Nashua, N.H.

Intel Corp. has signed a definitive agreement to acquire **Lantiq**, a leading supplier of broadband access and home networking technologies. The transaction is subject to customary closing conditions and regulatory approvals and is expected to close in approximately 90 days. Deal terms were not disclosed. This acquisition would expand Intel's success in the cable residential gateway market and broaden its offering to other gateway markets, including DSL, Fiber, LTE, retail and IoT smart routers.

Cornell Dubilier Marketing, Inc. announced that one of its subsidiaries has acquired the assets of **Illinois Capacitor** and its affiliates. The company sees this acquisition as a strategic move to grow its board-level power capacitor business and service customers in Asia through the sales, warehouse and logistics center that Illinois Capacitor currently operates out of Hong Kong. With headquarters and operations in Chicago, Illinois Capacitor has been in the capacitor business for more than 80 years and today supplies leading-edge aluminum electrolytic, film, conductive polymer, and electric double layer capacitors to industrial electronics companies worldwide.

CommScope Holding Company, Inc. has agreed to acquire **TE Connectivity's** telecom, enterprise and wireless businesses in an all-cash transaction valued at approximately $3 billion. The transaction, which was approved by the boards of directors of both companies, is expected to accelerate CommScope's strategy to drive profitable growth by entering into attractive adjacent markets and to broaden its position as a leading communications infrastructure provider. In addition, CommScope will have greater geographic and business diversity following the completion of the transaction.

ACHIEVEMENTS

A successful flight test of the **Raytheon**-built APG-79(V)X AESA radar system has demonstrated the functions needed to extend the relevance of F/A-18C/D Hornet fighter/attack jets, including extended detection ranges, simultaneous air-to-air and air-to-ground capabilities, production of high-resolution synthetic aperture radar (SAR) mapping and industry leading reliability. The company has delivered more than 500 tactical AESA tactical radars from its portfolio that includes the APG-79, APG-63(V)3 and APG-82(V)1 for F-15, F/A-18E/F, EA-18G and B-2 aircraft. The APG-79 system, a U.S. Navy program of record, flies globally on F/A-18E/F Super Hornets and EA-18G Growlers, and has seen service in four combat theaters since its first delivery in 2006.

ART-Fi's probe-array SAR measurement system ART-MAN received official acceptance by an R&TTE Notified Body, making it the first probe-array SAR measurement system to be accepted by any notified body worldwide. The landmark decision came from American Certifications Body, Inc. (ACB), and is valid for testing to Annex IV of the R&TTE Directive and RCB certification for Japanese MIC requirements.

For More Information

For up-to-date news briefs, visit mwjournal.com

Around the **Circuit**

Alvarion Technologies, a global provider of wireless solutions including Wi-Fi, point-to-point and point-to-multi point, announced their WBSn 2400 base stations are now Wi-Fi certified for Passpoint 1.0 by the internationally recognized Wi-Fi Alliance®. Wi-Fi certified Passpoint™ automates the entire process of finding and authenticating to a Wi-Fi network, enabling a cellular-like experience when connecting to Wi-Fi. The Passpoint certification marks Alvarion Technologies' ability to provide advanced, reliable and cost effective Wi-Fi solutions as they solidify their place in the smart cities and high-density event markets.

Delta Electronics Mfg. Corp. announced it is celebrating its 60th anniversary as a strong, valued corporation. Delta has developed into an innovative RF/microwave and millimeter wave interconnect company, providing high-quality interconnect solutions, including precision microwave components, cable assembly and value add products/services to the commercial, military and aerospace industries. Its unsurpassed customer service, quality products and services, utilizing its global manufacturing capabilities, has placed Delta into a significant technology/supplier role in the interconnect industry, both domestically and in the international space. Delta's founder, Nick Nikitas, started the company as a component specialist supplying RF connectors and cable assemblies to the private sector, distribution and government related businesses.

Keysight Technologies, Inc. announced that Frost & Sullivan has recognized Keysight with the 2014 Global Frost & Sullivan Award for Market Leadership in Instrumentation Software for excellence in capturing the highest market revenue within its industry. The award is based on Frost & Sullivan's recent analysis of the instrumentation software market.

CONTRACTS

Phonon Corp. has received an $8 million order from a leading defense prime contractor for SAW radar pulse compression modules, for 2015 delivery, for an air defense system. Phonon Corp designs and builds custom SAW devices and modules for defense and space.

Mercury Systems, Inc., a leading high-tech commercial provider of more affordable secure and sensor processing subsystems powering today's critical defense and intelligence applications, announced it received a $4.3 million follow-on order from a leading defense prime contractor for high performance signal processing subsystems for a ship-borne radar application. The order was booked in the company's fiscal 2015 second quarter and is expected to be shipped by its fiscal 2016 third quarter.

Advantech Wireless announced that it has been awarded over $3 million in orders from defense organizations to provide its GaN based SSPAs for Satcom-On-The-Move (SOTM) solutions and Flyaway terminals. The units will be WGS certified in Ka-Band and X-Band. Advantech Wireless has over 25 years of experience empowering military forces and government agencies, delivering cutting-edge innovations in communications that solve mission critical communications challenges. The company provides extensive technologies with proven flexibility to deliver video, voice and data transmissions to mobile groups at any time.

Antenna Systems Solutions S.L., a leading provider of antenna measurement solutions for the defence, government and wireless industries, announced that it has won a contract to upgrade an indoor antenna measurement system for a leading Swedish defence contractor. The project includes adding a spherical near field range to an existing far-field and RCS measurement range. Located in Sweden, the near field range will be used to measure reflector type antennas for aeronautical applications. After weighing various alternatives, the customer chose ASYSOL's innovative and cost-effective measurement solution package. This solution is based on ASYSOL's specially designed positioners and automated slides.

DiTom Microwave has received a contract from a major U.S. satellite manufacturing company for K-Band space qualified hardware. Under the contract agreement, DiTom will supply these components for a commercial payload. The manufacturing work will be performed at DiTom's facility in Fresno, Calif., and is expected to be completed by the end of the company's fiscal 2015 third quarter.

PEOPLE

▲ Ted Heil

Mini-Circuits announced that **Ted Heil**, Mini-Circuits' vice president and chief operations officer has been appointed as president. He succeeds Harvey Kaylie as the second president in the company's 46-year history. Mr. Kaylie will retain the position of chief executive officer, continuing his involvement in the company's development and business strategy. Mr. Heil has served Mini-Circuits for the past seven years as vice president and chief operations officer. He has over 30 years experience in the RF/microwave community in numerous executive positions.

▲ Jeff Howland

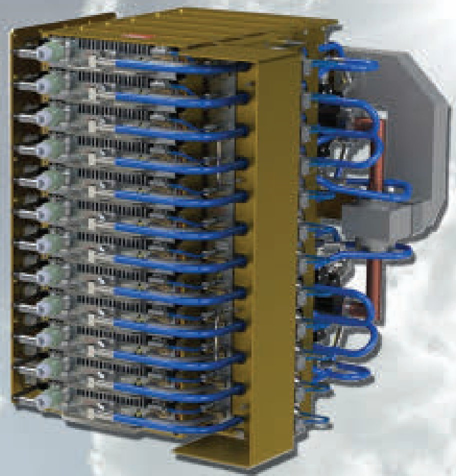
Qorvo, the company that resulted from the recent merger of RF Micro Devices Inc. and TriQuint Semiconductor, has hired a new corporate vice president and general counsel. **Jeff Howland** comes to Qorvo from Winston-Salem-based Womble Carlyle Sandridge & Rice, where he was a partner. While working for the law firm, he served more than 20 years as outside counsel to RF Micro Devices. Howland will report to Qorvo CEO Bob Bruggeworth in Greensboro, N.C.

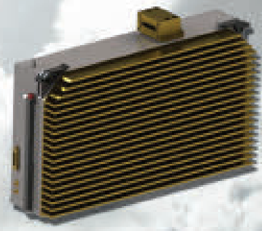
▲ Gerry Camacho

RFMW, Ltd. announced that **Gerry Camacho** has joined their organization as worldwide director of coaxial components. Camacho has served in senior management positions within RF distribution and engineering positions at well-known industry OEMs. His accomplishments include VP of techni-

Solid State Power Amplifiers

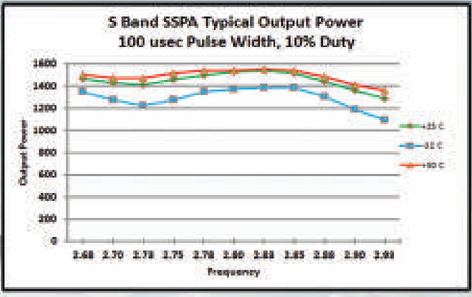
S-Band





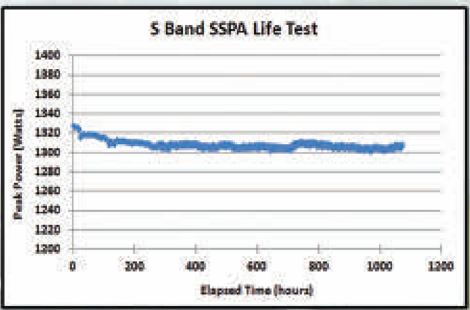
X-Band

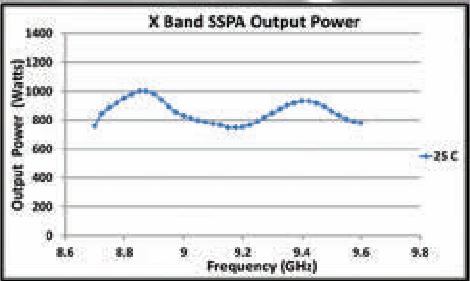
GaN Solid State Amplifiers



FEATURES

- High Efficiency Pulsed Modules (10% duty)
- BIT & Controls via - EIA 422
- Compact Light Weight
- High Reliability
- Field Replaceable Modules
- 9.0 - 9.2 GHz X-Band: 1 kW Modules
- 2.7 - 2.9 GHz S-Band: 1.3 kW Modules
- 1.2 - 1.4 GHz L-Band: 700 W Modules
- Power Combine Modules up to 25KW





For more information contact

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Phone:(978) 922-6000 Fax: (978) 922-2736
Email: bmdmarketing@cpii.com

Communications & Power Industries

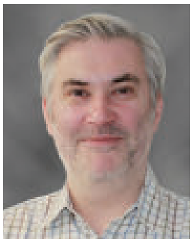
www.cpii.com/bmd
Beverly Microwave Division

Around the **Circuit**

cal marketing at Pasternack Enterprises, regional sales management, antenna and test engineering at Lockheed and TRW. Camacho brings his technical and web marketing skills to his new position where he is tasked with growing RFMW's RF interconnect and coaxial component business unit.

▲ Morgan Hanson

Flann Microwave, a manufacturer of precision waveguide instruments up to 500 GHz, announced the appointment of **Morgan Hanson** as international sales manager. Hanson comes to Flann Microwave from a long career in the electronic test and measurement market where he was senior account manager for a major international manufacturer. He is a 25 year veteran of the industry with a track record of success in the defense, telecommunications and research sectors and has held varied positions over this time in sales, marketing, business development and test engineering.



▲ Ian Gresham

Ian Gresham, **Anokiwave** Distinguished Fellow of Technology has been named a fellow of the Institute of Electrical and Electronics Engineers (IEEE) for technical leadership in commercial automotive radar sensors. The IEEE grade of fellow is conferred by the IEEE board of directors upon a person with an outstanding record of accomplishments in any of the IEEE fields of interest. The total number selected in any one year cannot exceed one percent of the total voting membership. IEEE Fellow is the highest grade of membership and is recognized by the technical community as a prestigious honor and an important career achievement.

▲ David L. Mason

Chesapeake Advanced Technologies, a technical sales organization for MD, DC, DE, VA, PA and NJ are delighted to announce the addition of **David L. Mason** as technical sales representative for the DC and Virginia territory. Mason brings a combination of successful business and technical knowledge to Chesapeake Advanced Technologies with his extensive career experiences. Mason most recently was a local representative supporting technical sales and product applications of Hittite (RFICs, MMICs and modules) and several RF & Microwave components manufacturers, for accounts in Maryland and Virginia.

Isola Group, a market leader in copper-clad laminates and dielectric prepreg materials used to fabricate advanced multilayer printed circuit boards (PCBs), announced that **Andrew Jor** has been promoted to executive director, business development-Asia. In this role, Jor will be responsible for driving the strategic business development goals for the Asian region. Additionally, Isola is pleased to announce that **Dick Leung** has been promoted to direc-

tor of regional business – Hong Kong and South China. In this role, he will lead Isola's sales teams in Hong Kong and South China, driving revenue growth in this territory.

IN MEMORIAM

▲ *Frank A. Brand Sr.*

Frank A. Brand Sr. of Boca Raton, Florida and Lynnfield, Massachusetts passed away peacefully after a brief illness on February 2, 2015. His early career included 20 years with Ft. Monmouth in Red Bank, New Jersey where he led their civilian electronics division while also serving as a Professor in Electrical Engineering at Monmouth College in West Long Branch, New Jersey. Following his time at Ft. Monmouth, he moved on to Microwave Associates in Burlington, Massachusetts as vice president of the semiconductor division. He later served as chief operating officer, chief technology officer and chief executive officer for MACOM in Burlington, Massachusetts. He was a fellow of the IEEE and served on numerous boards of directors including 20 years on the Nypro Inc. board. He received Bachelor of Science and Masters of Science degrees in Physics from Brooklyn Polytechnic University and earned his Ph.D. in Electrical Engineering from UCLA. Brand was instrumental in the development of the microwave industry and will be remembered for his many contributions.

REP APPOINTMENTS

Knowles brand **Syfer Technology** will now be represented by **TTI Inc.**, in the U.S. Already supported by TTI Inc. in Europe and Asia this move sees the brand available worldwide from this leading authorized distributor of interconnect, passive, electromechanical and discrete components. With a history traceable back to Erie Electronics in the 1960s, Syfer is a global leader in Capacitor products, EMI filters and EMC solutions. The company was later acquired by the Dover Corp. and is now part of The Knowles Corp., a recent spin-off from Dover. The brand is a constituent part of Knowles along with DLI, Novacap and Voltronics.

San-tron Inc., a leading manufacturer of RF and microwave coaxial connectors and cable assemblies, announced the appointment of two new sales representatives – **Sea-Port Technical Sales** and **Coastal RF Systems**. Sea-Port Technical Sales will handle the Pacific Northwest region, covering Idaho, Montana, Oregon, Washington, and British Columbia. Coastal RF Systems will cover Southern California.

photo courtesy of the
U.S. Military & NASA

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CERAMIC MMIC AMPLIFIERS

Low NF 0.5 dB *High IP3 up to 38 dBm* *Low DC current 65 mA* *$4.95 ea. (qty 20)*

When failure is not an option. Our new CMA MMIC amplifiers deliver outstanding performance in a rugged, nitrogen-filled, hermetic LTCC design, just 0.045" high. These models are so tough, they've qualified for use under MIL environmental conditions:

Robust performance across wide bandwidths makes them ideal for instrumentation, or anywhere long-term reliability adds bottom-line value. Go to minicircuits.com for all the details today, and get them in your hands as soon as tomorrow!

MIL Qualifications *(see website for complete list and details)*

Gross and Fine Leak	*HTOL (1700 hours+ @ +105°C)*
Mechanical Shock	*Thermal Shock*
Vibration	*Steam Aging*
Acceleration	*Solder Heat Resistance*
PIND	*Autoclave (and more)*

Electrical Specifications *(-55 to +105°C)*

3 x 3 x 1.14 mm

	Model	Freq. (GHz)	Gain (dB)	P_{OUT} (dBm)	IP3 (dBm)	NF (dB)	DC (V)	Price $ ea. (qty 20)
	CMA-62+	0.01-6	15	19	33	5	5	4.95
	CMA-63+	0.01-6	20	18	32	4	5	4.95
	CMA-545+	0.05-6	15	20	37	1	3	4.95
NEW	CMA-5043+	0.05-4	18	20	33	0.8	5	4.95
NEW	CMA-545G1+	0.4-2.2	32	23	36	0.9	5	5.45
NEW	CMA-162LN+	0.7-1.6	23	19	30	0.5	4	4.95
NEW	CMA-252LN+	1.5-2.5	17	18	30	1	4	4.95

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High Performance Front-end Modules

Dual-band 802.11a/g/n/ac Wireless LAN Front-end Module: SKY85806-11

- For set-top box, wireless high fidelity, USB dongle and personal computer applications
- All RF ports matched to 50 Ω
- Integrated 2.4 GHz PA, 5 GHz PA, transmit filter, diplexers and T/R switches
- Integrated logarithmic power detector for each transmit chain
- Bluetooth® ready; functional when V_{CC} = 0 or 3.3 V
- Package: QFN 28-pin 4 x 3 x 0.8 mm

5 GHz, 802.11ac Switch/Low-noise Amplifier Front-end Module: SKY85608-11

- For 802.11a/n/ac set-top box, TV, audio, personal computer and WLAN-enabled wireless video system applications
- Integrated SP2T switch and LNA with bypass mode
- Receive gain: 12 dB
- Noise figure: 2.1 dB
- Transmit path loss: 0.8 dB
- Package: DFN 8-pin 1.5 x 1.5 x 0.4 mm

2.4 GHz, 256 QAM Switch/Low-noise Amplifier Front-end Module: SKY85203-11

- For 802.11b/g/n set-top box, mobile device, gaming and tablet applications
- Integrates an SP3T switch and LNA with bypass mode
- Receive gain: 14 dB
- Noise figure: 2.1 dB
- Transmit/Bluetooth® path loss: 0.8 dB
- Package: QFN 12-pin 2 x 2 x 0.45 mm

2.4 GHz ZigBee® RF4CE/Smart Energy Front-end Module: SKY66109-11

- For set-top box, in-home appliance and smart meter applications
- Integrated PA with up to 24 dBm output power
- Integrated LNA with programmable bypass
- Integrated antenna switching with transmit and receive diversity function
- Package: MCM 20-pin 3 x 4 x 0.9 mm

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The Microwave Industry Visits the Olympic Village

Patrick Hindle, *Microwave Journal* Editor

The third annual Electronic Design Innovation Conference (EDI CON) China takes place April 14-16 at the China National Convention Center (CNCC) located in the Olympic Village in Beijing. The conference and exhibition has expanded in its first two years and outgrew its previous venue. Like the Olympics, this event draws some of the best "industry athletes" or experts from around the world. They come each year to share and exchange information on the latest developments and advances in our industry.

The conference kicks off at 10:00 on April 14 on the fourth floor of the CNCC with some exciting paper sessions including a full track on amplifier design that includes the latest on envelope tracking and DPD design. There are five parallel tracks including one on high frequency PCB and connector design with presentations from leading substrate material and connector companies from around the world. Another track includes high frequency and high speed design techniques covering various measurement & modeling subjects and mmWave topics. The system level measurement and modeling track features topics on the latest in OTA measurements, Wi-Fi and oscilloscope technology. The systems engineering track on Tuesday covers topics such as MIMO antennas, base stations and measurement chambers. The afternoon workshops build on these topics by offering tutorials from company experts involved in these subject areas.

At 15:30 on Tuesday, the keynote plenary talks commence in the auditorium on the fourth floor. EDI CON honorary chairman, Prof. Dr. Junde Song from Beijing University of Posts and Telecommunications will discuss how the "Construction of Smart Cities and Communities" is driving rapid development of ICT Industry in China. Dr. Song is leading many of the Smart Cities projects around China and is an expert in this area of research. His talk will be followed by Wai Chen from China Mobile Research Institute, discussing the latest developments in the Internet of Things (IoT). Hongbing Ma of China Unicom will then talk about 5G co-existing opportunities and challenges for future communications systems. Jian Li Wang, CTO of RF Products from ZTE will discuss the latest developments in 5G and massive MIMO. Our three major sponsors, Keysight Technologies, Rohde & Schwarz and National Instruments will also discuss their latest product developments and capabilities during the plenary talks.

I am especially excited about the addition of a full day 5G Forum on advanced communications taking place on Wednesday, April 15. The 5G Forum starts with a keynote speech by Dr. Zhengang Pan, principal scientist at China Mobile Research Institute about their vision of 5G and IoT followed by the latest developments from Ericsson. Next will be a panel session with various 5G experts discussing questions from the audience about 5G. The rest of the day includes eight sessions and two workshops covering topics such as massive MIMO, HetNets, phased array transceivers, timing and synchronization, testing challenges, SDR, new modulation schemes and mmWave technologies. This should be a very popular addition to the conference.

The second day also features some interesting tracks including an IoT design track with sessions about low power design, antenna tuning and switching. Another track features several talks on EMI modeling/testing and high speed design techniques. Radar design, test and simulation is the focus of another full day track for system level measurements and modeling plus the systems engineering track covers various topics in testing and designing high frequency and high speed digital systems. The paper session tracks will again be followed by workshops and a special GaN panel with industry experts discussing the status and future of GaN technology in a round table format.

The final day features tracks on microwave component design from VCOs to MMICs to PAs based on LDMOS and GaN technology. There is a measurements and modeling track covering device modeling topics and basic microwave measurement techniques. Another track features various topics on EMC/EMI and high speed measurements and modeling with the systems engineering track covering some high power subsystems and unique communications systems. These are followed by more workshops given by industry experts to close out the conference.

The third annual EDI CON China promises to be bigger and better than ever with a variety of high frequency, high speed and EMC/EMI topics planned over the three day event. EDI CON China 2015 has more than 95 paper sessions and 35 workshops so there is something for everyone. Please join us in Beijing this spring! ■

Tuesday, April 14, 2015

	Measurements & Modeling Track: PCB/Connector Focus	Design Track: Amplifier Focus	RF/Microwave & HSD Measurements/ Modeling Track	System-Level Measurements/ Modeling Track	Systems Engineering Track		
	Room 401	**Room 402A/B**	**Room 403**	**Room 405**	**Room 406**		
08:00 - 17:00	**On-Site Registration Opens**						
	General Technical Sessions						
10:00 - 10:20	TU_101 - Characterization of PCB Insertion Loss with a New Calibration Method *Cheng, Keysight Technologies*	TU_102 - Multi-Mode Stability Analysis of Power Amplifiers Employing Mixed-Mode Parameters *Yao, IMECAS*	TU_103 - Characterization Using Multi-Purpose Source & Load Pull Tuners (MPT) for Inverse Class F PA First-Pass Design *Tsironis, Focus Microwaves*	TU_104 - Hybrid Over The Air Throughput Measurement *Young, Pace Americas*	TU_105 - Power Distribution Control Room Electromagnetic Field Simulation Modeling *Du, CST*		
10:20 - 10:40	TU_201 - Testing High Speed PCBs with Vector Network Analyzers *Weiss, Rohde & Schwarz*	TU_202 - A Simple Method for Changing the Frequency Range of an RF Power Amplifier Circuit *Vigneri, Freescale Semiconductor*	TU_203 - High Speed Hybrid Active Injection Load-Pull (HAILP) *Tsironis, Focus Microwaves*	TU_204 - WLAN 802.11ad Spectrum and Modulation Measurements in the 60 GHz Range *Schmähling, Rohde & Schwarz*	TU_205 - Simulation Approach for MIMO Antenna Diversity Strategies *Futter, Altair*		
10:40 - 11:00	TU_301 - Performing Reliable, Repeatable RF Measurements Using RF Test Probes On Board to Board Connectors *Masnou, Radiall*	TU_302 - ET Test Solution and Result Analysis *Ma and Wang, Rohde & Schwarz*	TU_303 - A New Method for Noise Figure Measurement Base on Modern VNA *Li, Keysight Technologies*	TU_304 - From 802.11a to 802.11ah: A Survey of the New Features Available in 802.11ad/af/ah *Hall, National Instruments*	TU_305 - Addressing Multi-Channel Synchronization and Calibration Needs for MIMO Testing *Hsu, Keysight Technologies*		
11:00 - 11:30	**Tea Break - South Foyer**						
11:30 - 11:50	TU_401 - Effect of Laminate Thermal Conductivity, Dielectric Loss and Copper Roughness on the Temperature Rise of HF Transmission Lines/Devices *Aguayo, Rogers Corp.*	TU_402 - A High Voltage GaN HEMT Power Amplifier Design for Envelope Tracking *Wang, Microsoft*	TU_403 - Applying the Y-Factor Method for Noise Factor Measurements of LNAs *Hall, National Instruments*	TU_404 - 16 Bit Vertical Resolution on Oscilloscopes *Beer, Rohde & Schwarz*	TU_405 - Multiple Entities, Base Stations Efficient Testing of Real Life Scenarios *Thuemmler, Rohde & Schwarz*		
11:50 - 12:10	TU_501 - Material for Improved RFPA Performance *Zhang, Arlon*	TU_502 - Measuring the Time-Alignment in Envelope Tracking Power Amplifiers *Feng, Keysight Technologies*	TU_503 - Noise Parameter Measurement System Verification using On-Wafer Passive Attenuator *Tsironis, Focus Microwaves*	TU_504 - Using Real Time Scope to Fully Analyze High Speed Digital Signals *Lu, Keysight Technologies*	TU_505 - Improving Throughput of Multiport Network Analysis using PXIe Vector Network Analyzer *Hirato, Keysight Technologies*		
12:10 - 12:30	TU_601 - Applying VNA for PCB Power Plane Ultra-Low Impedance and Inductance Measurements *Ko, Keysight Technologies*	TU_602 - Envelope Tracking for Uplink LTE Carrier Agregation *Balteanu, Skyworks*	TU_603 - Methods to Improve Noise Figure Measurement Accuracy in Signal Analyzer *Rui, Keysight Technologies*	TU_604 - Using Sequencer Technique to Speed Up Femtocell Measurement *Cong, Keysight Technologies*	TU_605 - Accurate Simulation of Measurement Chambers *Futter, Altair*	**Press Conference** **Exhibition Hours** **12:00 - 18:30**	
12:30 - 13:30	**Lunch Break - Exhibition Floor**						**Poster Session: Exhibition Floor** **12:30 - 15:30**
	Workshops						
13:30 - 14:10	WS_TU101 - Measurement of the Effect of Laminate Material Properties on the Temperature Rise of High Frequency Devices *Rogers*	WS_TU102 - DPD, ET and Load Pull: Three PA Measurement Techniques Every Engineer Should Know *National Instruments*	WS_TU103 - Millimeter Wave VNA Development and Application *Anritsu*	WS_TU104 - Simulation Enabled 5G Antenna Design *CST*	WS_TU105 - LTE & LTE-A 4x4 MIMO Throughput Test Solution Based on SystemVue & PXI *Keysight Technologies*		
14:15 - 14:55	WS_TU201 - Impact of Cable Assemblies for Test and Measurement *W. L. Gore*	WS_TU202 - The Design and Optimization of Power Amplifiers Based on Test Techniques *Rohde & Schwarz*	WS_TU203 - Complete Millimeter Wave Test System Includes Noise Figure Measurements *Keysight Technologies*	WS_TU204 - Next Generation LDMOS for Multi-Markets *(NXP)* and Next Generation Industrial Innovation and Manufacturing *(Siemens)* *Transemic*	WS_TU205 - Understanding TD-LTE *Qorvo*		
15:00 - 15:30	**Tea Break - Exhibition Floor**						
15:30 - 17:30	**Plenary Session - Featuring Chair Dr. Song, BUPT; Sponsors; Guest Keynotes: China Mobile, China Unicom, ZTE Auditorium**						
18:00 - 20:00	**VIP Reception and Dinner (Sponsors and Invited Delegates) - Ballroom, First Floor**						

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

EDI CON

Wednesday, April 15, 2015

	Design Track: Antennas/IoT/MMICs	5G Forum	HSD/EMC Measurement & Modeling Track	System-Level Measurements/Modeling Track: Radar Focus	Systems Engineering Track	
	Room 401	**Room 402A/B**	**Room 403**	**Room 405**	**Room 406**	
09:30 - 09:50	WE_101 - Active Antenna and RF Systems Deliver Critical Connectivity for Wireless Devices – From Smartphones to IoT *Wang, Ethertronics*	WE_102 Keynote: 5G and IoT Vision *Dr. Zhengang Pan, China Mobile and Ericsson*	WE_103 - Understanding Fully-Differential Amplifier Specifications and the Benefits of FDAs When Driving ADCs *Sipp, Texas Instruments*	WE_104 - Integrated Framework for Radar Design *Paparisto, National Instruments*	WE_105 - Research and Applications on In-Circuit Test of Signal Processing Boards *Zeng, Beijing Herotec*	
09:50 - 10:10	WE_201 - New IoT RF & Protocol Testing *Ma and Feng, Rohde & Schwarz*	WE_202 - 5G Panel Session: *Keysight Technologies, Rohde & Schwarz, National Instruments, MACOM, China Mobile and Shanghai Tech*	WE_203 - Full-Wave Electromagnetic Simulation for SI and EMI in High Speed Connectors *Sun, CST*	WE_204 - Ultra High Definition (UHD) Imaging for Aerospace and Defense Applications; *Dimitrakopoulos, Rohde & Schwarz*	WE_205 - Simulation to Measurement Workflow for DDR4 Electrical and Timing Compliance; *Yang, Keysight Technologies*	
10:10 - 10:30	WE_301 - HFSS Component Model Libraries to Support Enterprise-Level Product Development and IoT Design *Chen, ANSYS*		WE_303 - Serial Data Link Analysis with Measurement and IBIS-AMI Simulation Correlation *Wang, Keysight Technologies*	WE_304 - A Bridge to Connect Antenna Design and Radar System *Xie, Keysight Technologies*	WE_305 - Real-Time DPD Design-to-Prototype *Inoue, National Instruments*	
10:30 - 11:00	**Tea/Coffee Break - Exhibition Floor**					
11:00 - 11:20	WE_401 - Design of W-Band MMICs Based on InP HEMT Technique *Yao, IMECAS*	WE_302 - Massive MIMO System Design and Consideration *Yang, Keysight Technologies*	WE_403 - High-Speed Circuit Board Clock Circuit EMI Simulation and Testing *Ren, CST*	WE_404 - Segmented Capture for Analysis of Long Pulse Sequences for RADAR Analysis *Schmähling, Rohde & Schwarz*	WE_405 - Implementing an FFT-Based EMI Measurement *Tye, Keysight Technologies*	
11:20 - 11:40	WE_501 - Broadband, Low-Loss Impedance Matching for W-Band Power Amplifier with 22 dB Gain *Yao, IMECAS*	WE_402 - Compact Measurement System for 5G mmWave Channel Sounding *Eichler, Rohde & Schwarz*	WE_503 - VFTO Radiated Interference Simulation in GIS Field *Liu, ANSYS*	WE_504 - Automatic Analysis of 500 MHz or 2 GHz Wide Frequency Hopping or Chirp Signals Used in Modern RADAR Applications *Schmähling, Rohde & Schwarz*	WE_505 - Optimization of EVM Testing with VSA/VSG for Modulated Signal Like 802.11 WLAN and LTE *Lin, National Instruments*	
11:40 - 12:00	WE_601 - Multiband Triangular Planar Inverted F-Antenna Design for Wireless Communication Applications *Ho*	WE_502 - Flexible Testbed for 5G Massive MIMO: From Theory to Reality *Jia, National Instruments*	WE_603 - Benefits of Multi-Tone Immunity Testing *Barth, AR*	WE_604 - Modeling and Measurements of Frequency Stepped Chirped Radar *Nguyen, National Instruments*	WE_605 - Design and Implementation of Large-Scale RF and Microwave Switch System *Qi, Pickering*	
12:00 - 12:20	WE_701 - Implementation of a Zigbee Circuit Reference Design *Leong, National Instruments*	WE_602 - mmWave MIMO Channel Sounding for 5G-Technical Challenges and Prototype System *Wen, Keysight Technologies*	WE_703 - EMI and Crosstalk Mitigation on Power Tray *Fan, Cisco*	WE_704 - Comprehensive Radar Testing *Heuel, Rohde & Schwarz*	WE_705 - HFC Improvement for DOCSIS3.1 Evolution *Huang, Keysight Technologies*	
12:30 - 13:30	**Lunch Break - Exhibition Floor**					
	Workshops & Panels					**Exhibition Hours 10:00 to 17:00**
13:30 - 14:10	WS_WE101 - Smart Antenna Technology and Multi-Channel RF Measurements *Keysight Technologies*	13:30 - 13:50: WE702 - Transceiver Module & Multi-Element Phased Array Design for 5G *Paparisto, National Instruments* 13:50 - 14:10: WE802 - Timing and CFO Synchronization in FBMC System Based on Superimposed Zadoff-Chu Sequences *Zhang, Keysight Technologies*	WS_WE103 - Minimizing EMI Through Effective Signal and Power Integrity *ANSYS*	WS_WE104 - An Active Solution & Service from Microwave to Terahertz for Communications/Radar/Sensor & Imaging Systems *Farran*	WS_WE105 - Commercialization of GaN for Cost-Sensitive Applications *MACOM*	
14:15 - 14:55	WS_WE201- Why Reaching 0 Hz Matters: The True DC Switch *Brown, Peregrine Semiconductor*	14:15 - 14:35: WE902 - Signal and Spectrum Analysis Challenges in 5G Test and Measurement *Schmähling, Rohde & Schwarz* 14:35 - 14:55: WE1002 - HetNet on LTE and Wi-Fi *Yang, Shanghai Tech*	WS_WE203 - 100G Backplane Test Challenges *Keysight Technologies*	WS_WE204 - Radar Complex Electromagnetic Environment Simulation and Evaluation Method *Rohde & Schwarz*	WS_WE205 - Small Cells Design Solutions *Richardson RFPD*	
15:00 - 15:30	**Tea/Coffee Break - Exhibition Floor**					
15:30 - 16:10	WS_WE301 - USB Spectrum Analyzer *Tektronix*	WS_WE302 - Verification and Testing 5G and Millimeter Wave Ultra-Wideband Signals *Keysight Technologies*	WS_WE303 - Automated Test Equipment (ATE) and WiMAX, Wi-Fi, 3G, 4G, LTE, DVB Fading Simulators *Mini-Circuits*	WS_WE304 - Advanced Modeling Techniques for Phased Array Antennas *Cao, ANSYS*	WS_WE305 - Efficiency Enhanced GaN HEMT Allowing Flexible RF Designs for LTE Applications *RFHIC*	
16:15 - 16:55	WS_WE401 - A Method to Reduce Voids in Solder Attach for RF Devices *Freescale*	WS_WE402 - Introduction to Software Defined Radio in LabVIEW *National Instruments*	WS_WE403 - Signal Integrity in Passive RF and Microwave Components *Huber+Suhner*	WS_WE404 - Wideband Impedance Control for Modulated Signals *Focus Microwaves*	PA_WE405 - GaN Panel *Freescale, Qorvo, MACOM and Empower RF* *Sponsored by: Richardson RFPD*	

EDI CON

Thursday, April 16, 2015

	Measurements & Modeling Track	Design Track	EMC/EMI & HSD Measurements/Modeling Track	Systems Engineering Track	
	Room 401	Room 402A	Room 403	Room 405	
09:30 - 09:50	TH_101 - A Finite-Element Thermal Model for Compound Semiconductor Devices Implemented in SPICE *Tarazi, MACOM*	TH_102 - Tunable VCO Filtering Circuitry *Ho*	TH_103 - Integrated Low Pass Filter with ESD Protection for Audio Applications *Liu, OnSemi*	TH_105 - System for Positioning and Locating of Missile Threats, Mountable on Airliners *Modammadi, BAAM*	
09:50 - 10:10	TH_201 - DynaFET: Accurate Modeling of III-V HEMTs Based on NVNA Measurements and ANNs *Long, Keysight Technologies*	TH_202 - Coupled Electro-Thermal Analysis of High Power RF Filters *Yuan, ANSYS*	TH_203 - Addressing the Challenges of PAM-4 Receiver Stressed Input Testing *Hoehne, Keysight Technologies*	TH_205 - A 60 and 80 GHz Point-to-Point Data Link with Throughput Up to 160 & 225 Gb *Modammadi, BAAM*	
10:10 - 10:30	TH_301 - Statistical Model Extraction Solution *Fei, Keysight Technologies*	TH_302 - Design Methodology for GaAs MMIC and/or Basestation PA *Lien, National Instruments/AWR*	TH_303 - Analysis of Small Voltage Variation Under Large Signal Conditions *Beer, Rohde & Schwarz*	TH_305 - A Novel Interpretation of Shipbourne EMI Measurements by Means of Fuzzy Theory *Macedo, Inmetro*	
10:30 - 11:00	**Tea/Coffee Break - Exhibition Floor**				
11:00 - 11:20	TH_401 - Understanding the Effect of Source Isolation on Intermodulation Distortion Measurements *Fernandez, National Instruments*	TH_402 - C-Band GaN Microwave Power Device Broadband Matching Circuit *Shen*	TH_403 - Advanced Techniques for Testing High Speed, Multi-Lane PCI Express 3.0 and 4.0 Devices *Eads, Keysight Technologies*	TH_405 - A BPSK Demodulator Design for Onboard Satellite Telecommand Receiver *Basit, UET Taxila Pakistan*	
11:20 - 11:40	TH_501 - Measurement of Passive Inter-modulation Using a Vector Network Analyzer *Bednorz, Rohde & Schwarz*	TH_502 - A Rigorous and Simple Method for Loop Circuit Stability Analysis *Yao, IMECAS*	TH_503 - How to Test the DDR4 Circuit and Timing Accurately *Zhao, Keysight Technologies*	TH_505 - Overcoming RF-System Level Challenges in an UHF Multi-Protocol RFID Reader Using Software-Defined Radio (SDR) *Wong, Avidus*	
11:40 - 12:00	TH_601 - Fundamentals of Pulsed Power Measurements *Fernandez, National Instruments*	TH_602 - A 790 to 960 MHz Wideband 600 W LDMOS Asymmetry Doherty Amplifier *Hao, Freescale Semiconductor*	TH_603 - Standard Document to the Test Floor Measurement - Challenges from the Bluetooth Perspective *Jia, National Instruments*	TH_605 - 200 W Power Amplifier/Transceiver Switch Assembly *Hou, Avidus*	**Exhibition Hours 10:00 to 15:00**
12:00 - 12:20	TH_701 - S-Parameter Measurements with Modulated Signals *Bednorz, Rohde & Schwarz*	TH_702 - Low Phase Noise and Fast Tuning Microwave Signal Generator *Fernandez, National Instruments*	TH_703 - NFC Analogue Measurement Uncertainty Brought by Position Accuracy *He, VI Service*	TH_705 - Microwave Power Combining System Based on Two Injection-Locked CW Magnetrons *Huang*	
12:30 - 13:30	**Lunch Break - Exhibition Floor**				
Workshops					
13:30 - 14:10	WS_TH101 - Application Circuit to Extend the Bandwidth of Narrow Band Matched MMIC Power Amplifiers *Mini-Circuits*	WS_TH102 - Highly Integrated mmWave PHEMT Foundry Processes *WIN Semiconductors*	WS_TH103 - Resolving Cavity Resonance Effects in Microwave Circuits *Leong, National Instruments*	WS_TH105 - Phase Coherent Signals, Challenges and Applications *Thuemmler, Rohde & Schwarz* and Facing Multi-Port Device Challenges with Modern VNA Testing Techniques *Bednorz, Rohde & Schwarz*	
14:15 - 14:55	WS_TH201 - PCB and Electronic Industry Materials Measurement Methods from Low Frequency to Microwave *Keysight Technologies*	WS_TH202 - A Fast and Reliable High Efficiency GaN PA Design Approach with Measurement Based Model *Maury Microwave*	WS_TH203 - *CETC41 Workshop*	WS_TH205 - Complex RF Environment: Challenges in Telecommunications and A&D; *Thuemmler/Heuel, Rohde & Schwarz* and A Method to Improve the Efficiency of Agile Frequency Synthesizer Testing *Peng, Rohde & Schwarz*	

INVITED PAPER

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Modular Solutions: Test With Confidence and Achieve Shorter Time-To-First Measurement

Mario Narduzzi
Keysight Technologies, Santa Rosa, Calif.

As technology evolves and new standards emerge, engineers face an ever-increasing array of challenges. These challenges only increase when testing at RF and microwave frequencies or when high performance measurements are required. While these challenges will vary depending on the technology, standard and even application in question, for device test engineers and managers at least one thing remains the same: the desire to test designs more confidently and start making measurements on those designs more quickly. Lofty goals indeed, but that's where the idea of modular instrumentation, via standards like AXIe and PXI, comes into play. Modular instrumentation not only offers space and cost savings, flexibility and scalability, but the high performance and speed needed to ensure fast and accurate measurements.

Clearly the concept of modular instrumentation is nothing new, but advances in PC technology today are allowing modular instrumentation to deliver even higher performance and speed. These improvements are enabling a solutions-based approach to measurement instrumentation that promises to more effectively solve engineers' real world problems. These AXI- or PXI-based "modular solutions" not only help engineers make their measurements more confidently, but speed time-to-first-measurement (TTFM) as well. Let's take a closer look.

WARNING: TECHNICAL CHALLENGES AHEAD

A critical task for device test engineers is to assess whether a given test solution meets their needs. Unfortunately, this process can take a tremendous amount of time and may not always return the desired result. Consider, for example, that a power amplifier (PA) design company has a customer — a mobile device or mobile RF module manufacturer — with very specific performance and throughput requirements for specific measurements. The company needs to find a solution to start making these measurements quickly and confidently, yet it can't afford to waste precious time evaluating test solutions due to tight design cycles and other customer commitments.

The PA company may even need to perform envelope tracking measurements for its customer. These measurements rely on the performance of a single instrument to generate the proper waveform (e.g., an arbitrary waveform generator) and on tight multi-instrument control to ensure the power envelope start and servo-loop control are time-synchronized and triggered correctly. Building and evaluating such a test solution could take months, and

there's no guarantee it would meet the company's requirements once finished.

For the PA design company, and others like it, modular instrumentation can be a highly advantageous solution to their challenges, offering the benefits of size, density, backplane speed and measurement speed. Traditionally, engineers have relied on a software defined radio (SDR) to leverage these modular benefits. With this approach, test vendors essentially provide the engineers with a blank slate to develop a test system. The downside, however, is that the engineers may not be aware of all of the adjustments that must be made to the system or the optimization required to get the best possible performance. Just as critical, given today's increasingly shorter time-to-market cycles, modularity via an SDR is simply not enough.

DEFINING MODULAR SOLUTIONS

A more compelling option to this dilemma is a modular solution, sometimes referred to as a reference solution. The modular solution provides the same basic hardware functionality as the SDR with an added layer of measurement application software. It comprises multiple modular AXIe or PXI test instruments that come with software drivers, measurement algorithms and sample programs. The result is a test system that provides a much more tailored solution to a specific application. Unlike the SDR, the modular solution has already been optimized by the test vendor, leaving the engineer free to focus on getting the job done, rather than having to make system adjustments (see ***Figure 1***).

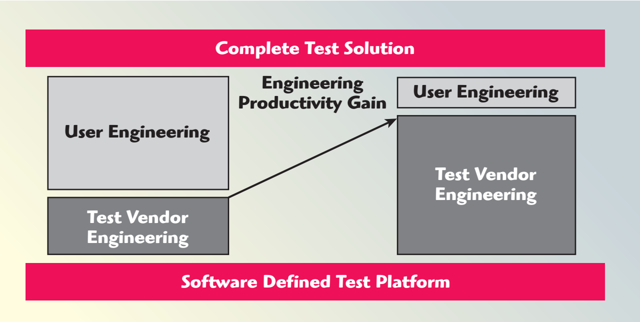


Fig. 1 Illustrates the gain in productivity when using a modular solution approach.

The modular solution's framework is built on standard application programming interfaces (API), common reusable libraries and a software infrastructure. The software provides the automation, managing the solution's resources so that its various modular instruments can work together seamlessly. This combination allows instruments to be combined to achieve a smaller granularity of measurement blocks, while simultaneously optimizing system performance.

Ideally the modular solution's framework will feature an open and flexible software solution that is not dependent on the programming environment. This allows engineers to automate the measurements in whatever programming language they prefer (e.g., .NET, C#, LabVIEW or MATLAB) and easily optimize the speed or performance of their test solution.

With a modular solution, the instrumentation is properly conditioned to make measurements, collect data in the correct format with the correct algorithm, then sent for analysis to be received and processed. However, system interdependencies or unwanted measurement conditions could cause the modular solution to generate incorrect or inaccurate results. The user might not even know a result is inaccurate. For example, a PA under test could be sent into a mode where gain compression is occurring, meaning the signal is becoming clipped and the amplitude measured at the output is lower than predicted or modeled in the design phase of the amplifier.

Fortunately, the modular solution's software effectively deals with issues related to measurement complexity without the engineer ever needing to understand them. One way in which it may do this is through use of a real time fast Fourier transform (FFT) capability that is built into a modular instrument, such as a vector signal an-

alyzer. Basically, once a signal is captured and prepared for analysis, the FFT capability in the signal analyzer measures the adjacent channel power (ACPR). Before generating the result, the filter shape is applied to the FFT bins to optimize the result without sacrificing any measurement performance (see ***Figure 2***).

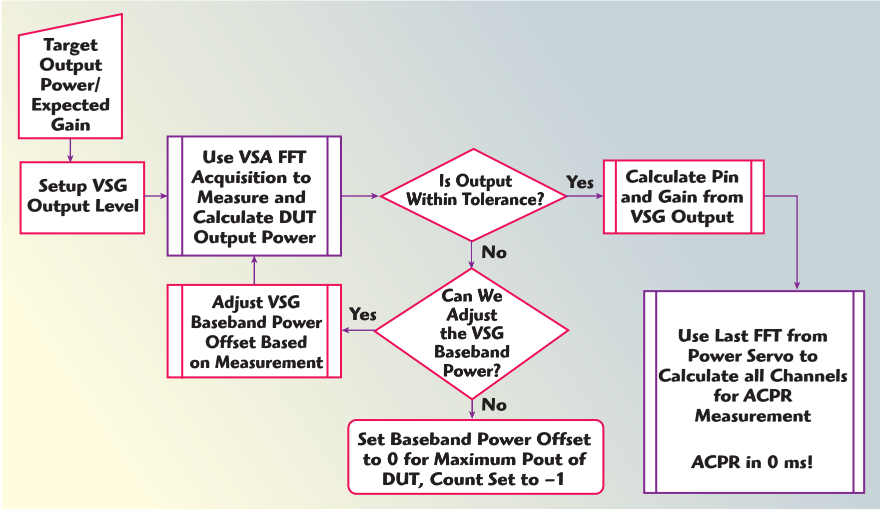
DELIVERING CRITICAL ADVANTAGES

The two main advantages to utilizing a modular solution are shorter TTFM and greater measurement confidence. Essentially, all the engineer has to do before a modular solution is ready to make measurements, is connect its mainframe and modules and power on the system. The entire process takes just a few hours – a far cry from the days and weeks it would typically take to set up a solution that had not been optimized with sample programs.

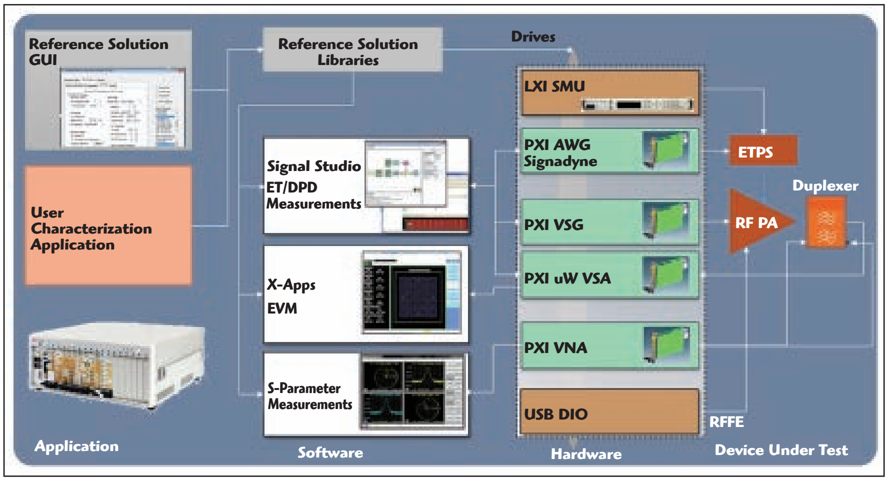
Modular solutions also provide test engineers with confidence that they no longer have to spend time optimizing system test solutions they are not familiar with. As modular products and modules become even more complex and difficult to optimize without the right expertise in RF test, especially when placed together in a system, this benefit will become all the more critical. Essentially, modular solutions will offer engineers the only way to get their first measurements quickly.

MODULAR SOLUTIONS IN ACTION

Modular solutions can be used in virtually any area where a modular platform would prove beneficial, such as in manufacturing or in market segments requiring multiple channels



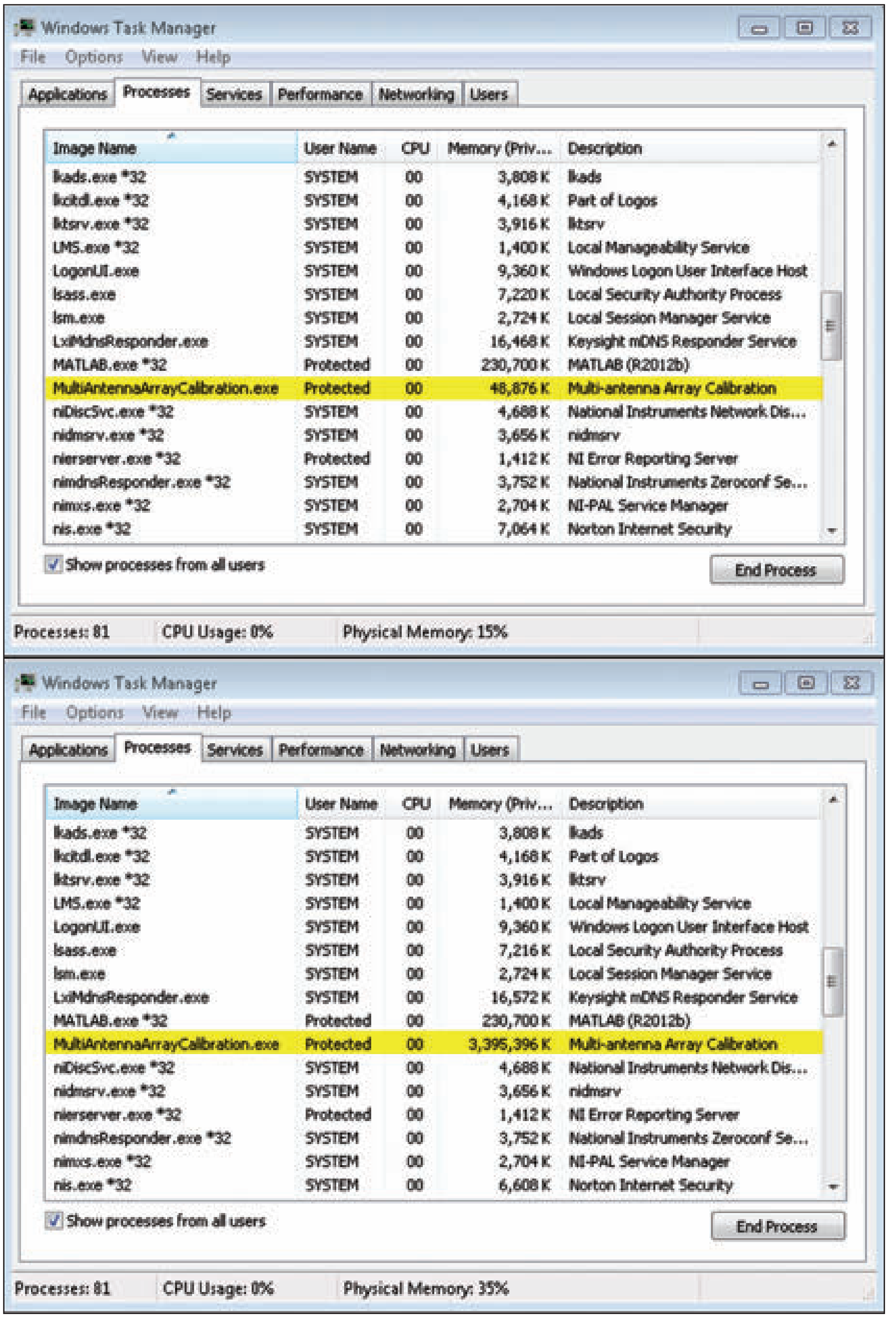
▲ *Fig. 2 A modular solution's software can handle measurement complexity to ensure accurate results.*



▲ *Fig. 3 This RF PA characterization and test reference solution utilizes Keysight PXI modules with LXI and third-party products. It is configurable to test devices without code changes for first level evaluation.*

(e.g., 5G wireless multiple-input-multiple-output antenna system designs). Another prime example is the design validation and production testing of PA or radio modules (see ***Figure 3***), where it is important to quickly develop metrics grade test stations to meet the fast delivery requirements of wireless device manufacturers.

One real-world example is an AXIe-based modular solution for multi-antenna calibration (MAC) that features four analog-to-digital converters with eight-channel AXIe digitizer modules, with precisely controlled on-board clock distribution networks. This configuration enables aggregation of a large number of channels, more easily scaling to 104 channel phase-coherent MAC configurations. Tuned modules can also be aggregated easily. Additionally, the MAC solution utilizes a PCIe backplane that supports up to 600 MB per second data offload rates. Support for .NET ensures there are tools and support for 64-bit architec-



▲ *Fig. 4 Before (top) and after (bottom) images show how Keysight's MAC modular Reference Solution manages multiple GB worth of data inside its custom database of I&Q samples. The MultichannelArrayCalibration.exe process size (memory) went from just 10s of KB (top) to greater than 3 GB (bottom).*

tures to optimize the code to compile into a 64-bit dynamic link library (DLL). Fast transfer and management of large multi-GB measurement records up to 16 GB are performed using a 64-bit .NET class library (see ***Figure 4***). The modular solution also features software specially designed to make cross-channel amplitude and phase measurements that can be modified to meet application-specific requirements.

The key advantage to using a modular solution such as this is the ability to make measurements across many coherent channels concurrently. The modular solution can also provide substantial increases in calibration throughput if supported by the antenna architecture and/or test range (Rx/Tx). Another advantage comes from its use of fast frequency switching sources, which provide additional throughput improvements, assuming the antenna can quickly settle as the stimulus steps to the various tones used in the calibration.

Various options can be added to modular solutions such as this to support the different needs of device test engineers and managers. Suppose, for example, that a company performing multi-antenna calibration on large multi-channel arrays requires a solution that reduces the calibration time by an order of magnitude while still maintaining the excellent sensitivity (dynamic range) of a traditional network analyzer for narrow bandwidths. As investment protection, the same hardware should be programmatically adjustable to support the use of wider bandwidths for calibrations using modulated signals (by trading off some reduction in sensitivity). These needs can be met with just a programmable digital down-converter (DDC) option running inside a modular digitizer's onboard FPGA. The MAC solution automates control of this DDC across multi-channel/multi-blade configurations to provide optimal phase-coherent sensitivity measurements, depending upon the application requirements.

THE BOTTOM LINE

While the use of an SDR offers engineers one way to access the benefits of a modular test system, modular solutions provide a much more compelling option now that PXI and AXIe can provide the performance necessary to meet the most challenging requirements in RF, microwave and high speed digital tests. Not only do they boast the benefits commonly touted by modular instrumentation, they are also tailored to specific real world applications. This enables a shorter TTFM with the capability to efficiently deal with issues related to measurement complexity without an engineer intervening. Since the test vendor optimizes the measurements, engineers can more confidently focus on just doing their job. These advantages, coupled with the growing need for smaller footprint test systems and optimized application-focused solutions, are sure to make modular solutions the ideal option for any engineer currently using modular instruments. ■

INVITED PAPER

Optimizing Wi-Fi Device Adaptability to High-Interference Environments

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Fanny Mlinarsky
octoScope, Littleton, Mass.

One of the more challenging issues facing Wi-Fi equipment suppliers today is that devices are unable to adapt well to high interference in an open air environment. Consequently, they do not provide optimum throughput at all times, with results that frustrate end users. Manufacturers try to make improvements, but often cannot accurately replicate problematic scenarios in their test labs. A promising test solution is to use a set of small, stackable anechoic RF isolation chambers as a test bed, along with a mixed domain oscilloscope (MDO). An MDO is an oscilloscope that is integrated with logic, spectrum and protocol analyzers in one instrument, all synchronized together to provide one view. This combination makes it possible to create repeatable, controlled test conditions for Wi-Fi signals, as well as replicate adverse conditions such as interference and multipath. In this way, engineers can characterize device performance under real-life conditions and perform an in-depth root cause analysis on the device itself.

You might think of a home as a place to hang your hat, rest your head, where the heart is and so on. You may also view it as a high interference environment – at least from a Wi-Fi perspective. A home these days may have one or more wireless access points, several Wi-Fi devices and a number of non-Wi-Fi devices that cause Wi-Fi interference. There may be a desktop computer and a router in the office, a laptop on the dining room table, a microwave oven in the kitchen and a wireless door opener in the garage. Mom and dad might each have a cell phone and tablet, while the kids may have a DS or other Internet-connected gaming device and cell phones of their own. A flat-screen HDTV with a couple of remotes might be in the living room, with a Netflix movie streaming through a set-top box that is wirelessly connected to the router upstairs. When you visualize the living room, don't forget the teenager sitting on the couch, cursing at the TV because the movie keeps stopping at the good parts, while the TV waits for more input so it can stream more video.

End user frustration with wireless signal quality, such as hiccupping throughput, is rivaled only by the frustration experienced by engineers trying to incorporate Wi-Fi into their designs. They tear their hair out to understand why throughput suddenly chokes and how to improve performance so that the flow of information is more consistent. Throughput and signal quality headaches are likely to grow as the inclusion of Wi-Fi radios into end user and machine-to-machine products continues to expand. The Wi-Fi Alliance reports an increase of 50 percent year over year of certified products, with 3,500 products certified in 2011 alone.

This plays out in many ways for electrical engineers who are confronted with having to add wireless local area network (WLAN) connectivity into their product designs. For instance, you can now buy a Wi-Fi-connected thermostat which provides the capability to adjust temperature from anywhere in the house, or a wireless roasting thermometer that remotely tells you when your turkey is done. You can change the heat setting on your bed, using a remote to warm it up for you while you brush your teeth. With such devices, engineers need to verify that the digital switching frequencies or noise from the rest of the design does not affect the WLAN module. Likewise, RF engineers may have to integrate multiple chips within an RF module, debugging the digital interface relative to WLAN behavior.

OPTIMIZATION AND TEST CHALLENGES

It is extremely difficult for designers to test for and understand what is actually causing a particular Wi-Fi communication breakdown and how it is doing so. First, they must determine why throughput is dropping or the connection is being lost. Are too many devices placing demands at the same time, causing a bottleneck? Is there a lot of interference? Or both?

To complicate matters, there are two kinds of interference that adversely affect signal throughput and quality. Multipath refers to reflections in the environment that are created by the transmission itself, bouncing from various surfaces and taking multiple paths back to the same point. These paths have different associated time delays, causing the same information to arrive at different times, asynchronous to the main transmission.

The other kind of interference comes from seperate devices. The number of devices emitting in the unlicensed band dwarfs the number of 802.11 devices. These include, for example, microwave ovens, cordless phones, Bluetooth devices, wireless video cameras, outdoor microwave links, wireless game controllers, fluorescent lights and WiMAX. Even bad electrical connections can cause broad RF spectrum emissions. Non-802.11 types of interference typically don't play well with 802.11 devices, and can cause a significant loss of throughput. What's more, they can cause secondary effects such as rate back-off, in which retransmissions caused by interference "trick" the 802.11 devices into using lower data rates than appropriate.

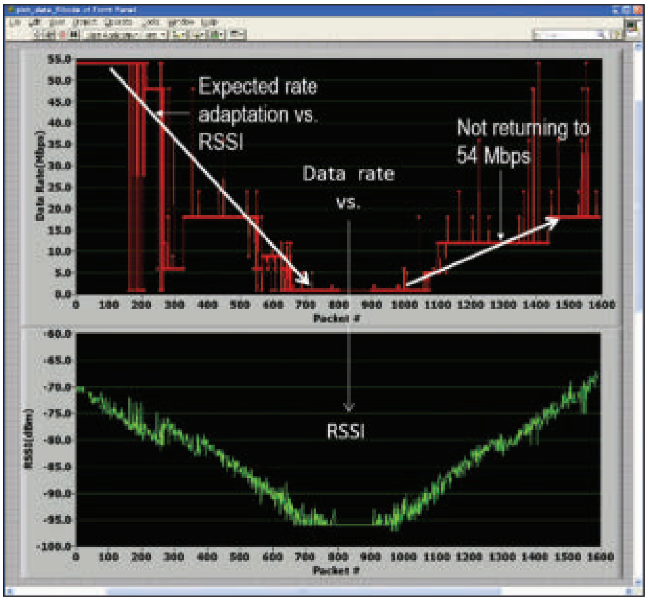
Wireless designers tend to view these problems in terms of how the algorithms inside the device are responding and adapting to what is happening in the environment outside. The algorithms that control the Wi-Fi device use a variety of techniques to adapt to the changing signal environment. While these algorithms can offer significant improvements, there is still plenty of room for further optimization.

The illustration in ***Figure 1*** provides more insight into the problem. In the top pane, a Wi-Fi transmission is humming along at a data rate of 54 Mbps when the received signal strength indicator (RSSI) starts dropping, possibly due to the motion of the two communicating radios away from one another. The RSSI is used to monitor the received signal strength in an IEEE 802.11 system and is basically an indication of the power level that is being received by the antenna.

As shown in the figure, the data rate drops to zero. Then, the RSSI starts increasing, possibly due to the radios moving closer together. The data rate recovers, via the data rate adaptation algorithm, but not completely. The data rate never recovers to its peak value of 54 Mbps, even though favor-

able channel conditions are restored. Meanwhile, the corresponding RSSI in the bottom pane provides no clue as to what is happening. In other words, the adaptation algorithms are inadequate for restoring the device back to its peak data rate. Finding out why and determining what to do is not easy.

One reason that the adaptation algorithms are difficult to optimize is that so many variables are in play (e.g., the statefulness of the algorithms and chipset to chipset interoperability) even in a controlled environment. When testing in open air, interference and multipath introduce even more variables into the mix, making it nearly impossible to determine what is happening and provide guidance to optimize the algorithms.



▲ *Fig. 1 802.11g transmitter rate-adapting from 54 Mbps down to zero in response to diminishing signal strength. After the signal returns to its peak level, the adaptation algorithm is expected to recover the data rate of 54 Mbps, but does not.*

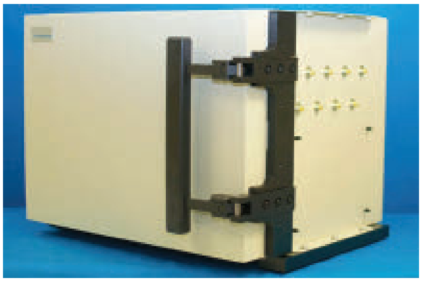
This is complicated by many different flavors of Wi-Fi that may be causing complex interactions. These must also be accounted for by the algorithms. For example, the set-top box might require 802.11ac while communicating with a router that only supports only 802.11n and a wireless headset that uses 802.11g. A headache, indeed.

To tackle the challenge of optimizing adaptation algorithms, designers must recreate the problem situations in order to see exactly what is impacting the signal and how the device is reacting. They need to emulate typical environmental conditions, including multipath and interference, and then reproduce the signal problem in a consistent fashion. With many variables in play and without a controlled environment, it is very hard to know what has happened and sort out potential causes. A controlled test environment is needed to perform the cycle of testing, tweaking of algorithms, testing and re-optimizing until the overall signal performance is fine-tuned.

This is far easier said than done. Standard open air test labs are full of their own uncontrolled interference and are not very suitable as test environments. It is hard to create a clean, pristine area for measuring and debugging. One could spend millions of dollars to build a large isolation chamber, but that is not an option for many labs. Further, these types of problems are so time consuming to resolve that they can become a research project; for busy labs chamber time may be a limited resource.

COMPACT ANECHOIC RF ISOLATION CHAMBERS

Fortunately, there are commercially available solutions. One approach is to use a set of small, RF isolation chambers as test beds, such as the one shown in ***Figure 2***. These provide stable anechoic (echoless) conditions for over the air (OTA) signal transmissions inside. The master wireless access point



▲ *Fig. 2 OctoScope octoBox – a small, anechoic RF isolation chamber.*

can be put inside one chamber and the receiving device in another. They can be stacked one on top of the other and tethered together with a set of antennas. With the system sealed in a controlled environment, it can then be bombarded with typical interference and multipath by connecting a multipath emulator (MPE) or interference generator (signal library) to the system via another antenna.

A test system with two stacked anechoic chambers is shown in ***Figure 3***. The chamber on top contains the wireless access point under test (e.g., a router). The chamber on the bottom contains the master client device (e.g., a PC tower). The stacked boxes are connected with a set of antennas, several programmable attenuators and an MPE. Extra antennas can be mounted to inject controlled interferences. The wireless link between the access point and the client device is established via the test antennas that couple the signal into the attenuators and then into the MPE. The attenuators model flat path loss caused, for example, by distance or walls. The MPE models the reflections from surfaces and walls in a typical house. This emulated but controlled environment presents realistic conditions that cause typical signal impairments in Wi-Fi networks.

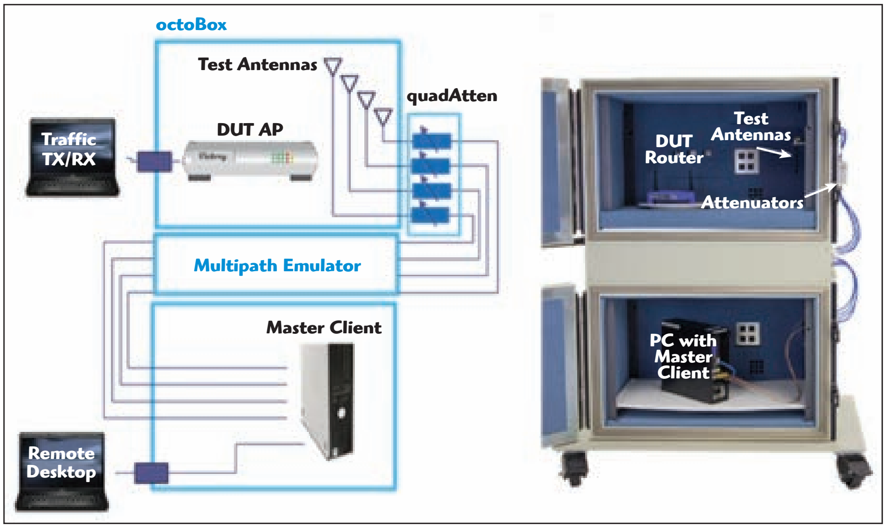


Fig. 3 General configuration of stacked octoBox anechoic chambers with a wireless access point in the top chamber and a client device (a PC) in the bottom chamber.

SIGNAL TROUBLESHOOTING

Having created a controlled, sealed environment and emulated typical multipath and interference conditions, the problem can be reproduced in a consistent fashion, debugged and analyzed. Visualization and analysis tools are added to the mix in order to view what is happening while the device being tested is sending information to the client device and gain insight into the quality of the signal. For example, while the system is bombarded with interference and multipath, is it still receiving enough power so that it can actually operate?

One approach is to connect a spectrum analyzer, oscilloscope, arbitrary waveform generator and other signal analysis equipment to the anechoic chamber stack through various antennas. The drawback of this approach is that it is quite hard to isolate the problem without the ability to cross-reference the frequency domain with the digital domain (where the algorithms are produced). Combining a spectrum analyzer with an oscilloscope into one instrument is an effective solution. A mixed domain analyzer (MDO) such as the one pictured in ***Figure 4*** includes a built-in RF input and wideband acquisition capability to capture the signals, as well as the ability to time-correlate the analog, digital and RF signals in a single instrument. Additionally, an advanced signal analysis capability can be provided via a live link from the MDO to vector signal analysis software running on a PC or laptop.

Using a set of anechoic chambers connected by antennas to an MDO and signal analysis software (see ***Figure 5***), an event can be triggered (such as a sudden drop in throughput or unusual

Fig. 4 Tektronix's MDO4000B combines a spectrum analyzer with an oscilloscope and an RF input. It can also connect via live link to the SignalVu-PC vector signal analysis software package.

roaming behavior) in real time across frequency and time domains. These can be correlated to obtain a clearer picture of cause and effect: visualizing effects on functionality immediately on the RF side and correlating them to algorithms on the digital side.

The MDO's spectral measurement and analysis capabilities (along with its connected signal analysis software) greatly simplify the process of making common transmitter measurements in a controlled environment. For example, you can create a spectral mask defined according to standards to check that the WLAN signal lies within this mask and view how clear and clean the spectral space is. You can do EVM measurements to look at the signal quality and compare it to a "golden reference." Once you start injecting multipath and interference into the system, you can easily measure the adjacent channel leakage ratio (ACLR).

The use of portable, stacked anechoic chambers with multiple connecting antennas provides great flexibility in test configurations. For example, one antenna might be connected to an MDO, one to a multipath generator and the third and fourth to different kinds of interference, such as microwave or cell phone communication.

CONCLUSION

The clean, controlled test environment and analysis tools offered by a combined set of anechoic chambers and an MDO can help reduce the amount of time it takes to analyze WLAN signals and resolve problems without investing milllions. This solution can also be used for other applica-

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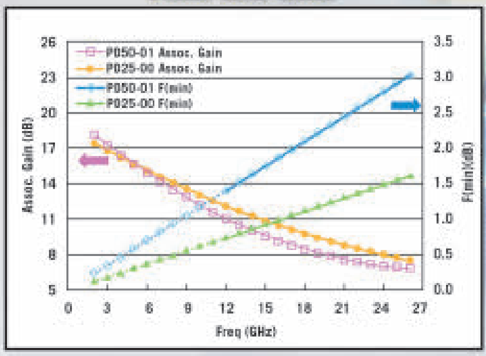
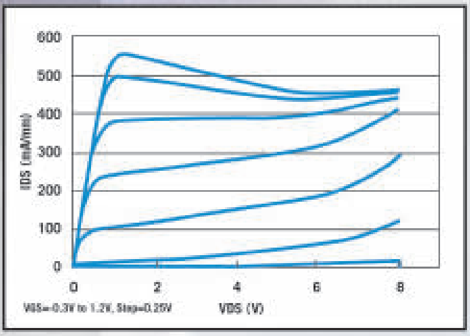
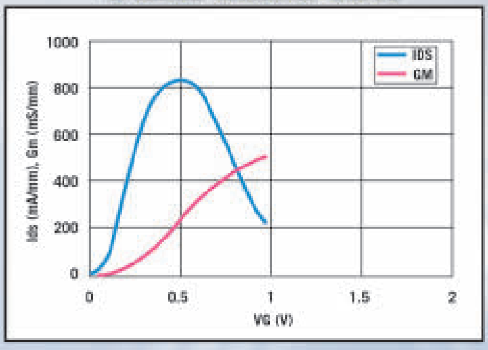


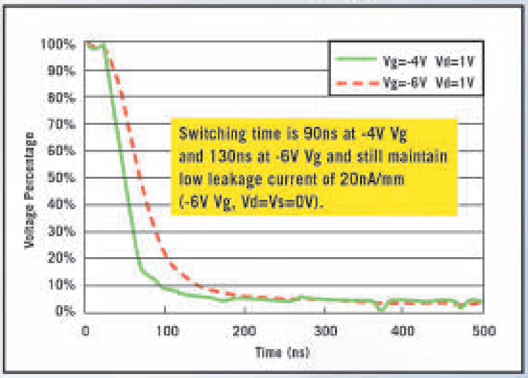
E-mode I-V Characteristics



E-mode Transfer Curve



D-mode Switching Speed



D-mode Device Performance

	PD50-01		PD25-00	
	Single	Triple	Single	Triple
Ron (ohm.mm)	1.9	3.7	1.3	2.2
Coff (fF/mm)	168	83	163	92
RonxCoff(ohm.fF)	316	310	209	198

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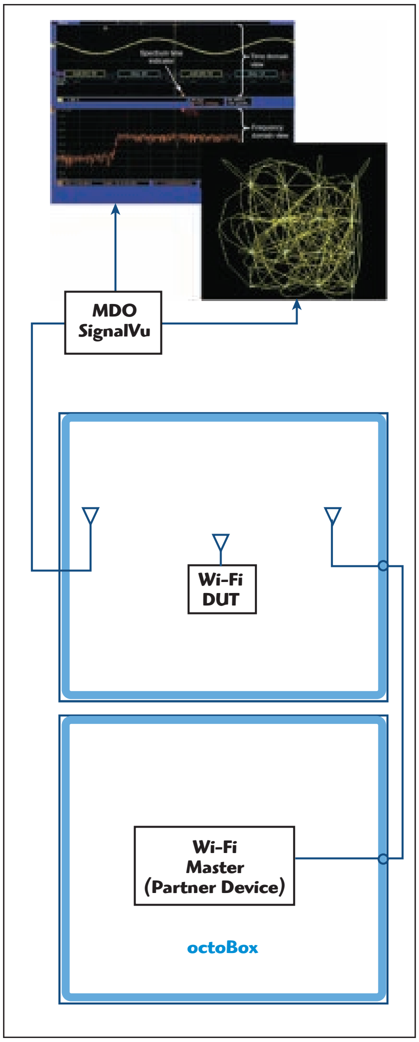

▲ *Fig. 5 MDO4000B and SignalVu-PC vector analysis software connected via antenna to the DUT in the top of a set of anechoic chambers.*

tions, such as pre-compliance testing, where a clean test environment can put you ahead of the game. ■

Dorine Gurney *has over 10 years of experience as a product planner at Tektronix. During her tenure she has supported multiple product lines including high performance oscilloscopes and more recently source/analyzer products and SignalVu solutions. Prior to Tektronix, Gurney worked as a product manager at Mentor Graphics. She has authored numerous application notes and technical articles and holds MSEE degrees from Rensslear Polytechnic Institute and Supélec.*

Fanny Mlinarsky *is the founder of octoScope, a wireless solutions and services company. Her background includes hands-on product development and R&D management. Prior to octoScope Mlinarsky was founder and CTO of Azimuth Systems, a wireless test equipment vendor. Mlinarsky has been an active contributor to the wireless standards being developed at 802.11 and 3GPP. She has published numerous articles, white papers and test reports on wireless topics.*

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INVITED PAPER

Automating Microwave Measurements with Software Defined Synthetic Instrumentation

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Wilkes University, Wilkes-Barre, Pa.

Traditional RF/microwave test and measurement (T&M) instruments are dedicated "boxes" built with application specific and general purpose silicon, firmware and embedded software. In contrast, software defined synthetic instruments (SDSI) "synthesize" multiple instruments – spectrum analyzers, digital storage oscilloscopes, RF receivers, signal generators – with digital signal processing (DSP) software and firmware on commercial embedded multicore processors and field programmable gate arrays (FPGA). SDSIs offer advantages over a suite of traditional instruments, dramatically reducing test system life cycle costs. Addressing equipment obsolescence and the portability of test programs are two of their most important benefits, especially to organizations with large fleets of RF/microwave test systems or performing production tests. SDSIs provide a watershed infrastructure for developing test systems that remain stable throughout the test life cycle.

Numerous standards and tools, at several levels of abstraction, are used to develop test programs, more formally known as test program sets (TPS). Interchangeable virtual instrument drivers (IVI) and instrument command sets, such as the standard commands for programmable instruments (SCPI), are at the lowest level. At the next higher level are test development languages, including automated test markup language (ATML), abbreviated test language for all systems (ATLAS) and standard programming languages such as C or C++. At the highest level of abstraction are test executive suites, such as National Instrument's TestStand, Keysight's Test Exec SL and Marvin Test's ATEASY. All of these test executive suites provide a TPS development environment that accommodates multiple instruments and devices under test (DUT).

However, even with all of these tools, obsolescence and TPS portability represent huge challenges to the industry because of the intrinsic hardware dependencies when using separate instruments. A TPS written for a fixed function instrument will likely require significant modification if the hardware changes. If the test executive changes, significant portions of the TPS must be refactored or recreated. A study conducted by the U.S. Army at the Tobyhanna Army Depot identified rewriting and requalifying Army TPSs – when traditional instruments reach the end of life – as one of the largest expenses during program life cycles.[1]

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SDSIs were conceived to address these challenges. The Synthetic Instrument Working Group (SIWG) was jointly formed in 2004 by the U.S. Department of Defense and industry to supported the development of SDSIs.[3] SIWG defined five goals for synthetic instruments (SI), adopting the fundamental premise that SIs can be reconfigured to:

- Reduce the total cost of ownership of the test system
- Reduce time to develop and field new or upgraded test systems
- Provide greater flexibility and interoperability of test systems
- Reduce the test system logistical and physical footprint
- Improve the quality of test

SDSI ARCHITECTURE AND BENEFITS

SDSIs combine RF T&M instruments in a single system with modular, commercial off-the-shelf (COTS) hardware and a unified software architecture. The instruments in an SDSI are software defined (i.e., synthetic) and essentially independent of the underlying hardware. SDSIs are really high performance software defined radios (SDR), with added T&M software in the form of applications (apps) that enable them to perform RF and microwave measurements. SDSIs digitize analog signals and store the data, allowing multiple concurrent operations to perform measurements and analyses.

Because the SDSI's instruments are software defined, they may employ software application programming interfaces (APIs) that comply with open standards and are built with common tools (Python, Java, C# or C++) or traditional test development languages and executives (ATML, ATLAS or Test Stand). With the SDSI's unified software architecture, the programming challenges that arise from the diverse standards and implementations across traditional instruments are eliminated. Unlike traditional fixed function instruments, which have dedicated hardware and software, SDSIs and their associated synthetic instruments evolve more easily to support the needs of the TPS.[2]

Using COTS hardware with T&M apps reduces test software development time and improves test software portability as well as measurement speed and efficiency. Additional benefits include significant reductions in size, weight and power as well as reduced cost for spares. Replacing multiple instruments with a single, multi-function instrument using a common development environment for its functionality, significantly reduces test development and refactoring time. In production bench-top test applications or automated test systems (ATS), multifunction SDSIs can support a broad range of different RF/microwave DUTs by simply changing the underlying TPSs and the physical interface to the DUT.

Since SDSIs synthesize their measurement functions atop COTS hardware, they do not suffer from the same hardware and software obsolescence problems that affect traditional instruments. When a traditional instrument goes end of life (EOL), users are con-

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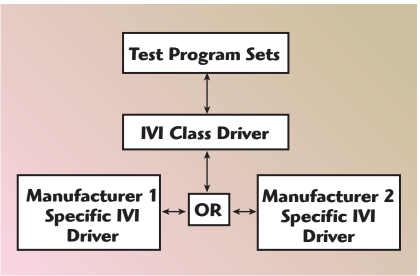
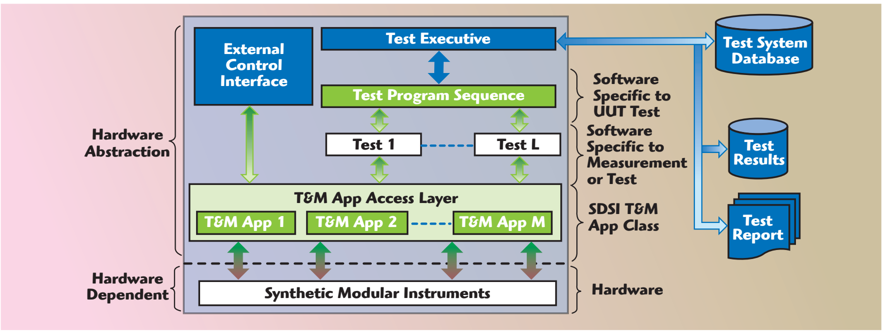


▲ *Fig. 1 IVI drivers allow a common test program (TPS) to control instruments from many manufacturers.*



▲ *Fig. 2 A system model for TPS portability.*

fronted with either buying additional units before production ceases or porting the TPS to the new instrument. With an SDSI, especially if its underlying hardware is modular, a new instrument can be synthesized on top of the replacement hardware, such that the APIs used by the TPSs are not affected. If the SDSI T&M apps (i.e., the SDSI instruments) are developed using object oriented techniques and design patterns, refactoring the T&M app to accommodate the replacement hardware and TPS interface will also be minimized. Hence, SDSIs address the problem of TPS portability, which the Army study shows leads to significant life cycle cost savings.

PROGRAMMING TRADITIONAL T&M INSTRUMENTS

With multiple manufacturers of test equipment and a need for automated control, the test industry developed a standard arbitration layer called the virtual instrument standard architecture (VISA). VISA allows software applications to communicate with an instrument regardless of the underlying hardware interfaces or equipment manufacturer.

Standard commands for programmable instruments (SCPI) was developed to standardize the command sets for specific instruments and, to some extent, across instruments. SCPI enables all compliant instruments within a given class (e.g., oscilloscopes) – even from different manufacturers – to respond to the same set of commands. Manufacturers usually extend the SCPI command set to their particular needs, since only a subset of SCPI commands are required to be compliant with the standard.[4] To address the commands tailored to manufacturers yet provide a consistent programming interface

to the end user, interchangeable virtual instrument (IVI) drivers were developed to standardize the controller software (see ***Figure 1***).[5]

IVI drivers allow test programs to use standard drivers for a specific instrument type or class; this standard driver calls a second driver specific to the manufacturer's equipment. A TPS developer writes only a single test program, and the IVI drivers handle the manufacturer-specific commands. If used correctly, test program developers can create robust, hardware-agnostic tests and TPSs using IVI. When TPSs only need core IVI driver functions, this system works well. However, different manufacturers often add functionality beyond the IVI drivers. These extensions, while useful, often result in TPS incompatibility when a different instrument is substituted for the original.

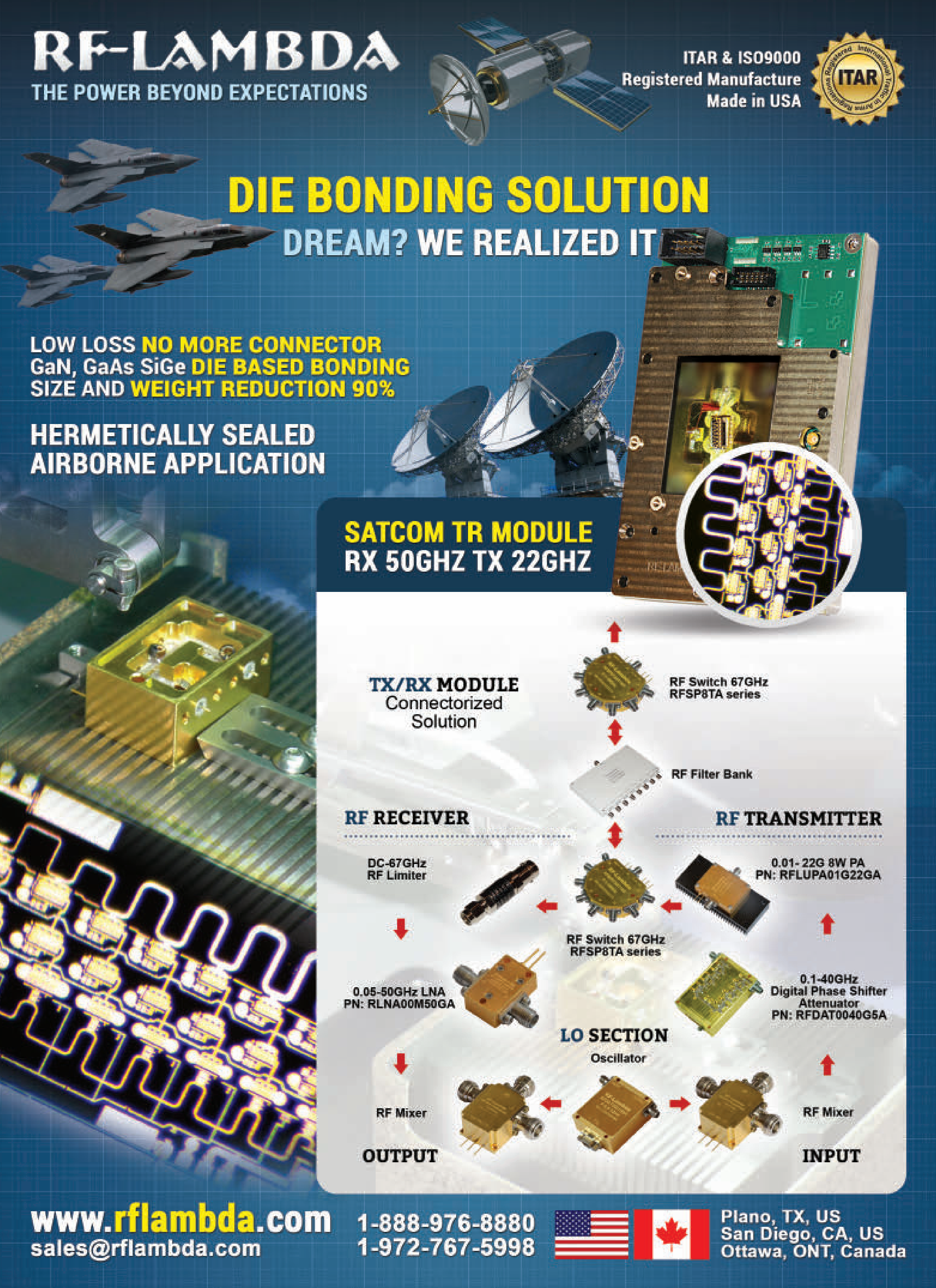
PROGRAMMING AN SDSI

An SDSI can be considered to be a tightly coupled collection of traditional instruments where each instrument is synthesized in the software using a combination of hardware and lower level software modules. The instrument modules are composed of T&M instrumentation software and firmware apps. Depending on the hardware configuration and the SDSI software design, the apps can run con-

TABLE 1

MICROWAVE TEST MATRIX

Test	VNA	SNA	Spectrum Analyzer	RMS Voltmeter	Digital Storage Oscilloscope	RF Signal Generator	Power Meter	Frequency Counter	Noise Source	Directional Coupler	Noise Figure Meter
Gain/Attenuation	1	2	4			3/4	3				
3rd Order Intermodulation			1			1/1					
VSWR	1	2	3			3/4	4			3/4	
Noise Figure			2/4			4	3		1/2/3		1
THD			1			1					
Harmonics (Max Power)			1			1					
Filter Roll-off	1	2	3			3					
Isolation/Crosstalk	1	2	4			3/4	3				
Phase Noise			1								
Bandwidth (3 dB)	1	2	3			3					
SFDR			1			1					
Phase Shift	1				2						
Oscillator Power			2				1				
Oscillator Frequency			2					1			
SNR (Demodulated Signal)			1			1					
SINAD (Demodulated Signal)			1	2		1/2					



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currently and independently. Each functions as a traditional instrument, so an SDSI appears to be a collection of traditional instruments to a remote test controller. Because of its system architecture, an SDSI can act as an instrument suite, a system controller and a TPS development environment.

To facilitate TPS portability, one of the primary development goals for an SDSI is creating a system where the same test programs can be run on the SDSI or using the traditional model of an external controller to the SDSI. Such control can be achieved via an open source API or app access layer that implements a VISA compliant interface into each app. ***Figure 2*** shows a notional system model to accomplish TPS portability. The SDSI contains a TPS development environment that communicates through the API to the T&M apps. The API uses the VISA infrastructure to communicate between the T&M apps and the TPS. To analyze test results for a fleet of DUTs, the SDSI uses a measurement database that is accessible both to the API and the application infrastructure. The same development environment that exists on the SDSI is used on an external controller. It communicates to the apps through a copy of the APIs which are local to the external controller and which use the VISA infrastructure to communicate over a remote connection to the apps.

Because the VISA infrastructure is leveraged, the TPS programming methods that have been refined by the industry are used. Instead of modifying a TPS to accommodate the API, the API or a software translation layer can be developed so that the TPSs do not change.

RF MEASUREMENT EXAMPLE

Verifying the functionality of microwave systems and components is not trivial because of the variety of unique tests and associated test equipment and setups. ***Table 1*** shows the possible tests that are performed in the left column and the typical instruments used for the measurements across the top row. The numbers in the table represent the instruments that can be used to perform a given test. To illustrate, gain or attenuation can be measured with four different instrument setups: a vector network analyzer (VNA), scalar network analyzer (SNA), an RF signal generator and power meter, and an RF signal generator and spectrum analyzer. For the majority of the measurements, the instruments are combined with external components, such as couplers and filters. With an SDSI, many of these external elements can be synthesized with DSP processing (e.g., filters) or integrated with the hardware (e.g., couplers).

The signal-to-noise and distortion ratio (SINAD) is a good example to show this approach, since the measurement traditionally requires external filters (audio and notch, depending on the technique employed). These filters may be designed using numerical methods with digital processing, enabling the test environment to directly filter the data.

Sensitivity specifies how well a receiver demodulates low power signals. For analog frequency modulated


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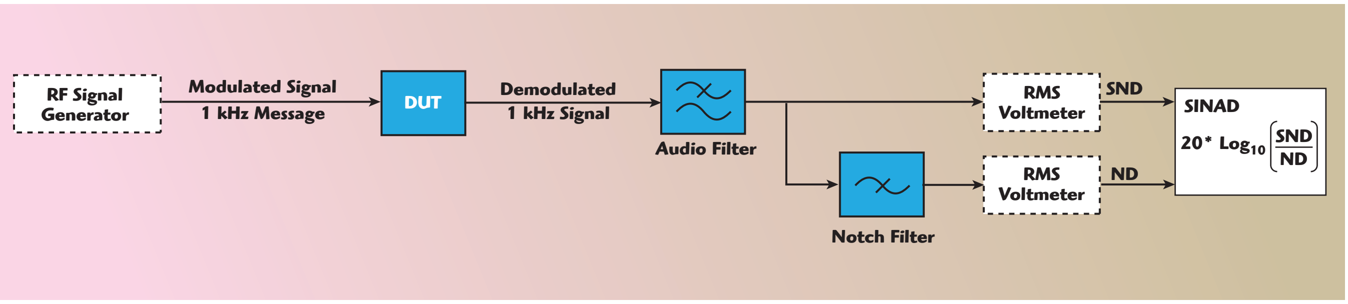


Fig. 3 Measuring SINAD using a notch filter.

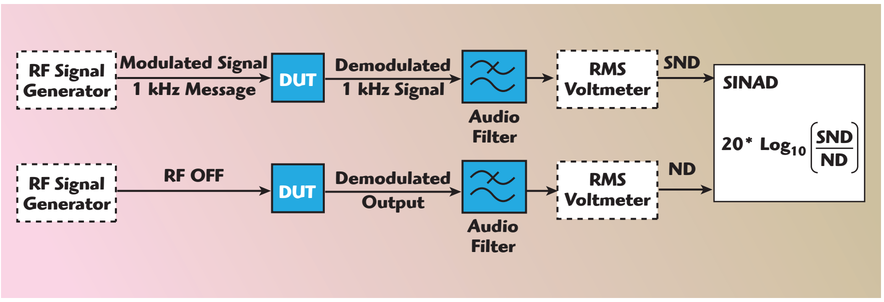
(FM) systems, SINAD is typically used to quantify sensitivity.[6] SINAD is computed as:

$$SINAD = 20 * \log_{10} \left(\frac{Signal + Noise + Distortion}{Noise + Distortion} \right) \quad (1)$$

SINAD is determined by measuring the RMS value of a demodulated signal with and without the message signal.

One traditional setup for measuring SINAD utilizes an RF signal generator, the DUT receiver, an audio filter, a notch filter and at least one RMS voltmeter (see ***Figure 3***). Two RMS voltmeters (or a two channel voltmeter) must be used if the signals at the output of the audio filter and the notch filter are to be measured at the same time. The signal generator frequency modulates the signal with a 1 kHz message tone. The receiver demodulates the tone and transmits it through an audio lowpass filter. The output of the audio filter feeds a notch filter, centered at 1 kHz, and an RMS voltmeter. The first voltmeter measures the signal plus noise plus distortion (S+N+D). The notch filter suppresses the 1 kHz signal in the demodulated output, and this signal represents just the noise plus distortion (N+D). SINAD is computed from the ratio of the two measurements (equation 1).

Another traditional method for measuring SINAD eliminates the notch filter by measuring the signal with the RF signal generator on and off (see ***Figure 4***). This setup reduces the number of instruments and components to a single audio filter and RMS voltmeter. Initially the RF signal generator transmits the same FM modulated signal with a 1 kHz message tone. Received by the DUT receiver, the signal is demodulated,



▲ *Fig. 4 A simpler method for measuring SINAD, using a single audio filter and voltmeter and without a notch filter.*

filtered with the audio filter and measured with the RMS voltmeter (i.e., S+N+D). With the RF output from the signal generator off, the resulting N+D signal is measured with the RMS voltmeter, and the SINAD is computed from the ratio of the two measurements.

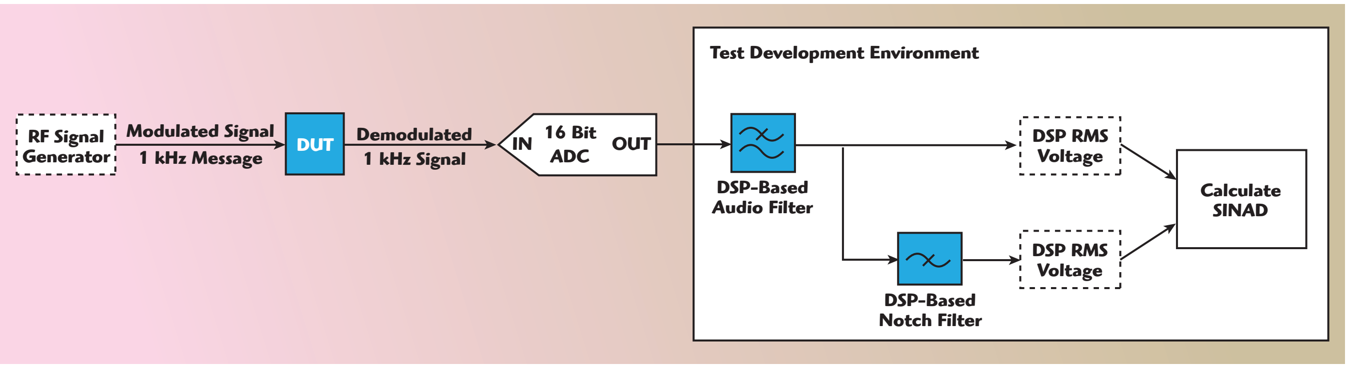
The notch filter used with the first setup is a potential source of error; it may filter out noise and distortion close to the 1 kHz signal. If the notch filter is not tunable, the test range of the receiver is limited. The second method doesn't have the same source of error, however the time delay between the S+N+D and N+D measurements may have different inaccuracies in the result.

To show the advantages of SDSI, the SINAD measurement examples mirror the previous test setups, even though other, DSP optimized, methods can be used. In the first method (see ***Figure 5***), the SDSI RF signal generator app generates the analog FM signal with the 1 kHz tone. After being demodulated by the DUT receiver, the signal is digitized with a 16-bit analog-to-digital converter (ADC), which is controlled by a digitizer app. The output of the ADC is captured, formatted in volts and filtered with a DSP audio filter in the SDSI test environment. This is the S+N+D signal. The output of the DSP audio filter is also filtered with a DSP-based notch filter, creating the N+D signal. The RMS values of both signals are computed using the classic algorithm for computing RMS voltage with a set of discrete measurements,[7]

$$V_{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V(i)^2} \qquad (2)$$

where N is the number of samples captured by the ADC. SINAD is then computed using equation (1).

The second method for the SDSI-based SINAD measurement, shown in ***Figure 6***, uses the same technique as the second traditional method. Instead of using a notch filter, the output of the DUT is measured with the RF signal generator alternately on (the S+N+D signal) and off (N+D). While the figure shows two signal paths, the setup would only use a single RF signal generator and single ADC.



▲ *Fig. 5 The SDSI approach to measuring SINAD with a notch filter (the configuration of Fig. 3).*

The SDSI contains all required instruments within a single enclosure and uses numerical methods to calculate SINAD. With both SDSI implementations, the fixed function hardware is minimized. The analog filters (now DSP based), RMS voltmeter, DUT stimulus and signal capture are all contained within a single system and controlled through a single test development environment. By using DSP and numerical analysis techniques, the test program is hardware agnostic. If the underlying ADC changes, the test program remains the same. If the RF signal generator subsystem changes, the T&M app abstracts these changes and provides the same command interface to the TPS.

CONCLUSION

While multiple standards have attempted to reduce the problems of hardware obsolescence and interchangeability, significant challenges remain. An SDSI mitigates many of these through a T&M platform that is fundamentally software defined. Software interfaces remain the same to the TPS development environment while the underlying hardware and low-level software can be updated to improve performance or respond to obsolete hardware. This allows TPSs to migrate to new hardware without changing the underlying code. For new TPSs, development environments that utilize open source programming languages and numerical processing software packages enable developers to minimize the use of specialized, discrete hardware components. Open source languages and software enable better software compatibility. The same version of the development environment can be used on the SDSI itself or on an external system controller, if the SDSI is part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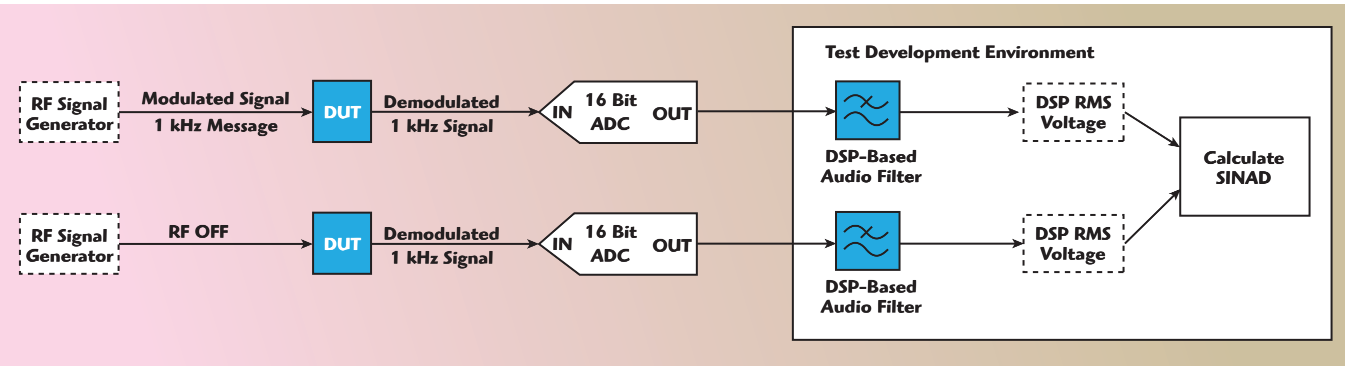

▲ *Fig. 6 The SDSI implementation of the simpler SINAD measurement of Fig. 4.*

of a larger ATS.

For systems designers, SDSIs reduce the test footprint, as many instruments are hosted in a single enclosure. Microwave measurements often require a variety of instruments and components. An SDSI reduces the equipment and ancillary hardware. In the SINAD measurement, the traditional method requires an RF signal generator, analog audio filter, analog notch filter and at least one RMS voltmeter. The SDSI method requires only the SDSI; the software within the SDSI performs the RF signal generation, audio and notch filtering and RMS voltage measurement. ■

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Anritsu
Morgan Hill, Calif.

Traditional de-embedding techniques are oftentimes insufficient for today's high-speed component designs utilized in high data rate applications. As frequencies approach 70 or even 110 GHz, errors related to fixturing can mask the behavior of the device under test (DUT). Poor de-embedding can lead to both passivity and causality errors. In addition, high fixture loss may affect the accuracy and repeatability of de-embedding. Anritsu Co. has developed enhancements to its VectorStar™ MS4640B vector network analyzers (VNA) that make embedding/de-embedding straightforward and simpler, enabling users to obtain more accurate measurements of their DUT's performance.

The new de-embedding capabilities of VectorStar VNAs can be used to remove test fixture contributions, modeled networks and other networks described by S-parameters (S2P files) from the measurement results for greater accuracy and repeatability. Similarly, the enhanced embedding function can simulate matching circuits to optimize DUT performance, which is very helpful in applications like amplifier design. The function can also be used to add effects of a known structure to a measurement. With the new capabilities, engineers have a greater ability to locate design weaknesses such as discontinuities, impedance changes and crosstalk issues in high-speed DUTs.

As an example, VectorStar users can combine a wide range of calibration capabilities with up to seven de-embedding techniques to address the various situations found in many high-frequency component designs. By matching the calibration and de-embedding method to specific DUT and fixture structures, measurement accuracy and repeatability are improved. In addition, unlike other VNAs that require external software to de-embed differential devices, VectorStar includes four-port differential de-embedding as part of the package of techniques for fast and accurate differential device analysis.

BETTER DEVICE MODELING

With the enhanced embedding/de-embedding capabilities, better device modeling data

ProductFeature

can be acquired, resulting in greater design confidence and fewer design turns. Other features of the VectorStar MS4640B support improved device models as well, specifically the broad frequency coverage from 70 kHz to 70/110/125/145 GHz in a single connection. The highly accurate low-end frequency coverage enabled by a hybrid bridge-coupler VNA architecture reduces the risk of DC extrapolation errors in device models. Additionally, the wide frequency coverage eliminates the time-consuming, error-prone, concatenation process across the RF, microwave and millimeter bands.

VectorStar users can also improve their device modeling by taking advantage of high data resolution of 100,000 points and 700 kHz frequency step size to provide highly accurate, highly resolved, low pass mode measurements. The high resolution provides the ability to zoom in on narrow band responses without re-calibrating as well. When calibration is needed, it can be performed with Precision AutoCal®, which combines one-button ease with higher accuracy than the traditional SOLT technique.

VectorStar offers a number of features for improved high-frequency component testing, such as two software applications which provide unique analysis capability. PulseView™ (see ***Figure 1***) allows DUTs to be tested and characterized under pulse conditions. The 2.5 ns resolution with 100 dB dynamic range of VectorStar, coupled with independent measurement gates, provides industry-leading insight into component behavior. The ultra-high resolution enables users to see performance perturbations not only within a pulse, but on the rising/trailing edges as well. With the 500 ms capture time, amplifiers can be measured under long pulse repetition interval conditions. The software also allows for pulse-to-pulse measurements to be conducted over an extended number of pulses. An additional IF digitizer option, as well as four internal pulse generators, are required to utilize the PulseView application.

▲ *Fig. 1 PulseView™ setup.*

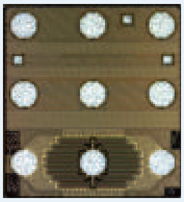
DifferentialView™, together with an optional internal second source, provides the ability to evaluate differential amplifier designs under true mode stimulus (TMS) conditions. The VectorStar graphical user interface (GUI) allows engineers to change parameters and see the results immediately without switching screen displays thereby reducing setup errors and reducing test time.

A noise figure option is also available for component testing applications. The noise figure measurement is based on a cold source technique for improved accuracy. Various levels of match and fixture correction are available for additional measurement enhancement.

With enhanced embedding/de-embedding capabilities coupled with frequency coverage from 70 kHz to 70 GHz, highly accurate calibration techniques and select options, the VectorStar series of VNAs provides the performance necessary to address the challenges of high frequency component design.

VENDORVIEW

Anritsu
Morgan Hill, Calif.
www.anritsu.com



Cavendish Kinetics' RF MEMS Fine-Tunes nubia's LTE Smartphones

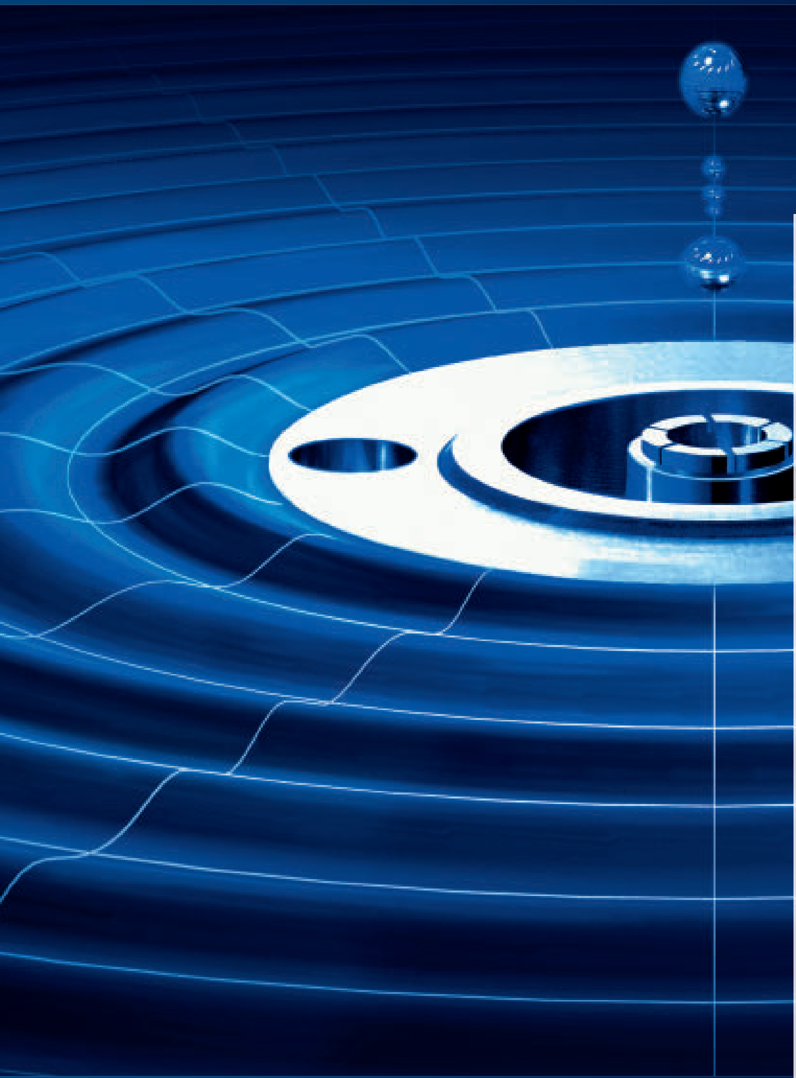
Cavendish Kinetics, a leading provider of high-performance RF MEMS tuning solutions for mobile and wearable devices, announced its first commercial shipments in October 2014, with China's nubia, the premium smartphone brand of ZTE Corp. nubia's new Z7 LTE smartphone antenna is tuned with Cavendish Kinetics' patented SmarTune™ Antenna Tuning solution, enabling the Z7 antenna to provide peak efficiency across all of China Mobile's LTE spectrum bands.

As wireless operators add new spectrum bands to their LTE networks, the efficiency of traditional smartphone antenna designs degrades significantly. This problem is worsened by ever slimmer smartphone designs that use metal frames, which further impacts antenna efficiency. In order to support all LTE/3G/2G bands in China, ranging from 850 MHz to 2.7 GHz, nubia selected Cavendish's SmarTune antenna tuning solution. This allowed nubia to design an antenna that provides outstanding efficiency in all LTE bands, thereby maximizing the signal strengths, which in turn leads to increased data throughputs and extended battery life for the end user.

SmarTune antenna tuning solutions are based on Cavendish's revolutionary RF MEMS capacitor, which provides an industry-leading 'quality factor' of greater than 200, has near zero insertion loss and enables antennas to tune across all LTE frequencies. Cavendish's SmarTuners have proven their accuracy and reliability in over 100 billion cycles of testing, and with only a 2 mm^2 footprint, SmarTuners are easy to implement in the latest smartphones and wearable designs. Antennas using Cavendish RF tuners deliver 2 to 3 dB stronger signals than traditional antenna designs using simple RF band switches.

Cavendish Kinetics is headquartered in San Jose, Calif., with offices in Korea, Taiwan, China and the Netherlands.

Cavendish Kinetics
San Jose, Calif.
(408) 457-1940
www.cavendish-kinetics.com



Ultra-Miniature 50 MHz Space VHF OCXO Series

The 9800QT is a quick-turn high performance OCXO that is designed for space qualified applications where fast delivery (as short as four weeks) is critical to the program's success. Available in 50 and 100 MHz versions, the 9800QT features a standard 12 V power supply and is pcb mounted with a compact size of 1.33" × 1.33" × 1.33".

It is an ultra-miniature ovenized crystal oscillator that provides a high stability VHF sine wave output. The use of hybrid circuitry facilitates the greatest possible reduction in size without compromises in performance or reliability.

NASA APPROVED STANDARDS

Assembly is performed by skilled operators certified to NASA approved workmanship standards. Hybrid circuits are produced at facilities qualified to MIL-PRF-38534 and all discrete components are manufactured and tested to S-level (space-qualified) standards.

The ruggedized 9800QT features an SC-cut quartz resonator and sustaining electronics that are controlled at a precise temperature to achieve temperature insensitive performance, excellent phase noise and aging characteristics. This allows it to meet the challenges of military or space specifications for time and frequency standards, even under adverse environmental conditions.

SIMPLIFIED DESIGN

The 9800QT combines spectral purity and long-term stability. Tight initial accuracy with low aging and temperature coefficient yield a low EOL frequency deviation, which simplifies system design.

Lead times are four weeks for engineering models and 12 weeks for flight models.

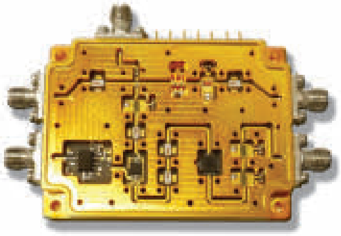
Microsemi Corp.
Beverly, Mass.
www.microsemi.com

Planar Monolithics Industries, Inc.

LEADER IN CUSTOM DESIGNS OF DC-40GHz, MINIATURE INTEGRATED MIC/MMIC MODULES & ASSEMBLIES

- Amplifiers
- Attenuators - Variable
- DLVA & ERDLVA & SDLVA's
- DTO's & Frequency Synthesizers
- Filters
- Form, Fit & Function Products
- IFM's & Frequency Discriminators
- Integrated MIC/MMIC Modules
- I/Q Vector Modulators
- Limiters & Detectors
- Log Amplifiers
- Pulse & Bi-Phase Modulators
- Phase Shifters
- Rack & Chassis Mount Products
- Receiver Front Ends & Transceivers
- Single Sideband Modulators
- SMT & QFN Products
- Solid-State Switches
- Switch Matrices
- Switch Filter Banks
- Threshold Detectors
- USB Products

INTEGRATED DOWN-CONVERTER CONTROL MODULE
MODEL No: LCM-7R7G8R2G-CD-1



SPECIFICATIONS

- Frequency Range: 7.7 to 8.2GHz (J1, J2, J4, J5)
- Gain (J1 - J2): 16dB ±2dB Maximum at 0dB Attenuation
- Output 1dB Compression (J2): 28dBm Typical
- Conversion Gain: 0dB ±3dB Maximum (J1=10dBm, J4=-10dBm)
- Tap Output Insertion Loss (J1-J5): 16dB ±2dB Typical
- Survival Input Power: 20dBm (J1) & 14dBm (J4) Maximum
- VSWR (All Ports): 2.0:1 Maximum
- Size: 2.5" x 1.75" x 0.4"

LNA 1, 2 & 3:
- Gain: 14dB
- Psat: 16dBm
- Noise Figure: 2.5dB
- Reverse Isolation: 40dB

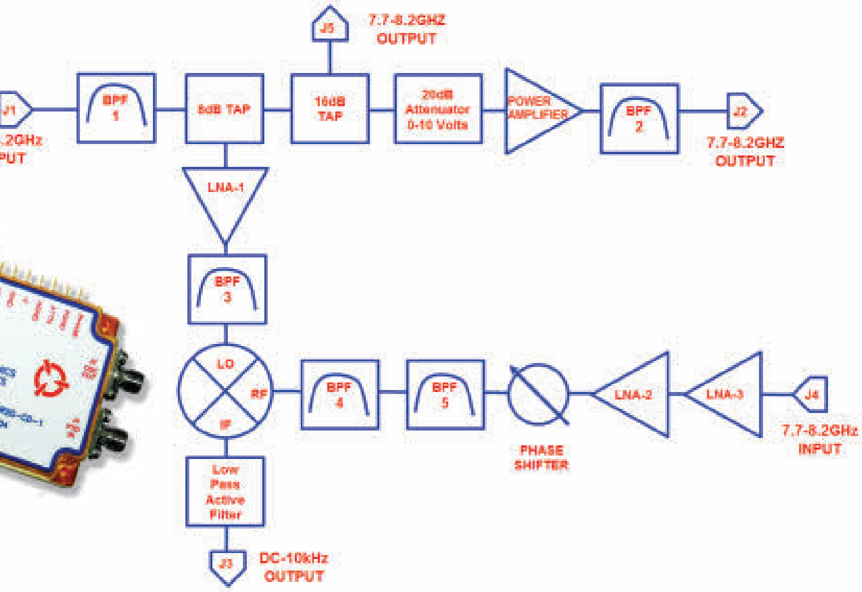
PHASE SHIFTER:
- Phase Shift Range: 0 to 360 Degrees Minimum
- Control Range: 0 to 10 Volts
- Non-Linear Slope Ratio: 4:1
- Switching Speed: 200ns Maximum

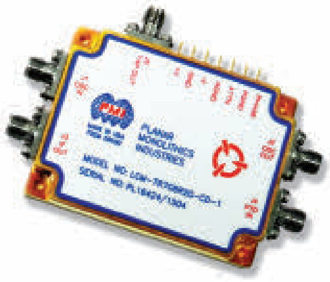
ATTENUATOR:
- Attenuation Range: 0 to 20dB Minimum
- Control Range: 0 to 10 Volts
- Non-Linear Slope Ratio: 8:1
- Switching Speed: 1us Maximum

FILTERS 1 - 5:
- 2dB Passband: 7.7 to 8.2GHz
- Lower Stopband: -20dB at DC to 6.8GHz
- Upper Stopband: -20dB at 10.3 to 18.0GHz

IF ACTIVE LOWPASS FILTER:
- Passband: DC to 10kHz Minimum (J3)
- Stopband: 10kHz (Roll Off of 6dB per Octave)

FUNCTIONAL BLOCK DIAGRAM





West Coast Operation:
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
ISO9001:2008 REGISTERED
Email: sales@pmi-rf.com

East Coast Operation:
7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
ISO9001:2008 REGISTERED
Website: www.pmi-rf.com

Hermetic Sealing, High Reliability to Mil-Std-883, Small Quantity Requirements accepted & we offer Custom Designs too.

TechBrief

Low Power Series for VNA Frequency Extension Modules

The low power VxxVNA2-LP series has been added to OML's VNA Frequency Extension family. Maintaining the current VNA's capability to expand existing VNA systems to conduct millimeter wave S-parameters measurements, the new low power VNA series now offers a maximum output power of 0 dBm. The low power module also provides the option to test low power active devices.

SPECIFICATIONS

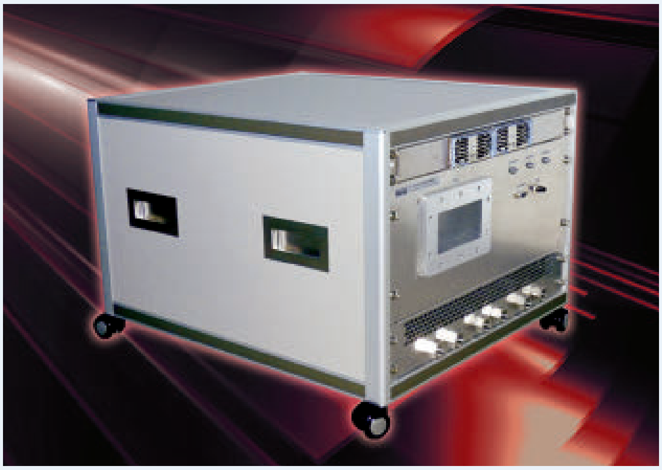
With its maximum output power of 0 dBm the low power series still offers the same top-quality specifications as the original VNA. Featuring OML's high performance coupler and millimeter wave isolator, this unit is stated to provide superior results of a typical raw directivity of 37 dB and typical dynamic range of 110 dB.

This module can be utilized to display two port S-parameter measurements (S_{11}, S_{21}, S_{12} and S_{22}) on the VNA. Tailored to fit customer needs, modules can be set up with four different architectures: 1-port, scalar 2-port, 1-path/2-port and fully reversing 2-port. Measuring 12.6" × 4.3" × 2.7" (320 × 109 × 69 mm) the sleek design can also be used with probe stations.

MANUAL ADJUSTABLE ATTENUATOR

Options for this series still include a manual adjustable attenuator (0 to 25 dB) to the RF path; addition of an amplifier (15 dB gain) in LO path for drive input of -5 dBm; and intermodulation distortion measurement (IMD). The low power VxxVNA2-LP series is currently available in waveguide bands from 50 to 110 GHz.

OML Inc.
Morgan Hill, Calif.
www.omlinc.com



2.45 GHz ISM Band Solid-State High Power Replacements for Magnetrons

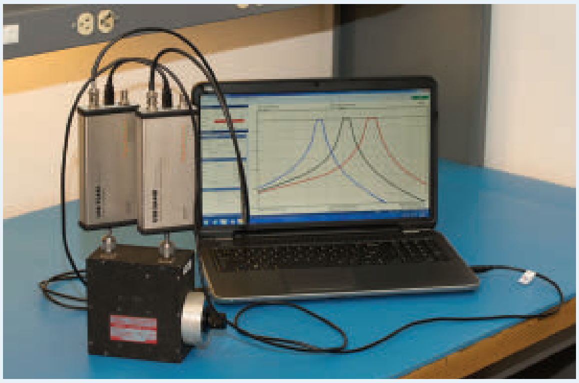
Tokyo Keiki and CEL are introducing a new generation of 2.45 GHz solid-state power oscillators (SSPO™) and solid-state power amplifiers (SSPAs) for high power microwave signal generation, realizing power levels up to 3 kW. Applications requiring high microwave power include semiconductor manufacturing plasma generation, chemical analysis, specialized medical surgery, medical thermotherapy and various other industrial and medical equipment.

SSPOs are available with output powers of 50, 100 and 200 W. Each includes a tunable phase-locked oscillator, driver amplifier, balanced output power amplifier and output RF isolator. Output power can be controlled from 1 W to the rated output power of the device. A 30 VDC power supply is required for biasing.

An SSPO can be used as a stand-alone microwave power generator or it can be cascaded with a higher power SSPA, available with output powers of 500 W, 1, 2 or 3 kW. Optional SSPA features include input protection, alarms and shut-off protection. Air cooling fans and, if required, water cooling are also included.

This new generation of products utilizes the latest semiconductor technology to provide many advantages over the traditionally used magnetrons. Advantages include 200 times longer lifespan, greater frequency stability and tunability, precise control of output power and lower power supply bias voltages.

California Eastern Laboratories
Santa Clara, Calif.
(408) 919-2500
www.cel.com/TK-MJ



"Spike" Software Boosts Performance

Signal Hound announced a significant software upgrade — called Spike — that will integrate all of its SA-series spectrum analyzers and TG-series tracking generator models, past and present, under the same open source graphical user interface (GUI) platform as the Signal Hound BB60C spectrum analyzer.

The Signal Hound USB-powered SA44B and SA124B are software defined radios (SDR) optimized as spectrum analyzers. The SA44B operates from 1 Hz to 4.4 GHz and the SA124B operates from 100 kHz to 12.4 GHz. The Signal Hound TG44A and TG124A are tracking generators that work with the SA-series spectrum analyzers. Both the SA-series and TG-series instruments are compact, simple to use, and effective troubleshooting tools for field use, general lab use, engineering students, ham radio enthusiasts and electronics hobbyists.

The new Spike software allows the SAs to function as real time spectrum analyzers for sweeps of 250 kHz and less — that means every RF event will be captured when using spans that are ≤ 250 kHz. Another improvement is sweep speeds that are up to 8× faster for spans between 500 kHz and 2 MHz. In addition, the SA graphics now include color persistence and a 2D waterfall display. The TG devices also benefit from Spike. Long-standing stability issues are resolved, to include making the high dynamic range user friendly and efficient. The tracking generators can also save 1000-point data files that are loaded in the path loss table for normalizing precision measurements using RF cables and/or antennas. New to both the BB60C and the SA devices is a zero span pre-triggering function and calibrated I/Q data streaming.

Developers are able to customize the Spike software by changing, adding and deleting functions, layouts, and utilities in the SA and TG devices. A liberal software license allows developers to compile the modified spectrum analyzer code for redistribution. Even though the SAs are hardware limited when compared to the BB60C, they can now enjoy the flexibility and power of the BB60C software platform. The software is available free of charge due to the continued support and loyalty of the Signal Hound user community. Visit www.signalhound.com/spike for a free download.

Signal Hound
La Center, Wash.
(360) 263-5006
www.signalhound.com

SQ-, TQ-, IQ-, BQ-, CQ- =
connecting 4, 7, 8, 10 or 12 coaxial RF-Lines at once
RQ23-DC26 =
connecting 23 coax RF-
& 26 Signal Lines at once
Spectrum
Elektrotechnik GmbH
when Quality is needed
Hermetically
Sealed Adapters
2.92mm, TNC, N, Feedthroughs
with venting holes for Vacuum Test Chambers
360° @ 1 GHz
230° @ 12 GHz
350° @ 18 GHz
500° @ 26 GHz
590° @ 40 GHz
400° @ 50 GHz
600° @ 63 GHz
85° @ 2 GHz
520° @ 12 GHz
770° @ 18 GHz
The new
52 pages
Catalog
Adjusting
Phase
Spectrum
Big and Small,
we have 'em all
Almost any Waveguide to almost any Coax Connector
WG Materials : Aluminum, Copper, Brass
Connectors : 1.92mm ...SMA....
TNC....N...7/16
www.spectrum-et.com
Telephone: +49-89-3548-040
Email: Sales@Spectrum-et.com
Facsimile: +49-89-3548-0490

WebUpdate

360° Product Views

Anapico steps into the future with the launch of their new website. In addition to a new design, which facilitates your search for the right product, other exciting new features include 360° product views and a YouTube channel with new tutorials. Anapico is a Swiss manufacturer of leading-edge RF and microwave signal generators and synthesizer modules, signal source analyzers and dedicated phase noise test systems for automated testing, laboratory or field use.

AnaPico

www.anapico.com

Website Redesign

VENDORVIEW

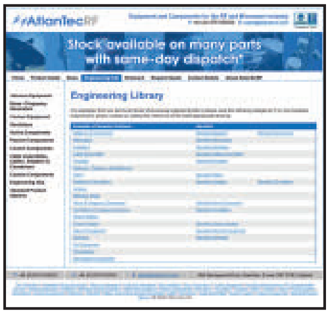
AR has made numerous changes to enhance both their corporate and RF/Microwave Instrumentation websites by giving them a more modern look and feel, while offering easier navigation and more comprehensive information. The menu system and flash spotlights have been redesigned to be compatible with various touch screen tablets and mobile devices, and enhanced streamlining of code makes them much more search engine friendly and easier to read. Visit the new corporate site at www.arworld.us or the AR RF/Microwave Instrumentation site at www.arww-rfmicro.com/html/00000.asp.

AR RF/Microwave Instrumentation

www.arworld.us

Engineering Library

VENDORVIEW



Engineers often have specific requirements which may not be available in the standard range of products. AtlanTecRF is able to optimize, customize or design a specific solution to meet customer needs with the release of over 120 drawings across 19 component categories via the company's online engineering library. Engineers can view all the company's standard products, plus highly modified solutions and ideas. All AtlanTecRF sales engineers have an RF/microwave background and welcome inquiries for unusual or technically challenging requirements.

AtlanTecRF

www.atlantecrf.com

A Seamless Experience

Centerline Technologies, a leader in lapping, polishing and other precision finishing processes has redesigned their website to improve ease-of-use. New features include a clutter-free navigation bar, Google-powered search box, plus more technical data is now available on products, services and news pages. Additionally, those who wish to request a quote or contact a Centerline Technologies representative may do so from any page. Centerline has made these changes and more to ensure that visitors have a seamless experience.

Centerline Technologies

www.centerlinetech-usa.com

Space Capabilities

VENDORVIEW

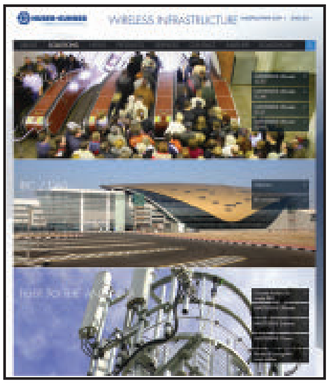
DiTom Microwave has launched a new section on their website that features space qualified isolators and circulators. In this section, you'll find space qualified isolators and circulators from L- to Ka-Band readily available for delivery in just four weeks. DiTom's new space capabilities section also includes the company's manufacturing processes, in-house testing capabilities and acceptance/qualification test plans. Call (559)255-7042 or email sales@ditom.com for additional information.

DiTom Microwave Inc.

www.ditom.com/space

Wireless Infrastructure Microsite

VENDORVIEW



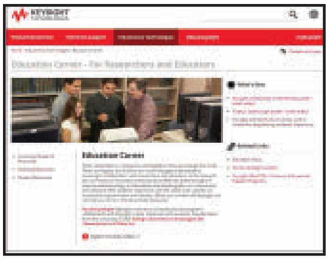
As the global market leader for fiber to antenna, power to antenna, and hybrid to antenna products for remote radio heads, HUBER+SUHNER has developed a range of innovative installation solutions specifically tailored for the next generation of small cell wireless infrastructure products. HUBER+SUHNER's extensive portfolio of radio frequency connections also includes distributed antenna systems for small cells and in-building coverage. Visit HUBER+SUHNER's wireless infrastructure microsite at www.wirelessinfrastructure.com to find out how these applications can meet your needs.

HUBER+SUHNER

www.hubersuhner.com

Education Corner

VENDORVIEW



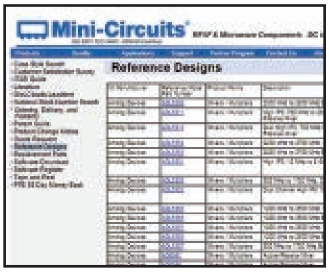
The refreshed "Education Corner" feature on Keysight's website provides resources for researchers, teachers and students. For the researcher, get the latest information to keep labs state of the art. For the teacher, engage and inspire students with real-world tools, teaching kits, software education programs and pre-written labs and java animations. For the student, get iOS apps on engineering formulas, calculations and graphs while enhancing your resume with industry-relevant skills and experience, plus explore internships and job opportunities through Jobs@Keysight. Visit and bookmark the site at www.keysight.com/find/edu.

Keysight Technologies Inc.

www.keysight.com

Reference Design Index

VENDORVIEW



Mini-Circuits has created an online index of more than 80 integrated silicon reference designs and corresponding recommended Mini-Circuits models. This resource makes it quick and easy to find the Mini-Circuits components suggested for use with the ICs in your system. Use the simple table on the reference designs page to locate the integrated circuit used in your system, listed alphanumerically by part number, and refer to the companion Mini-Circuits model numbers in the same row. Visit the company's website to find the best model for your system fast.

Mini-Circuits

www.minicircuits.com

RF Control Materials and Services

MWT Materials is a full-service RF control business. They evaluate, design, manufacture, modify and install RF control and test systems for commercial, military and industrial applications. Their website features the company's line of RF shielding and RF absorption products – customized to your needs. Highlights include their PR-20, 2 to 18 GHz NIST portable reflectometer, and their thin, flexible and easy to handle MAC-8000 series of RF absorbing materials which afford significant savings in labor and space when compared to traditional pyramidal foam RF absorbers.

MWT Materials Inc.

www.mwt-materials.com

A New Look

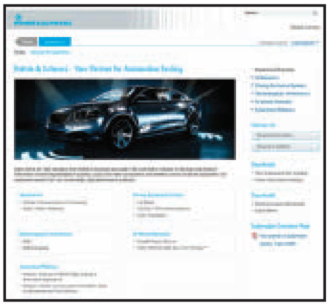
Peregrine Semiconductor's new website offers a fresh look and feel, while adding easy-to-find and relevant content for visitors. The markets section offers detailed information on Peregrine's role in markets ranging from communications and industrial, to aerospace and IoT. An enhanced technology tab details Peregrine's UltraCMOS® technology and its history. The refreshed news tab extends beyond press releases to include feature articles in industry publications, blogs and SOI University, a resource for engineers to learn more about RF SOI technology.

Peregrine Semiconductor

www.psemi.com

Your Partner for Automotive Testing

VENDORVIEW

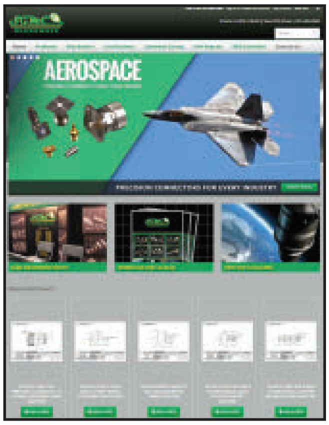


State-of-the-art T&M solutions from Rohde & Schwarz are used in the automotive industry to develop and produce information and driving assistance systems, audio and video components, and wireless communications equipment. Customers benefit from future-ready, high-performance products. Rohde & Schwarz has gathered their T&M solutions for the automotive industry on a specific website. Browse through the web pages sorted into four categories: infotainment, driving assistance systems, electromagnetic interferences and in-vehicle networks. Access webinars on automotive topics and other material as well.

Rohde & Schwarz

www.rohde-schwarz.com/automotive

Precision Coaxial Connectors



SGMC Microwave manufactures precision coaxial connectors including cable connectors, adapters and receptacles. The company website features their full line of precision grade products for the microwave and millimeter wave industry. Most standard products are available off-the-shelf for immediate delivery through their distributor, C.W. Swift, and custom designs are typically available in 8 to 10 weeks or sooner. The new site is highly interactive with online shopping, RFQ, information requests, customer surveys and a downloadable catalog. Visit today for quality, performance and reliability you can count on.

SGMC Microwave

www.sgmcmicrowave.com

WebUpdate

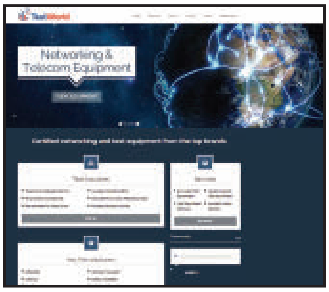
Product Search Simplified

SV Microwave launched their new ultimate user-friendly website which includes a redesigned product search function that simplifies product selection by allowing users to drill down to their selection from predefined categories. Created to streamline the product selection and order placement process, the new site also allows users to view product information, check availability and place orders all from one page. Explore the new product search at www.svmicrowave.com/products.

SV Microwave

www.svmicrowave.com

New Website Launch



After two years of development and anticipation, TestWorld Inc. officially launched its fully featured website, www.testworld.com. With a modern design with ultimate usability, the new site features an extensive product catalog of over 5,000 unique part numbers with information and specifications from key test equipment manufacturers such as Keysight, Rohde & Schwarz, Tektronix and Fluke. The site also focuses on the financing options for highly expensive test equipment, including renting and leasing. Other features include datasheets, manuals and application notes for beginner, novice and expert engineers in the telecommunications, general RF test and electromagnetic compliance industries.

TestWorld Inc.

www.testworld.com

Microwave/RF Assembly Calculator

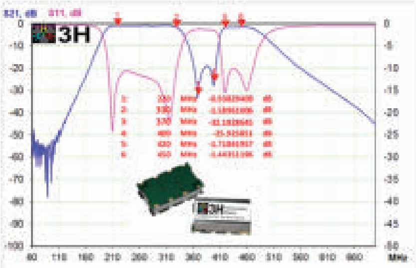
W.L. Gore & Associates introduced an online tool designed to complement the existing GORE™ Microwave/RF Assembly Builder. The new GORE™ Microwave/RF Assembly Calculator calculates insertion loss, VSWR and other parameters of GORE® Microwave/RF Assemblies for different cable types. The calculator is particularly useful when the initial cable type is unknown and needs to be specified independent of the connector. It includes a conversions page that has most of the everyday conversions, including distance, frequency, power, temperature, VSWR/return loss and weight. Visit tools.gore.com/gmcacalc.

W.L. Gore & Associates

www.gore.com

Components

SMT Bandpass Filter



3H Communication Systems model number XLCN400-30-7SS is a leadless SMT bandpass filter with a notch integrated into the passband. Insertion loss at 235 to 345 MHz is < 2 dB and < 2.5 at 435 to 465 MHz. The notch band is centered at 400 MHz with a 30 MHz notch band of > 15 dB attenuation. The filter size is 0.74"L × 0.44"W × 0.27"H and is suitable in tape and reel packaging.

3H Communications Systems
www.3hcomm.com

Ka-Band Space Qualified Isolator

DiTom Microwave has released a Ka-Band (27 to 31 GHz) space qualified isolator. The DS1017 is manufactured to meet or exceed environmental space-level reliability including thermal shock, sine and random vibration, temperature cycling, and thermal vacuum survivability over a specified qualification and acceptance test plan. DiTom's current space level manufacturing process allows for delivery in as quickly as four weeks depending on the test requirements.

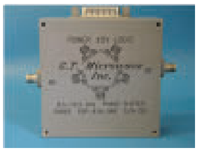
DiTom Microwave
www.ditom.com

Externally Biased Balanced Mixers

It is always a concern at high millimeter wave band that there is not enough power to drive the mixer, especially full waveguide band. Model FDB-XX-E1 series externally biased, balanced mixers are developed especially for this purpose. The mixers are offered in four waveguide bands to cover frequency spectra from 50 to 140 GHz. These mixers employ high performance GaAs Schottky beamlead diodes and balanced configuration to produce superior performance with a very low LO pumping level.

Ducommun Inc.
www.ducommun.com

PIN Diode 360° Phase Shifter

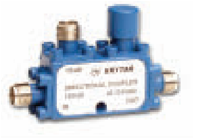


Model P2P-61A-5AR is a digitally controlled PIN diode 360° phase shifter with low phase noise option that operates from 9.5 to 10.5 GHz in 0.087 monotonic dB steps. Across the entire band, phase accuracy is ±5 degrees and an amplitude balance of ± 1 dB. It features a low phase noise of 132 dBc/Hz at 10 kHz and 142 dBc/Hz at 100 kHz with an insertion loss less than 12 dB and VSWR less than 1.9:1 in 50 Ohms.

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

Compact Directional Coupler

KRYTAR Inc. announced a new directional coupler operating from 6 to 26.5 GHz and offering nominal coupling of 6 dB in an extremely compact package. KRYTAR's new directional coupler, model 106026506, offers wide frequency coverage using stripline designs. Stripline designs offer superior low insertion loss, high directivity and tight coupling. The new directional coupler lends itself to emerging wireless ultra-broadband designs and many test and measurement applications.



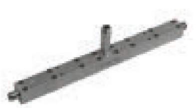
KRYTAR Inc.
www.krytar.com

Rotary Joint for Ka-Band Satcom

The AM28RJD dual-channel rotary joint features a high power/low loss WR28 waveguide transmit channel, together with a coaxial receive channel offering a high current rating of 2A at 24 VDC, which enables it to power the antenna's LNB and servo motors without the need for additional slip rings. The central transmit channel has a frequency range of 29 to 31 GHz, with an average power rating in excess of 50 W, a typical insertion loss of just 0.5 dB and a maximum VSWR of 1.7:1.

Link Microtek
www.linkmicrotekeng.com

Unequal Power Splitters



MECA's new line of unequal power splitters consists of six models offering a 2, 3, 4, 6, 8 or 10:1 signal-split ratio respectively, over 698 to 2700 MHz (cellular, PCS, AWS and BRS/EBS frequencies) and feature low PIM ratings – (better than 150 dBc), with ultra-low VSWR and minimal coupling variation over the entire frequency band. They easily handle high power levels of 300 W (CW) and have an operational temperature range of 55° to +85°C.

MECA Electronics Inc.
www.e-meca.com

Sharp Cut-Off, RF Lowpass Filter

Microwave Filter Co. offers this medium power lowpass RF filter from 50 to 500 MHz. Model

19141 is designed for use in any medium power application (100 W or less) that requires harmonic band rejection of up to 6 times the fundamental cut-off frequency (Fc). Filters and components offered from stock or custom designed to meet specific applications.

Microwave Filter Co. Inc.
www.microwavefilter.com

Extended Value Ranges

Passive Plus Inc. now offers extended-values for the traditional NP0, Hi-Q 0505 (.055" × .055") – now available up to 1000 pF; and 1111 (0.110" × 0.110") – now available up to 10,000 pF (0.01 uF). These parts exhibit low ESR/ESL, low noise, high self-resonance as well as ultra-stable performance over temperature. Usually used for wireless broadcasting equipment, mobile base stations, GPS, MRI and radar applications, and offered in magnetic and non-magnetic terminations.

Passive Plus Inc.
www.passiveplus.com

Broadband Power Combiners

Pasternack introduced a new line of broadband RF power combiners. The broad bandwidth of these new combiners makes them the perfect complement to systems using components such as power amplifiers, antenna feeds, attenuators and switches. A special area of usage for these power combiners is in combining individual power amplifiers together into a large power block in an amplifier system. The new RF power combiners are offered in the popular two- and four-way configurations and deliver high power up to 600 W.

Pasternack Enterprises Inc.
www.pasternack.com

Surface-Mount Isolator and Circulator

For X-Band earth terminals, REC has designed a high peak power, surface-mount isolator and circulator, 2SMH8ND and 3SMH8NF with low loss and operating over a wide temperature range of -55° to 100°C. Light weight and compact, features include low loss and wide temperature stability. For earth and airborne systems, these products improve systems performance and are for high reliability applications.

Renaissance Electronics & Communications LLC
www.rec-usa.com

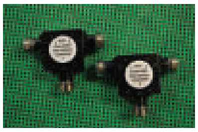
NewProducts

Flange Mount Termination and Resistor

Res-Net Microwave Inc. released the RPT1900-1200-50-5 flange termination and the RPR1900-1200-XXX-X flange mount resistor. The new RPT1900-1200-50-5 flange mount termination features power handling of 1.2 kW and has a maximum VSWR of 1.25:1 to 1 GHz. This terminations is ideal for various high power commercial and military applications. The new RPR1900-1200-XXX-X flange mount resistor handles 1.2 kW of average power and is available in 10 to 200 Ohm resistance values.

Res-Net Microwave Inc.
www.resnetmicrowave.com.

Weatherized Circulator



Response Microwave Inc. announced the availability of its new 30 dB weatherized circulator for use in harsh, moist environments. The new RMCI.895-935Nfw covers 895 to 935 MHz offering typical electrical performance of 0.25 dB insertion loss, VSWR of 1.20:1 and minimum isolation of 30 dB. Average power handling is 100 W and the unit is operational over the -55° to +85°C range. Mechanical package is 38 × 35 × 15 mm, plus N female connectors. Internal seals and black epoxy paint provide protection against moisture penetration.

Response Microwave Inc.
www.responsemicrowave.com

DOCSIS 3.1-Compliant Switch

VENDORVIEW

Richardson RFPD Inc. announced the availability and full design support capabilities for a new reflective, single-pole double-throw (SPDT) RF switch from Peregrine Semiconductor Corp. The PE42722 is designed for use in customer premises equipment (CPE) cable applications, including DOCSIS 3.0/1 cable modems and set-top boxes. The new switch delivers high linearity and excellent harmonics performance in the 5 to 1794 MHz band, along with low insertion loss and high isolation performance.

Richardson RFPD Inc.
www.richardsonrfpd.com

High Frequency Surface Mount Cavity Filters

RLC Electronics introduced a series of high frequency surface mount cavity filters for small scale, low profile system integration. Designs are created and constructed using proprietary techniques resulting in rugged, stable performance over a full range of environmental stresses. High Q cavity filter performance is available up to 30 GHz with profile height as low as 200 mm. The surface mount design is suitable for reflow attachment, providing savings on size, cost and weight.

RLC Electronics Inc.
www.rlcelectronics.com

W-Band Active ×2 Multiplier

VENDORVIEW

Model SFA-104104213-10VF-S1 is a 102 to 103 GHz ×2 active multiplier. The active multiplier converts 51 to 51.5 GHz/+5 dBm input signal to deliver 102 to 103 GHz with minimum +13 dBm output power. The output spurious and harmonic levels of the multiplier are -60 and -20 dBc, respectively. The multiplier draws 460 mA current from a +8 V DC DC power supplier. The multiplier is equipped with a V (F) connector as its input and a standard WR10 waveguide with UG387/U-M flange as its output.

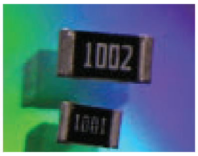
SAGE Millimeter Inc.
www.sagemillimeter.com

Waveguide Series V-Band Biased Mixer

Spacek Labs model MV-1B is a wideband biased mixer with full V-Band coverage in the RF and LO ports. The RF and LO ports span 50 to 75 GHz in WR15. The local oscillator power is reduced to only 0 to +5 dBm by applying a DC bias. The IF port covers 10 MHz to 3 GHz and is supplied with a DC block on the SMA (f) connector. Conversion loss is 6 dB typical and 9 dB maximum.

Spacek Labs Inc.
www.spaceklabs.com

RNCF Series Resistors



Stackpole's thin film, precision RNCF series has expanded its value ranges to be one of the broadest in the industry for 0.01% tolerances and 10 ppm TCR. The new ranges are RNCF0402 - 49.9 to 12K ohms, RNCF0603 - 24.9 to 100K ohms, RNCF0805 - 24.9 to 200K ohms and RNCF1206 and larger sizes - 24.9 to 500K ohms. The RNCF series is also available in 0201 case size down to 0.5% tolerance and ±25 PPM (49.9 to 5K).

Stackpole Electronics Inc.
www.seielect.com

4-Port Bidirectional Coupler

The SCL-1D-BD is a small surface-mount, bidirectional coupler optimized for applications in the frequency band of 2 to 300 MHz. The insertion loss is 0.3 dB typical and 0.5 dB maximum; the directivity is 20 dB typical and 15 dB minimum across the specified bandwidth. Other specifications include typical VSWR of 1.10:1 all ports. It has power handling capability of 1 W, and is an ideal building block for signal sampling, power detectors, uneven signal splitting and VSWR measurements.

Synergy Microwave Corp.
www.synergymwave.com

75 Ohm Digital Attenuator

VENDORVIEW

Vaunix's new 75 Ohm model LDA series digital attenuator offers up to 120 dB of programmable attenuation through 6000 MHz. The LDA-102-75F has input power of up to 1 W, attenuation range to 95 dB, and offers frequency coverage from 10 to 1000 MHz. This unit is powered and controlled by connection to a PC or self-powered USB hub, and programmable for fixed attenuation or swept attenuation ramps directly from the included graphical user interface (GUI) software.

Vaunix Technology Corp.
www.vaunix.com

MIL-PRF-55342-Qualified Thin Film Resistors

Vishay Intertechnology has enhanced its E/H series of precision MIL-PRF-55342-qualified thin film surface-mount resistor chips to offer a "T" level failure rate for critical space applications. The QPL devices are qualified to TCR characteristics E, H, K, L and M in 12 case sizes. The established reliability of the Vishay Dale thin film resistors

New**Products**

is assured through 100% screening and extensive environmental testing. In addition, the thin film resistors meet the ASTM-E595 requirements for outgassing in a vacuum environment.

Vishay Intertechnology Inc.
www.vishay.com

Octave-Band Coaxial Circulator

Model F2823-0150-67 is an octave-band SMA (or Type N) connectorized circulator covering 100 to 200 MHz. It features 1 dB insertion loss, 15 dB minimum reverse isolation, 1.50:1 VSWR and can handle 20 W of CW power. Higher power version up to 100 W is available with reduced bandwidth. Package size is 2.09" × 3.03" × 1.02".

Wenteq Microwave
www.wenteq.com

Custom Power Dividers Up to 18 GHz

Werbel Microwave designs and manufactures custom power dividers to your specifications with no minimum order. The 2PA1500 covers 12 to 18 GHz with 1.5:1 VSWR, 17 dB minimum isolation and 0.6 dB maximum insertion loss. Its footprint is only one square inch. SMA female.

Werbel Microwave LLC
www.werbelmicrowave.com

Cables and Connectors

Flight Cable Assemblies

Florida RF Labs launched its next generation Lab-Flex® Q and Lab-Flex® AF cable assemblies. Both cable lines have gone through extensive qualification testing in order to validate them for today's rigorous application requirements. Lab-Flex Q® assemblies use very low loss ePTFE insulation, and are constructed with materials that meet the outgassing requirements of NASA/ESA when tested per ASTM E595.

Florida RF Labs
www.rflabs.com

Ultra Low Loss Cable Assembly

VENDORVIEW

For static and dynamic applications up to 29 GHz, the new SUCOFLEX 229 ultra low loss cable assembly claims to offer outstanding electrical performance. Its ultra-low loss characteristic of .1 dB maximum at 18 GHz provides greater signal integrity during testing and its excellent phase stability versus temperature (maximum 600 ppm) will improve the system performance.

Fully MIL/DTL–17 qualified, with excellent return loss, improved system performance due to reduced phase changeover temperature and higher signal integrity due to lower loss, the SUCOFLEX 229 assemblies come standard with SMA, N, TNC and SK connectors.

HUBER+SUHNER
www.hubersuhner.com

90° In-Series Adapter

SGMC Microwave introduced its internally swept right angle type N male to female in-series adapter. This adapter features DC to 18 GHz, low VSWR and insertion loss and passivated 303 stainless steel robust construction for repeatability. Ready to ship today. Quality, performance and reliability you can count on.

SGMC Microwave
www.sgmcmicrowave.com

Ultra-miniature 0.9 mm SuperMini Connectors

Southwest Microwave Inc. introduced a new series of ultra-miniature 0.9 mm SuperMini DC to 67 GHz connectors. Connectors in the 0.9 mm SuperMini product line provide the superior performance of Southwest Microwave's standard-size, high frequency connectors in a miniaturized footprint that is ideal for reduced size PCB and panel applications. Offering ultra-broad bandwidth and coupling nut mating, this new series includes field-replaceable two and four-hole flange mount and thread-in connectors, solder-on end launch and 4-post vertical launch connectors and direct solder cable connectors.

Southwest Microwave Inc.
www.southwestmicrowave.com

Amplifiers

1 to 6 GHz Amplifier

VENDORVIEW

Models 25S1G6AB, 50S1G6AB and 100S1G6AB are solid-state; 25, 50 and 100 W Class AB amplifier designs that instantaneously cover 1 to 6 GHz in a single benchtop unit.

IEEE COMCAS 2015

International Conference on Microwaves, Communications, Antennas and Electronic Systems

IEEE COMCAS 2015 continues the COMCAS tradition as a multidisciplinary forum for the exchange of ideas, research results, and industry experience in the areas of microwave/RF/mm-wave engineering, communications, antennas, electromagnetic compatibility, solid state circuits, electronic devices, engineering in medicine, radar, sonar and electronic systems. The technical program includes invited talks by international experts and contributed papers and will be complemented by a large industrial exhibition.

Important Dates

Submission of summary:
30 May 2015

Notification of acceptance:
15 July 2015

Submission of final paper:
20 September 2015

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www.comcas.org
Email: comcas@ieee.org

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Antennas
Smart Antennas, Beamforming and MIMO
Wave Propagation and Channel Modeling
Wave Scattering and RCS
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Sonar Systems and Applications
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Terahertz Systems

General topics
Education and E-Learning
Papers not fitting under other headings

Regular verbal presentations will be 20 min. in length; there will also be Poster sessions. All submitted papers will be peer reviewed. Accepted papers will be published in the COMCAS 2015 Proceedings, which will be submitted for publication in IEEE Xplore® after the conference.
For author's instructions and further information, see www.comcas.org.

New**Products**

These amplifiers provide 25, 50 or 100 W output power, depending on the model, in approximately half the size of a traditional Class A design with increased efficiency and a more economical price.

AR RF/Microwave Instrumentation
www.arworld.us

Digital Variable Gain Amplifiers

BeRex announced the BVA303 and BVA305, 6-bit DVGA offering high linearity, low noise and require only a single 3 V power supply. Both DVGAs are capable of working at up to 4 GHz without external matching components and are provided in a space saving 4×4 mm, 24-pin QFN package. Designed primarily for 3G/4G wireless infrastructure equipment, satellite radio and other high end wireless applications, the BVA303 and BVA305 provide outstanding RF characteristics and the flexibility of digital parallel and serial programming of the gain control with very fast switching speeds.

BeRex Corp.
www.berex.com

Benchtop Amplifiers

VENDORVIEW

Cernex's Benchtop amplifiers are designed for use in a wide range of general purpose applications such as laboratory test equipment, instrumentation and other applications. Reliable operation is achieved using rugged stripline circuit construction with selected GAas FETs, PHEMTs and MIMICs. LNAs and broadband power amplifiers up to 5 W.

Cerxex Inc.
www.cernex.com

dB-3840 TWTA

dB Control introduces the dB-3840 TWTA for electronic countermeasures, EW simulation, RF components testing, SAR, manned/unmanned airborne platforms. It features 700 W pulsed, 34.5 to 35.5 GHz and outdoor hub-mount Ka-Band. Applications include: radars, test and measurement, antenna pattern, radar cross-section measurements and electronic warfare (EW) simulation.

dB Control
www.dbcontrol.com

80 to 1000 MHz, 500 W HPA

VENDORVIEW

Empower's model 2175, covering 80 to 1000 MHz and delivering 500 W of broadband output power in a 3U, air cooled chassis is market released and available for immediate purchase.

Offering unrivaled size/power advantages and building on a design architecture that has been a catalyst for technology upgrades from customers with diverse requirements from multiple markets, Model 2175 provides excellent performance for end applications that include, but are not limited to, test and measurement, electronic warfare and communications.

Empower RF Systems Inc.
www.empowerrf.com

Solid State High Power Amplifier

Model AMP1095 is a new high power SSPA module that operates from 4 to 18 GHz at 20 W P1dB and 30 W Psat. This small form factor module uses state-of-the-art Chip & Wire GaAs and GaN devices, exhibits good linearity and operates at 32 VDC with 19A maximum consumption.

Exodus Advanced Communications
www.exoduscomm.com

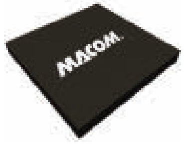
5 GHz, WLAN, Access Point Amplifier Drivers

Guerrilla RF Inc. introduced the newest members to the company's family of 5 GHz ultra low noise amplifier/linear power amplifier drivers. These new devices feature best-in-class noise figure, gain and linearity. The cost-effective, small footprint, flat-gain solutions are designed for WLAN access points offering the highest levels of performance for demanding 802.11ac applications.

Guerrilla RF Inc.
www.guerrilla-rf.com

S-Band, 7 W, Pulsed High Power Amplifier

VENDORVIEW



MACOM announced the release of a high power pulsed amplifier designed for civil air traffic control and weather radar applications. The device can be used individually or in a complete MACOM chipset solution. The MAAP-011022 is a balanced high power amplifier covering 2.7 to 3 GHz in a 6 mm PQFN 28-lead SMT package. The device boasts 7 W of pulsed power, 23 dB small signal gain and is designed to provide very rugged performance under load mismatch.

MACOM
www.macom.com

2 to 18 GHz DLVA

VENDORVIEW

PMI model no. ERDLVA-218-DC-LPD is an extended dynamic range DLVA designed to

AMTA 2015

37th Annual Symposium of Antenna Measurement Techniques Association

The Antenna Measurement Techniques Association is a non profit, international organization dedicated to the development and dissemination of theory, best practices and applications of antenna, radar signature and other electromagnetic measurement technologies. Visit www.amta.org for more information.

Nearfield Systems Inc. (NSI) is proud to host the 37th Annual Meeting and Symposium of the AMTA at the Hyatt Regency Long Beach in California, USA. The host committee cordially invites you to attend and participate in this annual event.

- High-quality technical papers presented on a continuous basis over four days.
- Practical full day short course:

  Near-Field Measurement Error Analysis & Computational Electromagnetic Modeling
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CONTACT INFORMATION

For more information about AMTA2015, please visit

www.amta2015.org

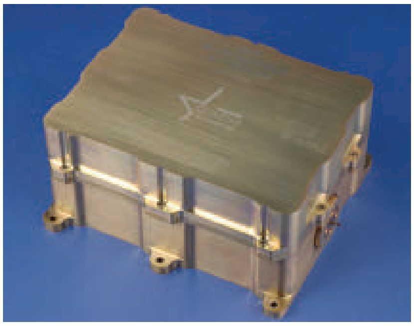
Or contact Kim Hassett, AMTA2015 chair
Nearfield Systems Inc.
2015host@amta.org

NewProducts

operate over 2 to 18 GHz. It employs planar diode detectors and integrated video circuitry for high speed performance and outstanding reliability. Superior construction using state of the art MIC/MMIC technology.

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

Solid State Power Amplifiers



QuinStar introduced a new line of ultra-compact millimeter wave SSPA over 27 to 110 GHz with power levels ranging from 2 to 50 W at 94 GHz and 40 to 200 W at 35 GHz. Both pulsed and CW versions are offered with integrated power supplies and pulsing-generating circuits. Many user-specific optional features are also available. Airborne and space-worthy versions can be produced for radars and communication transmitters.

QuinStar
www.quinstar.com

Sources

Synthesized Signal Generator

VENDORVIEW

Mini-circuits' SSG-4000LH (RoHS compliant) is a wideband synthesized signal generator operating at 250 to 4000 MHz. The signal generator is cased in a rugged metal shielded package (11" × 8.5" × 2.15") and equipped with an N-type 50 Ω connector at the RF output port. The signal generator is controlled through a USB 2.0 interface using unique user friendly GUI software allowing the user to select one of several different output modes including multiple pulsed RF options, frequency sweep and power sweep (up, down or bidirectional).

Mini-Circuits
www.minicircuits.com

Low Phase Noise OCXO

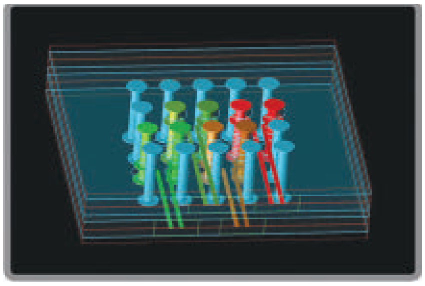
VENDORVIEW

Morion announced a new low profile, high precision, low phase noise OCXO. The MV331 is available from 10 to 20 MHz and has phase noise of -152 dB/Hz at 100 Hz, -160 dB/Hz at 1 kHz and -165 dB/Hz at 10 kHz. Long term stability is 2E-8/year, with temperature stability (-200° to +700°C) of 3E-9. The MV331 package measures 25.8 × 25.8 × 10.6 mm, is available with 5 or 12 V supply and output of Sinewave or HC-MOS.

Morion US LLC
www.morion-us.com

Software

PinBuilder for XFdtd



Remcom has a new capability to share that is coming soon in XFdtd: PinBuilder EM Model Automation. PinBuilder is an application that automates the creation of pin-field breakout models for XF simulations. PinBuilder creates complete XF models, including high speed printed circuit board (PCB) layout traces and via geometries for validating critical signal integrity performance. Parameterized simulation model creation with PinBuilder facilitates the proactive exploration of pin-field designs and their signal integrity performance trade-offs before the printed circuit board layout is performed.

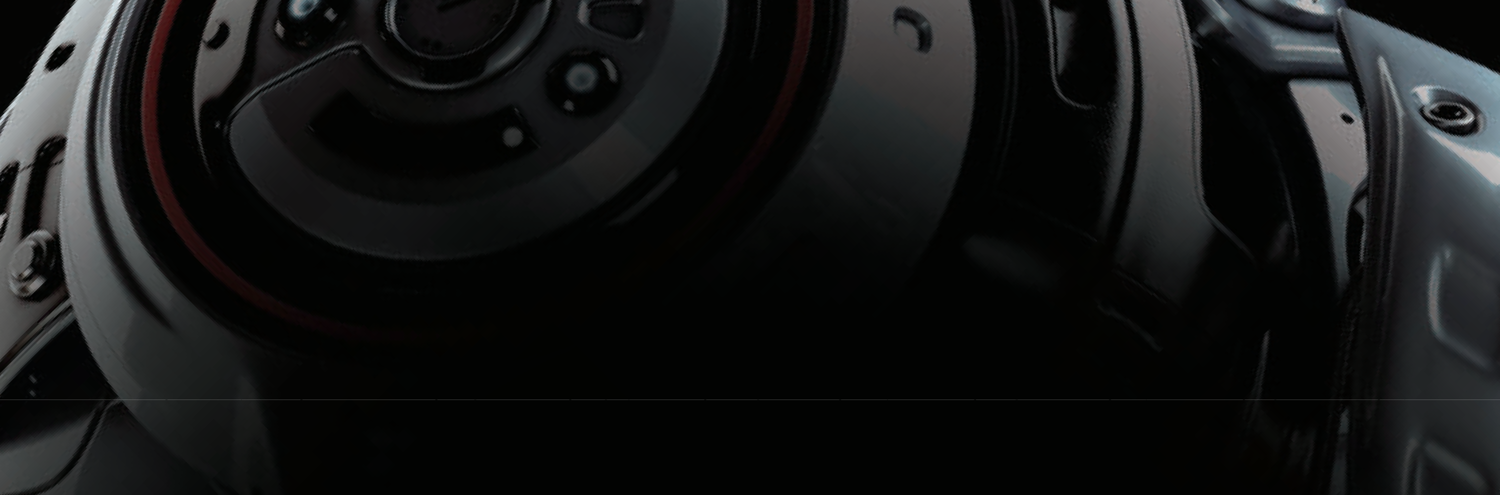
Remcom
www.remcom.com

Test Equipment

Communications Test System

Astronics' ATS3000P is a compact, ruggedized, battery-operated communications test system for frontline diagnostics. Featuring 23 instruments and automated/stand-alone modes to test, record and diagnose faults, the ATS3000P provides complete RF, analog and digital capabilities, including sophisticated IF and baseband I/Q DSP required for modern radios. The field-upgradeable, software-defined architecture enables testing with minimal operator intervention. TPSs are available for a full range of tactical radios or create TPSs easily using the TestEZ® software.

Astronics Test Systems
www.astronics.com



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To capture a piece of the $1 trillion mobile market, you can't just dip in your toe.
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Modern RF and Microwave Measurement Techniques

Valeria Teppati,
Andrea Ferrero and
Mohamed Sayed

This month's bookend, "Modern RF and Microwave Measurement Techniques" provides an extensive tutorial of RF and microwave measurement techniques and test equipment including vector network analyzers (VNA), real time spectrum analyzers, microwave synthesizers, microwave power meters and sampling oscilloscopes.

The editor's stated objectives are to:

- Provide an overview of the techniques for measurements at RF and microwave frequencies
- Be comprehensive and treat the concepts in a unitary way
- Discuss the techniques used today, including the state of the art

Eleven of the 15 chapters probe linear (e.g., S-parameters, noise figure) and nonlinear (e.g., load- and source-pull) measurements, their associated errors and calibration techniques. Each chapter maps a measurement to the test equipment used to perform it. An exception to this approach is a chapter focusing on the evolution to modular and virtual instruments. It explains the motivation behind the trend and the developments in software and hardware that have made it viable.

Before launching into the subject of the book, the first two chapters introduce basic microwave concepts to those readers without a strong background. The topics include transmission lines and the underlying principles of transmission and reflection, S-parameters, the Smith Chart, reference planes, microwave probes and the ever-elusive ground.

The three editors enlisted 18 additional contributing authors who reflect the core of the test and measurement (T&M) industry, including Anritsu, Agilent/Keysight Technologies, National Instruments, the National Institute of Standards and Technology (NIST), Phase Matrix, Tektronix and Teledyne LeCroy. They dedicate the book to Roger Pollard, an icon in the T&M industry and one of the contributors before his death in December 2011.

Larry Dunleavy, president and CEO of modeling firm Modelithics, said the book is "complete in its coverage of this very broad field from linear to nonlinear and addressing both frequency and time domain measurements."

"Modern RF and Microwave Measurement Techniques" should be a reference in every RF and microwave engineer's library.

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FABS and LABS

Werlatone's Recipe for Success

What's the recipe for growing a company from a startup to a global enterprise? Just ask entrepreneur Glenn Werlau. In 1965, he began Werlatone by designing and building high power passive components in his Brewster, N.Y. garage. After only a few years, Glenn outgrew his small garage and began renting space from a local lawn mower repair shop. With his first large order from ITT, Glenn moved into a 4,000 square foot facility in Brewster and expanded it to 7,000 square feet. Now celebrating 50 years in business, Werlatone recently added a 19,000 square foot facility in Patterson, N.Y. allowing for full production, test and research capabilities.

Those are the signs of success, but Werlatone's inventive designs are a key ingredient in its recipe. Werlatone builds high power passive products that include directional couplers, combiners/dividers and absorptive filters. High power translates to tens of kilowatts at several MHz and lower power levels at several GHz. Werlatone's products are found worldwide in both commercial and military systems, including land mobile radios, military radios and jammers, as well as industrial/scientific/medical applications.

Werlatone's conference room proudly displays various patents, awards and achievements. Most prominent are the 30 active patents with extensive foreign coverage. Several additional patents are currently pending. US Patent 6750752 B2 is a key design technique that was granted for a balun that overcomes some of the traditional limitations in bandwidth due to parasitics. The balun comprises two or more impedance segments connected between the balanced and unbalanced terminals; each segment is formed by winding a coaxial transmission line about a magnetic core. This invention extends both the high and low frequency ends of the usable frequency band, resulting in an ultra-wideband, high power balun with low parasitics. Building on their patents, the company's engineers develop new products using the latest 3D tools.

A dedicated manufacturing and engineering staff, combined with extensive in-house, high power test capabilities, are also part of Werlatone's recipe. Their high power test lab, assembled over many years at considerable investment, allows Werlatone to evaluate protoypes and prove out new designs. The equipment in their test lab ranges from tube-based power to modern solid-state models. Testing capabilities include 10 kW CW at the HF band, 5 kW CW to 220 MHz, 1 kW CW to 1000 MHz and 400 W CW to 4 GHz. On the production floor, skilled workers assemble components into finished products. Before delivery, full assemblies can be tested at temperatures ranging from -50° to +85°C using on-site environmental chambers.

Mindful of his company's success, Glenn Werlau wants to give back to the school, profession and industry that contributed to his success. He recently helped fund, organize and host an educational seminar for students and faculty at his alma mater, the SUNY Canton School of Technology. During the visit, company employees shared "life in the real world" of high power RF components. The students and faculty toured the work areas and learned how products are designed, assembled, tested and marketed. Glenn spoke about business trends and the future of the RF industry. He told of the inspiration and dedication that fuels a successful entrepreneur and the challenges and rewards when growing a company from a startup to a global enterprise. Glenn's hard work, drive and determination are a testament to what makes an entrepreneur in our industry so successful.

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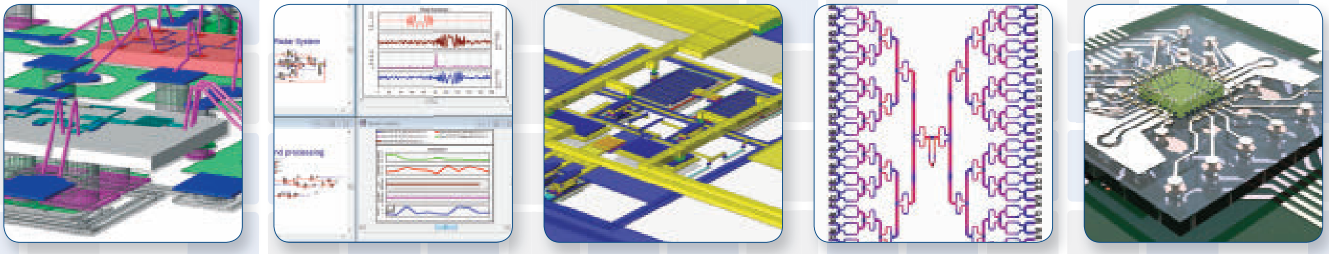

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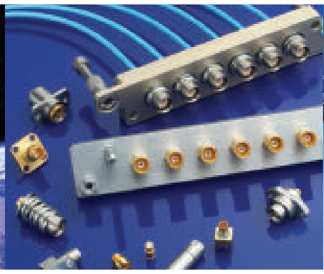

Cables and Connectors

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INVITED PAPERS FROM
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W. L. GORE AND ASSOCIATES (GORE)

"Leaky" Cables Make Fine Broadband Antennas

Editor's Note: A cable that leaks electromagnetic energy sounds like a defective cable. Yet, ironically, it makes an excellent broadband antenna. To avoid confusion, antennas based on this approach are called leaky feeders. They are typically used in environments that mirror the cylindrical shape and length of the cable: tunnels, mines, aircraft, railroad tracks and skyscrapers.

CST provides a tutorial explaining the basic theory and electromagnetic performance. Turning theory into practice, with assistance from W. L. Gore, we examine their use enabling Wi-Fi and cellular service on commercial airlines and corporate jets.

PRINCIPLES OF LEAKY FEEDER ANTENNAS

Franz Hirtenfelder and Stephen Murray
CST – Computer Simulation Technology

The leaky feeder antenna is an adaptation of the standard coaxial cable, with one key difference: the outer conductor is slotted or punctured, allowing the cable to radiate. Based on cables, leaky feeders are strong, flexible and robust against environmental conditions. Together, these characteristics make leaky feeders a good candidate for providing mobile connectivity and RF sensor coverage in confined, challenging environments such as tunnels, underground facilities, mines, factories, ships and aircraft.

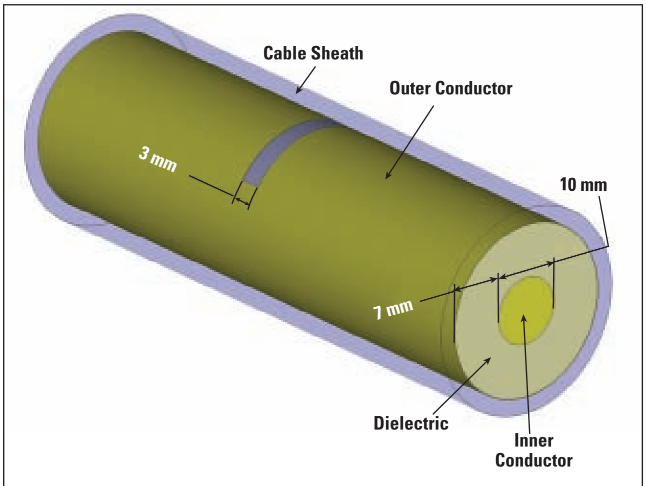

Fig. 1 A simulation model of a coaxial cable with a single slot.

The leaky feeder doubles as both a transmission line and an antenna. Waves propagate through the dielectric, with currents running along the inner and outer coaxial conductors. These waves can "leak" through gaps in the outer conductor. In a normal coaxial cable this is, of course, unintended behavior, however this is what allows the cable to act as an antenna.

A leaky feeder antenna is effectively an array, with numerous radiating slots along its length. There are several classes of leaky feeders, which depend on the shape of the slots. This explanation of the antenna characteristics will focus primarily on the simple case where the slots are rectangular, regular and run circumferentially perpendicular to the axis of the cable. The same principles apply to a wide range of leaky feeder antennas.

The first step in understanding how a leaky feeder antenna operates is to examine the behavior of a single slot (see ***Figure 1***). Although radiation from leaky feeders is described in layperson's terms as the fields "leaking" through the shield, there are really two distinct modes: radiated and coupled.

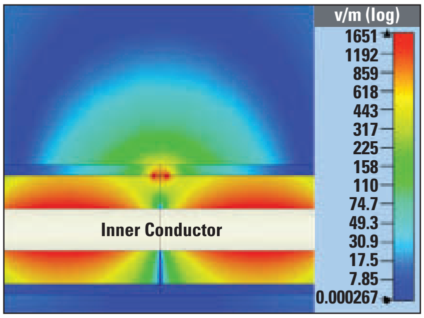

Fig. 2 *Simulated E field at 3 GHz, inside the cable and around a slot.*

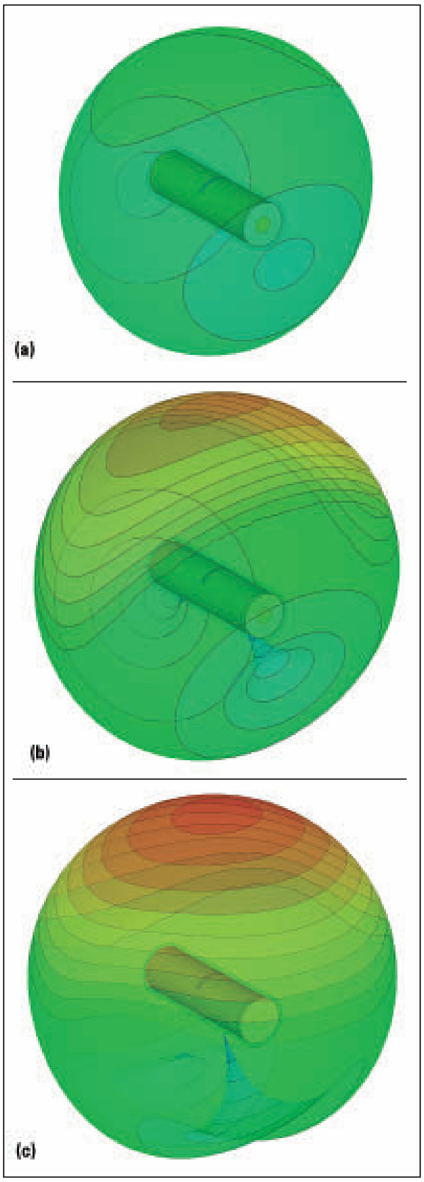

Fig. 3 *Simulated 3D far field radiation pattern for a single slot on a short length of cable at 1 GHz (a) 1.5 GHz (b) and 3 GHz (c).*

RADIATED MODE

In radiated mode, each slot behaves as a magnetic dipole antenna. The slot will interrupt the current lines running along the outer conductor of the coaxial cable, which causes the slot

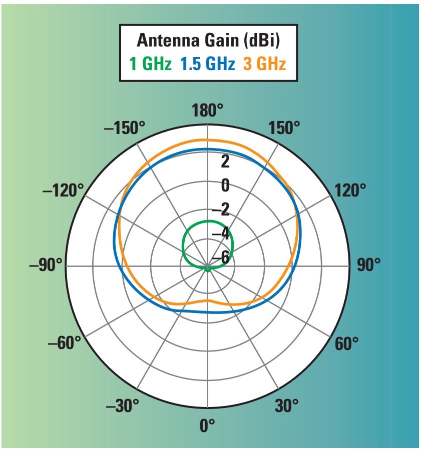

Fig. 4 *Simulated 2D far field radiation patterns vs. frequency (plane midway through the slot and perpendicular to the cable length).*

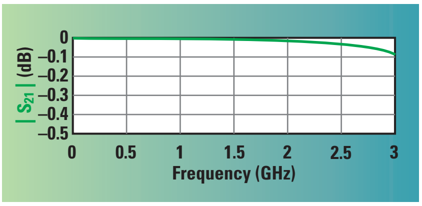

Fig. 5 *Loss vs. frequency for a short cable section with a single slot.*

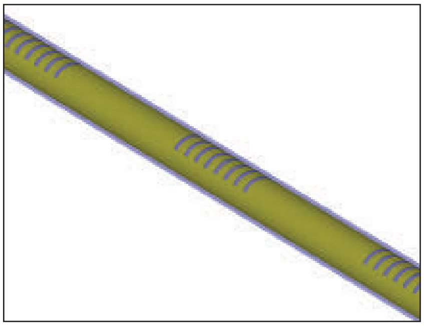

Fig. 6 *A length of leaky feeder with alternating leaky and shielded sections.*

to radiate as simulated[1] in ***Figure 2***. The radiation pattern for the slot is directional, but the width of the main lobe is very large, as shown in ***Figures 3*** and ***4***. This offers good coverage within the tightly enclosed spaces in which leaky feeders are used. For this simple slot design, the radiation efficiency increases with frequency, as the wavelength of the radiation becomes comparable with the length of the slot. More complex designs can be used to adjust the electrical size of the slot to tune its radiation properties more finely.[2] Individually, a single slot is not a very effective radiator. By design, the slots are not usually resonant, which would improve the radiation.[3]

Analyzing the loss through the cable, ***Figure 5*** shows the simulated S_{21} for a short section with a simple slot (Figure 1) is only -0.097 dB at 3 GHz. However, a 100 meter run of a leaky feeder may include thousands of slots, and the losses will quickly accumulate resulting in significant attenuation of the signal. In applications with long cable runs – a tunnel or mine, for example – booster amplifiers will be installed at regular intervals to compensate for the losses.

As a compromise between maximizing antenna efficiency and minimizing coaxial mode attenuation, leaky feeders are often designed with leaky sections interspersed with shielded sections (see ***Figure 6***). This also improves the directionality of the antenna by suppressing higher-order harmonics outside the cable, as shown in ***Figure 7***.

When multiple slots are combined, they behave as an array. This significantly affects the performance of the leaky feeder, compared to individual dipole slots. The phase difference between the slots, proportional to the distance between the slots relative to the wavelength in the dielectric, causes constructive and destructive interference. This interference results in beam steering, meaning the maximum gain is not normal to the cable; rather, it is directed

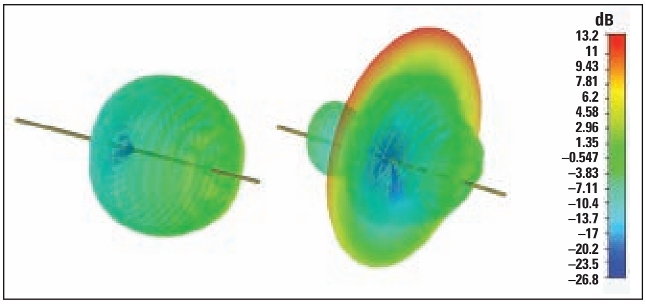

Fig. 7 *Comparison of the simulated radiation patterns for 2 m of continuously slotted cable (left) and periodically slotted cable (right) at 1.5 GHz.*

at an angle that varies with frequency (see ***Figure 8***).

The leaky feeder resembles a conventional slotted waveguide antenna with one key difference: in leaky feeder antennas, the n = 0 harmonic does not radiate. This means that it is not necessary to alternate the placement or alignment of the slots to cancel this harmonic.[3]

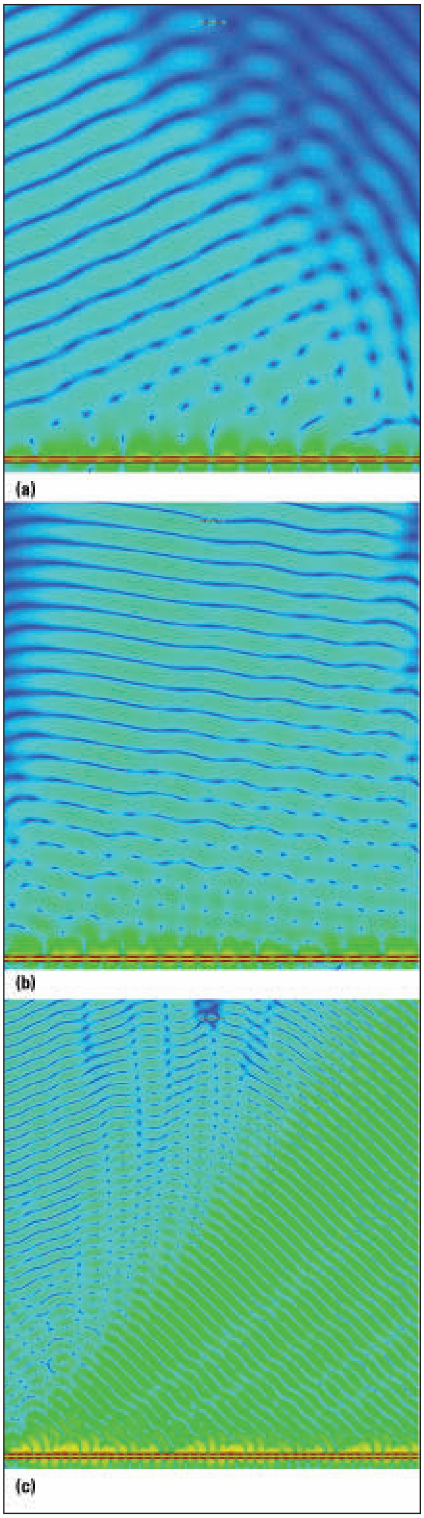

Fig. 8 Simulated E field around a 2 m length of periodically slotted leaky feeder at 1 GHz (a) 1.5 GHz (b) and 3 GHz (c). The changes in beam orientation with frequency reflect the cumulative phase interference from the individual slots.

The leaky feeder is typically used in an enclosed space, such as a tunnel or aircraft fuselage. Since the frequency of operation is much greater than the cutoff frequency of the enclosure, propagation of the radiated mode through the enclosure is mainly by reflection. ***Figure 9*** shows the propagation in a concrete tunnel, simulated with a ray-tracing asymptotic solver.[1]

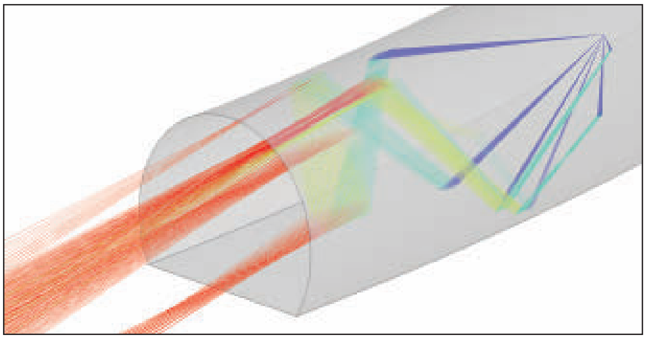

Fig. 9 Simulated propagation from a short length of leaky feeder cable (not shown) in a concrete tunnel at 3 GHz. The colors distinguish the direct signal from the various reflections.

COUPLED MODE

While radiated mode can operate in free space, coupled mode relies on the interaction between the cable and its environment – typically enclosures that act like waveguides. Consider a leaky feeder running through a tunnel. The outer conductor of the leaky feeder can be considered the inner conductor of a much larger coaxial cable, where the walls of the tunnel form the outer conductor (see ***Figure 10***). The leaky feeder is a mode convertor between the coaxial mode (in which the coaxial cable is the waveguide) and the monofilar mode (in which the tunnel itself is the waveguide).[2] Coupled mode dominates at low frequencies, where the wavelength is much greater than the slot spacing.[5] In this mode, the antenna radiates at discontinuities, such as irregularities in the wall and interactions with the cable mounts. The radiation increases when the cable is close to the wall, where the interaction between the coaxial mode and the discontinuities is stronger.

The performance of the leaky feeder in a waveguide enclosure will also be improved by alternating leaky and shielded sections. Currents propagate along the outside shielded sections, allowing the cable to radiate without significant attenuation in these regions.[2,5] Although the requirement for an outer wall restricts the use of coupled mode to specific applications, reducing attenuation allows the distance between amplifiers to be increased, which improves the performance of the leaky feeder.[6]

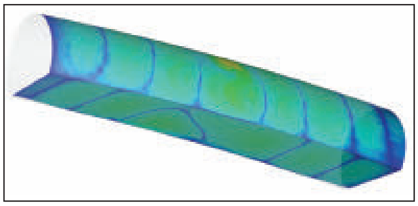

Fig. 10 The simulated E field from a short section of leaky feeder cable (not shown) in a 5 m diameter concrete tunnel at 60 MHz. The tunnel acts as a waveguide.

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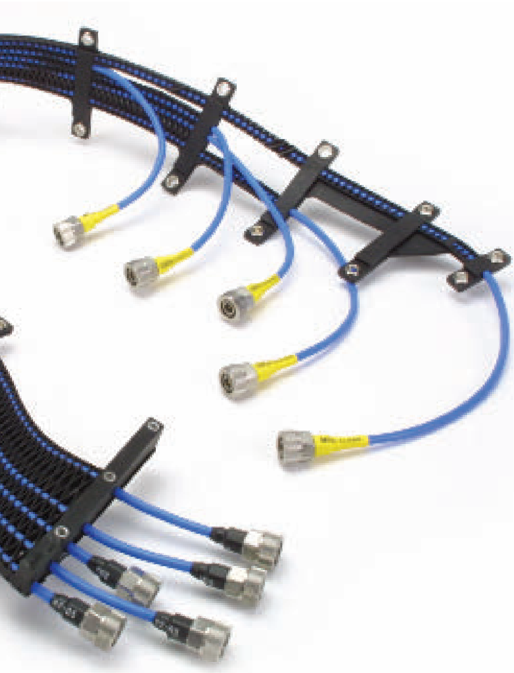

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LEAKY FEEDERS ENABLE AIRLINE Wi-Fi

W. L. Gore and Associates (Gore)

Major airlines are offering Wi-Fi access to the Internet on many of their flights and moving quickly to deploy the service to virtually all aircraft. Some airlines outside the U.S. — Emirates, for example — also offer cellular connections, allowing passengers to text and make calls using their mobile phones. Within just a few years, Wi-Fi has moved from a unique feature to attract flyers, to a frustration when connections are slow or it is not offered on the flight. The growth in demand has service providers such as Global Eagle, Gogo and ViaSat upgrading their systems to increase data rates and provide global coverage.

If you fly frequently, none of this is news. What you may not know, though, is that leaky feeder antennas are an important part of the system.

Whether the aircraft is connected to the Internet with a radio link to the ground or to a satellite (and then back to earth), the onboard equipment is similar (see ***Figure 11***). A Wi-Fi access point routes data back and forth between the passengers and an onboard processor, using a leaky feeder as the antenna. If the airline also offers cellular service, a separate picocell connects to the same leaky feeder antenna through a diplexer. The size of the aircraft determines the number of access points and picocells, which defines the number of leaky feeder runs in the cabin. For a wide-body aircraft like the Airbus 330 or Boeing 777, each aisle will have a leaky feeder, as illustrated in ***Figure 12***.

While uniform RF coverage throughout the cabin is important to passengers, the leaky feeder must also be airworthy, meeting requirements for flame and smoke toxicity. The antenna must be strong mechanically to withstand vibration and abrasion, ensuring it does not fail during the lifetime of the aircraft.

W.L. Gore and Associates is the leading manufacturer of leaky feeder antennas for aircraft applications

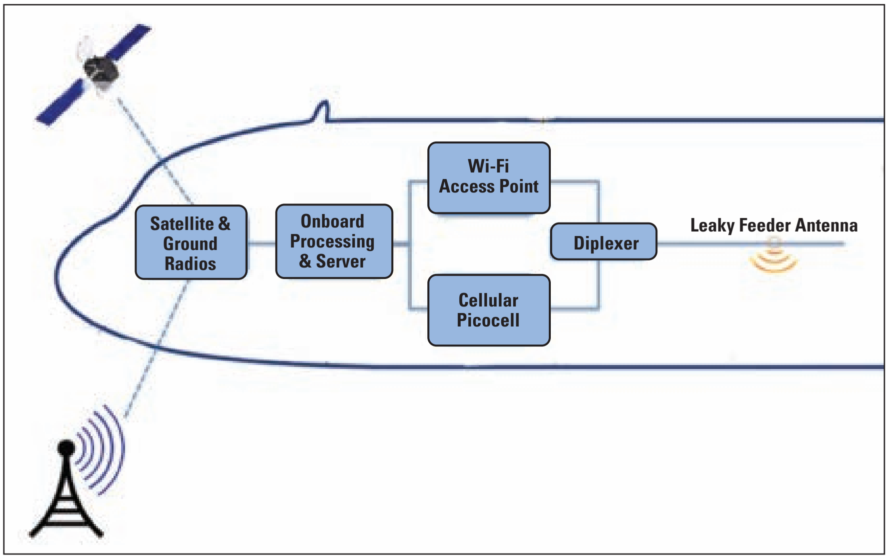

Fig. 11 Simplified block diagram of system for providing inflight Wi-Fi and cellular service.

Fig. 12 The leaky feeder antennas are mounted in the aircraft ceiling above the aisles.

Fig. 13 GORE Leaky Feeder Antennas look like a traditional RF cable.

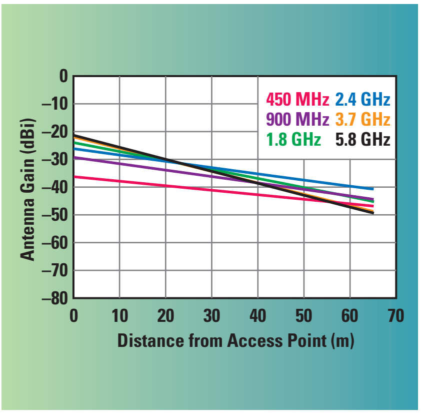

Fig. 14 Antenna gain vs. frequency and distance from the access point.

and one of few suppliers certified, according to Gore product specialist, Adrian Milne. He estimates that Gore's antennas are flying on more than 1000 commercial aircraft, including Airbus and Boeing. Dassault Aviation selected their leaky feeders for the Falcon 7× corporate jet, as part of a system that provides cellular service during flight.

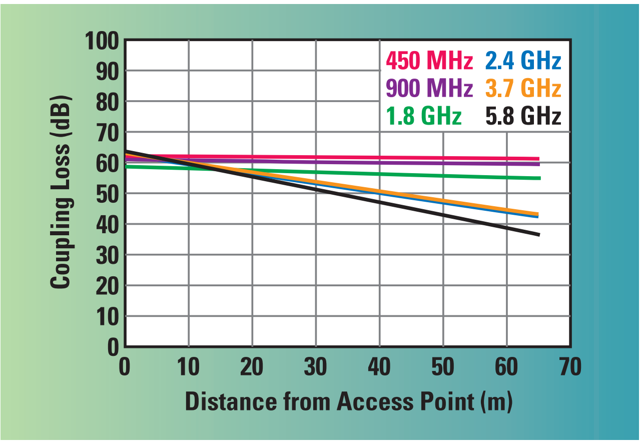

Fig. 15 Antenna coupling loss vs. frequency and distance from the access point.

The frequency response of GORE™ Leaky Feeder Antennas (see ***Figure 13***) covers 400 MHz to 6 GHz, so a single antenna run handles all cellular and Wi-Fi bands. The antennas are manufactured in three diameters, from 6.5 to 11.7 mm, with the smaller diameter cable lighter and with a tighter bend radius. The trade-off with the smaller diameter is lower gain.

Figure 14 shows the measured gain of the smallest diameter leaky feeder as a function of frequency and distance from the access point. The measured coupling loss for the same antenna versus frequency and distance is plotted in ***Figure 15***. For reference, the length of the cabin in an Airbus 330-300 is 50 m.

Both the antenna gain and coupling loss were measured according to the free space method specified by the International Electrotechnical Commission (IEC) in standard IEC-61196-4. The leaky feeder is elevated to 2 m above the ground, held by non-metallic posts, and the measurement antenna is positioned at the same height and 2 m from the leaky feeder. The data reflects only the radiated mode of the leaky feeder, not any interaction that the antenna would have with the metal fuselage of the aircraft.

Airline flights used to offer harried travelers a few hours of isolation and thoughtful reflection, disconnected from the world by the limitations of technology. No longer. The leaky feeder antenna is playing a part in the encroachment of 24/7 connectivity — even in the skies. ■

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INVITED PAPER

Realistic Shielding Effectiveness Measurements of Coaxial Cable Assemblies

Gerald Womer and John Lewis
Micro-Coax, Pottstown, Pa.

Shielding effectiveness is the ability of a cable assembly to either reject interference from the surrounding environment or to prevent the signal in the cable assembly from 'leaking' into the surrounding environment and causing interference to other nearby systems or subsystems. While there have been a number of measurement techniques and standards established over the years for the individual components of a cable assembly (i.e., cable and connectors),[1-3] it is desirable to know the shielding effectiveness of the entire cable assembly so the designer can have confidence that overall system performance will not be compromised.

The mode-stirred method is invaluable in establishing the shielding effectiveness of an entire cable assembly. This is performed in accordance with IEC International Standard 61000-4-21[4] and detailed in Annex F of this standard.[5] The most significant aspect of performing the shielding effectiveness test to IEC 61000-4-21, Annex F is the use of a reverberation chamber (as opposed to an anechoic chamber). An advantage to using a reverberation chamber is stated in IEC 61000-4-21 and is cited here: "Realistic environments for propagation of electromagnetic waves are often characterized by multiple reflections and multipath effects. Reverberation chambers go some way to simulate such complex environments in an extreme manner (worst-case effect) and may be more representative than other EMC test methods in this respect. An advantage of reverberation chambers is the ability to generate a statistically, isotropic, homogeneous, unpolarized and uncorrelated interior field, through the action of the tuner/stirrer."[4]

For this reason, Micro-Coax has installed and operates a mode-stir test facility at its factory in Pottstown, Pa. This facility enables real time characterization of shielding effectiveness on microwave cable assemblies from 1 to 18 GHz.

The broad frequency range for this testing dictates the physical size of the chamber since a particular number of 'modes' must be present at all frequency points within the chamber

▲ *Fig. 1 Internal view of reverberation chamber.*

to have a statistically uniform RF field within the test volume. As such, a physically larger chamber than might otherwise be expected is required to accommodate lower frequency measurements. A mode stirrer (or tuner) in the chamber then ensures that the internal EM field boundaries of the chamber are constantly changing in order to prevent standing waves. During the measurement cycle, the mode stirrer rotates at a slow uniform rate. The dimensions of the mode stirrer must provide changing boundary conditions across the chamber's useable frequency range.

An internal view of a typical reverberation chamber showing the mode stirrer (bent structure at top of picture), transmit antenna (red double-ridged horn antenna) and cable assembly under test on the EM field transparent table is shown in ***Figure 1***. The chamber's internal dimensions are 4.83 × 3.61 × 3.05 m with a lower useable frequency of 200 MHz.[6] Ancillary equipment used to generate the RF field within the chamber can restrict the useable frequency range from 1 to 18 GHz.

SETUP

During initial chamber calibration, it is important to determine the location of the 'working volume' within the chamber. This is where the E-field of the RF signal is uniform within 3 dB regardless of the direction from which the RF field enters the working volume. This is verified by a series of measurements using directional E-field probes at each corner as well as the center of the working volume (9 locations in all). At each of these locations, individual measurements are made with the directional E-field probes oriented in the 'X', 'Y' and 'Z' directions. This assures that any device under test placed within the working volume is uniformly illuminated by the RF field from every direction. Once uniformity of the E-field is verified, technicians lock down the position of the transmit antenna within the chamber so that the generated fields within the working volume are always uniform.

Using this equipment (see the Associated Equipment Requirements section of this article), typical average E-field values present in the chamber during testing are between 75 and 100 volts/meter in the 1 to 4 GHz frequency range. The average E-field from 4 to 18 GHz falls off linearly from roughly 90 volts/meter at 4 GHz to about 58 volts/meter at 18 GHz. This follows the expected chamber loss documented by the manufacturer and is thus deemed typical for a chamber of that size.

CALIBRATION AND VERIFICATION

The periodic calibration performed consists of two major steps. The first is to make a measurement of the strength of the RF field within the chamber. This is done by using a receive antenna as the DUT. The receive antenna is the same make and model as the transmit antenna so it exhibits the same gain characteristics. The receive antenna is placed at several random positions within the working volume and at various orientations to provide unbiased measurements. Averaged together, these measurements create the overall chamber 'baseline'.

The second step is known as the 'leakage' measurement. Here the DUT is a well-shielded load. The purpose of the leakage measurement is to determine the minimum signal which can be detected within the chamber. The transmit antenna delivers the same power level to the chamber as during the baseline measurement and the resultant detected signal level shows any flaws in the interconnect cabling present in the chamber as part of the test setup.

The dynamic range of the chamber is the difference between the 'baseline' and 'leakage' values. One can think of this dynamic range as being the chamber's 'noise floor'. The dy-

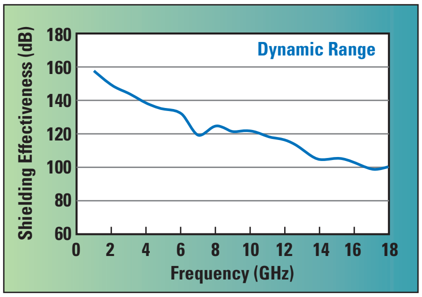

Fig. 2 Dynamic range of reverberation chamber.

namic range is typically greatest at the lower frequencies and decreases as the RF frequency increases. Micro-Coax normally achieves no less than 100 dB dynamic range across the entire 1 to 18 GHz frequency range. When a cable specification calls for 90 dB of RF shielding, the 100 dB dynamic range allows a 10 dB margin in the measurement range. This is a typical margin recommended by various industry specifications. A plot of the chamber's dynamic range is shown in ***Figure 2***.

To verify the periodic calibration, two gold standards are employed. One is a cable assembly fabricated from 0.141" diameter semi-rigid cable. This cable has a solid copper outer conductor and uses well-shielded fully soldered SMA connectors. This standard is used to represent a fully shielded cable assembly. From a practical perspective, nothing is fully shielded, but when RF shielding measurements are performed on this device, the resulting measurements are expected to track the dynamic range curve shown in ***Figure 3***. Note that it has been questioned on occasion as to why this standard gives results that are sometimes better than the dynamic curve. The dynamic range is also close to the noise floor of the measurement equipment and the randomness of noise within the equipment can often give these types of readings. This is one reason why the dynamic range of the chamber must be at least 10 dB better than the expected RF shielding measurement.

The second gold standard is known as a 'leak standard'[7] designed to provide a known amount of RF shielding. The leak standard is patterned after that described in IEC-61726, Annex C and is similar in construction to the fully shielded standard but with a single 0.1" diameter hole drilled in its outer conductor at approximately the midpoint of the assembly. The equations in this IEC specification and the actual RF shielding measurements made with a 'leak standard' have been validated to correlate nearly identically to the results shown in Figure 3.

Use of both the well shielded cable assembly and the leak standard cable assembly provides a high degree of confidence in the accuracy of shielding measurements made on cable assemblies, since these assemblies normally fall between the RF shielding values of the two gold standards.

The actual value for RF shielding of a cable assembly is then the difference between the measured RF signal of the cable assembly when placed in the working volume of the chamber and the 'baseline' value obtained during the periodic calibration.

Note that verification of the measurement of the leak standard as well as sample cable assemblies has been performed in similar (but not identical) reverberation chambers at test laboratories in the United States as well as

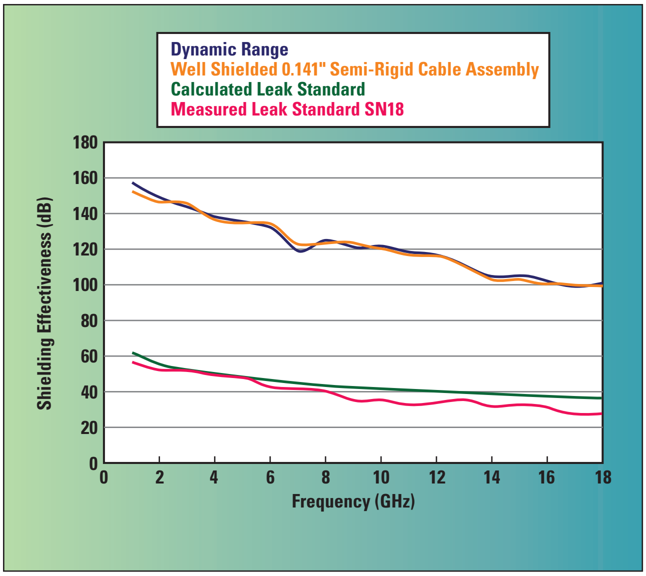

Fig. 3 Gold standards measurements.

in Europe. The close correlation of these independent measurements indicate that the mode-stirred reverberation chamber method of performing shielding effectiveness provides consistent and valid data.

ASSOCIATED EQUIPMENT REQUIREMENTS

The entire RF shielding test is controlled by a proprietary software program developed specifically for this purpose. The signal fed into the chamber is produced by a microwave signal generator driving a switchable power amplifier. The output of the amplifier feeds a securely mounted double ridged horn antenna. RF energy coupled into the DUT is then fed out of the chamber to a spectrum analyzer and converted by the software program into tabular and graphical reports. The internal reference oscillators of the signal generator and the spectrum analyzer are frequency locked.

The spectrum analyzer is set to zero span mode with a very narrow bandwidth. In this configuration, it is essentially a single frequency receiver locked to the same frequency as the signal generator, and displays the signal strength as a function of time. The mode stirrer in the chamber is set to a rotational speed such that in a single sweep on the spectrum analyzer (7 seconds), it will rotate approximately $1\frac{1}{2}$ times. The signal detected by the spectrum analyzer has peaks and valleys and the software program commands the spectrum analyzer to place and read a marker at the peak of the response for each measured frequency.

EXTENDED CAPABILITY

A physically smaller mode-stirred chamber is used to perform shielding measurements from 18 to 40 GHz. This chamber measures 0.4 × 0.5 × 1.1 m. Pre-measurement calibrations are the same as described for the larger 1 to 18 GHz chamber. Dynamic range is at least 100 dB across the entire 18 to 40 GHz frequency range. Chamber performance is verified by using both the well shielded 0.141" diameter semi-rigid cable assembly as well as the known leak standard.

PRACTICAL MEASUREMENTS

In order to obtain accurate and meaningful shielding effectiveness measurements of a cable assembly, certain practices must be observed. The first is to ensure that the cable assembly is positioned correctly within the working volume of the chamber. No part of the assembly should be allowed outside the working volume as the EM field values have not been measured and verified during chamber calibration and will not fall within the established statistically uniform EM field limits.

Next, it is critical that the connectors on the cable assembly under test be properly mated to the interconnect leads within the chamber. For threaded type connectors, this involves making sure that the proper torque specifications are observed. For push-on and blind-mate connectors, it is necessary that the correct force be used to hold the mating connectors together. If adapters are required, they may be sources of unintended signal leakage and must be validated. Wrapping connections and/or adapter bodies with some form of shielding material may also be required to reduce or eliminate leakage. Typical materials for shielding include bronze and copper wool and copper tape. It is important that any additional shielding material be properly grounded to the cable assembly, otherwise it may become an additional receptor of the EM field surrounding the cable under test and allow extraneous EM energy to be coupled to the inside of the cable assembly.

If the shielding effectiveness measurements appear to be uncharacteristically poor, and all connectors are properly torqued and shielded, any solder joints between the connectors and cable may be suspect. A cable assembly which measures electrically good in terms of insertion loss and VSWR as measured on a network analyzer may still have small voids in the connector to cable solder joint which can allow EM fields at certain frequencies to pass through with little or no attenuation.

Once connectors and solder joints have been validated, the next source of leakage may be the cable itself. A poorly constructed coaxial cable with minimal braid coverage cannot be expected to yield high values of shielding effectiveness. A damaged cable may also leak.

Troubleshooting these types of failures is normally accomplished by trial and error. One approach is to shield various sections of the assembly until the leak is found. Another is to employ methods such as real time X-ray. At the measurement stage, there is little that can be done to correct the effects of using a damaged cable and typically requires replacement. If replacement is impossible, additional shielding may be added over the entire cable in the form of an external braid or sock. This will add weight and cost to the cable assembly, and unless the additional braid is grounded properly to the rest of the cable assembly, could actually cause the shielding effectiveness to deteriorate.

CONCLUSION

RF shielding measurements have been found to be an effective tool in helping to determine the quality and more importantly, the long term reliability of microwave cable assemblies. The mode-stirred method is invaluable in establishing the shielding effectiveness of an entire cable assembly and can be performed in accordance with IEC International Standard 61000-4-21. ■

References

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2. Military Specifications, MIL-PRF-39012, MIL-C-85485.
3. Industry and International Standards, EIA-364-66A, IEC 60096-1.
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6. ETS-Lindgren SMART™ 200 Chamber, www.ets-lindgren.com/SMART200.
7. IEC International Standard 61726:2001 Annex C, "Example of a Calibrator."

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Mechanical Characteristic	Diameter 0.195" Min. bend radius only 1"	Diameter 0.235" Min. bend radius only 1.2"	Diameter 0.3" Min. bend radius only 1.5"
Cable Insertion Loss (typ.)	0.36 dB per Ft @ 18 GHz	0.31 dB per Ft @ 18 GHz	0.219 dB per Ft @ 18 GHz
Excellent Phase Stability vs. Flexure	± 3.6° @ 18 GHz (When wrapped 360° around a 1.95" radius mandrel)	± 3.6° @ 18 GHz (When wrapped 360° around a 2.35" radius mandrel)	± 5.4° @ 18 GHz (When wrapped 360° around a 3.0" radius mandrel)
Amplitude Stability vs. Flexure	⩽ ± 0.2 dB @ 18 GHz		
Good Phase Stability Over Temperature	250 ppm max. @ + 22 ~ + 100°C		
Operating Temperature for Cable Assembly	- 50 ~ + 125°C		
Common Features	Ultra low loss, higher power handling capacity and lighter weight compared with other similar size cables		
Application	Commercial Systems, Test&Measurement, Military, Aerospace,		

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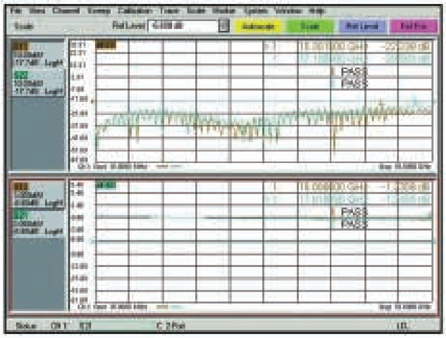
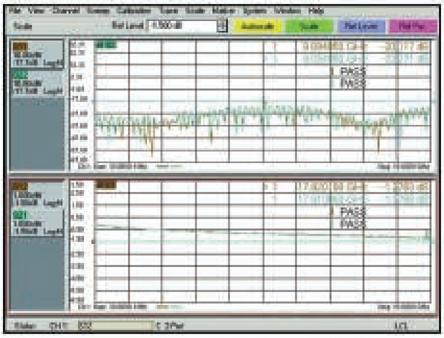
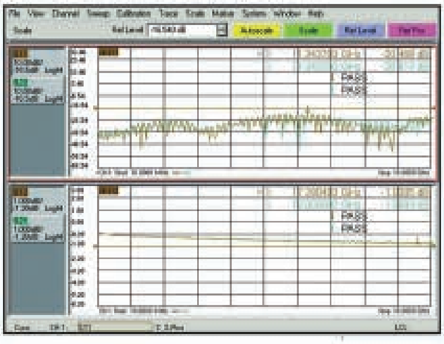
Insertion Loss and Return Loss for LL142, SMA M-SMA M, 18GHz (Typ.)



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



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



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INVITED PAPER

RF Stability of Cable Assemblies – More Than Meeting IEC or MIL Standards

Fred Hull
San-tron Inc., Ipswich, Mass.

When discussing RF coaxial cable assemblies, we frequently hear "What is the RF stability of the assembly?" The trouble is, depending on the application, a variety of answers may apply. With this article, we intend to illustrate the value of employing a conservative methodology that closely aligns with published International Electrotechnical Commission (IEC) documents and is tailored to environmental conditions to arrive at test procedures that will absolutely ensure performance in the field. By comparing and contrasting our own San-tron test procedures with those published by the IEC, we hope to demonstrate how a different perspective and approach nets optimal results in the field. We note, however, that the evolution of test protocols that originated within the U.S. military procurement agencies (MIL-STD) and were adopted and updated by the IEC may still develop into more improved practices.

In the process of implementing test procedures, it is essential to first identify the true intent of the testing. One may be to characterize the limiting performance characteristics of the assembly. As a result, the test protocol will require manipulation of the cable to its actual limiting parameters, as opposed to those outlined by the "standard." For example, these would include dynamic minimum bend radius, maximum torque and the operational thermal limits of the components. Another intent may be to characterize the cable performance within the scope of an operational deployment, such as avionics, outdoor cellular communications or test and measurement. In so doing, it becomes easier to compare alternative solutions and how they will support the intended application.

In this article, we will demonstrate the characterization of test port cables used for vector network analyzer (VNA) and passive intermodulation (PIM) testing. The typical test port cable will range in length from 40 inches (1 m) to 13 feet (4 m). Access to the device under test (DUT) varies: it can be located on a test bench, within an environmental chamber, a rack-mounted subsystem, tower mounted system or an aircraft installation. In all of these applications, a test cable will be subjected to repeated bending and twisting. Therefore, we generalize that the cable deployment can be characterized by three basic activities: folding and twisting the cable about a mandrel and low frequency vibration. Regardless of the cable size, it will be subjected to these realistic stresses and strains.

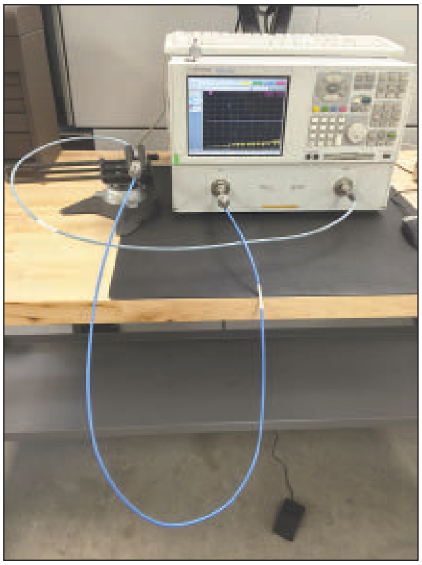


Fig. 1 *The baseline performance data for the cable being tested (blue outer sheath) is taken with the cable in a U shape.*

TABLE 1					
WORST-CASE TEST RESULTS					
Cable Test	**Freq (GHz)**	**$\lvert S_{21} \rvert$ (dB)**	**dB/GHz**	**S_{21} Phase (deg)**	**deg/GHz**
Baseline	10	-0.024	-0.0024	-0.30	-0.03
Clockwise	10	-0.010	-0.0010	-1.61	-0.16
Unfold	10	-0.027	-0.0027	0.81	0.08
Counter-Clockwise	10	-0.003	-0.0003	-0.90	-0.09
Unfold	10	-0.042	-0.0042	2.64	0.26
Positive Twist	10	-0.004	-0.0004	5.42	0.54
Untwist	10	-0.048	-0.0048	7.09	0.71
Negative Twist	10	-0.004	-0.0004	4.54	0.45
Untwist	10	-0.049	-0.0049	7.40	0.74
Maximum		0.00	-0.0003	7.40	0.74
Minimum		-0.05	-0.0049	-1.61	-0.16
Range		0.05	0.0049	9.01	0.90

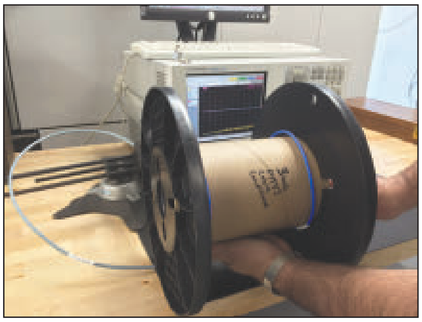


Fig. 2 *Test setup for the cable folding test.*

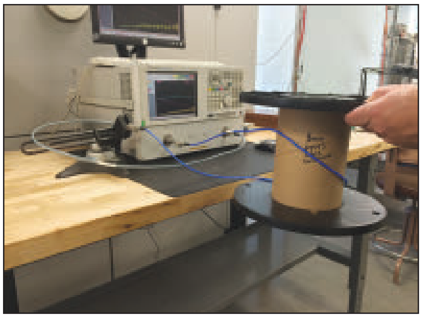


Fig. 3 *Test setup for the cable twist test.*

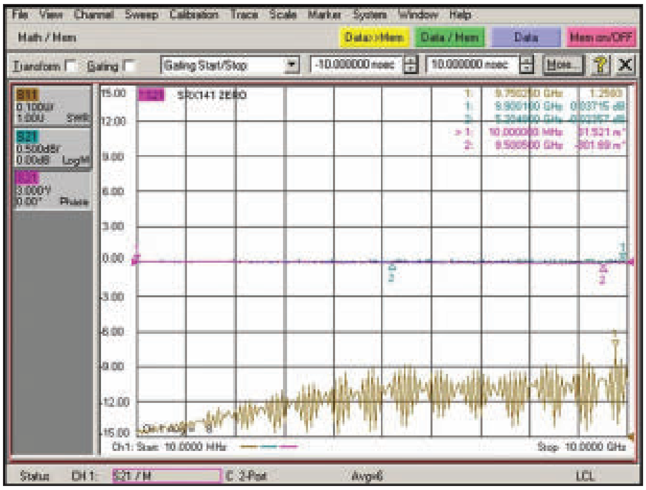


Fig. 4 *Baseline performance of the test cable.*

ASSESSING PHASE STABILITY

To illustrate stability characterization, we use a SRX141™ coaxial cable with eSeries™ connector terminations, the most widely used product from San-tron's SRX™ series of assembly solutions for both system integration and test and measurement.

The original prototype for this cable was a fluorinated ethylene propylene (FEP) jacketed cable with silver (Ag) clad copper (Cu) wire braid, Ag clad Cu foil helix, polytetrafluoroethylene (PTFE) dielectric, and Ag clad solid Cu center conductor. Using the cable fold test outlined in the standard for STI 8.2.4-14 A1, the prototype functioned very well. During the cable twist test (STI 8.2.4-14 B1), however, measurements showed instabilities in both insertion loss and PIM performance. Applying the vibration test of STI 8.2.4-14 C2, we saw catastrophic degradation of the cable's performance over time. The root cause was the physical makeup of the cable loosening under the weave of the braid, generating PIM signals and varying insertion loss. The failure mode prompted a design review and process upgrade, and we ultimately developed a cable structure that maintains its performance through harsh environments and test protocols.

For this demonstration, the test cable was an SRX141 cable assembly, rated for PIM applications, that was 60 inches long and terminated with straight eSeries Type N male connectors. The VNA was setup with one test port cable and a full two-port calibration from 10 MHz to 10 GHz using a Type N calibration kit. After calibration, the test port cable was secured with a 10 lb table vise to prevent the test setup from introducing variation. The test cable was then mated to the VNA and laid out in a U shape, as shown in ***Figure 1***. The test cable was first subjected to five cycles of the cable fold test (see ***Figure 2***) and then five cycles of the cable twist test (see ***Figure 3***). The worst-case results are summarized in ***Table 1***.

The initial phase baseline measurement, shown in ***Figure 4***, established the "zero" line between -0.30 and +0.03 degrees. Folding the sample

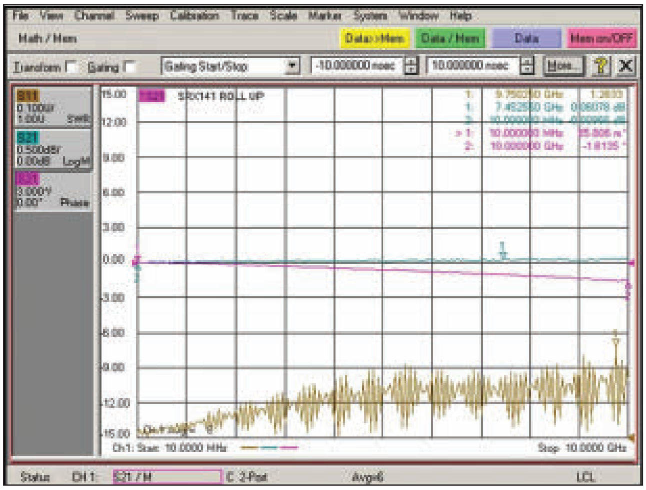


Fig. 5 The S_{21} phase change after the test cable is folded clockwise.

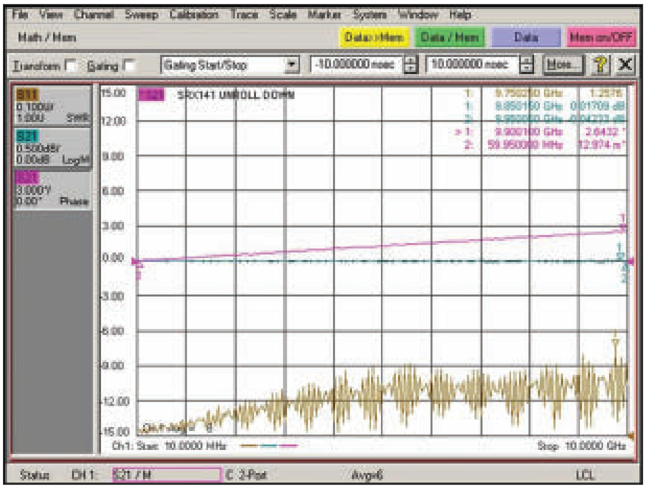


Fig. 6 The S_{21} phase after the test cable is unfolded. Note that the phase response does not return to the baseline.

cable assembly for five repeated cycles in both directions about the 5 inch diameter mandrel resulted in phase shifts with the extreme readings shown in Table 1. The electrical length increased to -0.16 degrees/GHz with clockwise folding (see ***Figure 5***). Unfolding the sample decreased the electrical length to +0.08 degrees/GHz, which is a 0.11 degrees/GHz offset from the baseline measurement. Next, counter-clockwise folding of the sample expanded the electrical length to -0.09 degrees/GHz. Unfolding the sample resulted in +0.26 degrees/GHz (see ***Figure 6***), a 0.29 degrees/GHz offset from the initial condition. The measurements show an asymmetrical variation in phase shift from randomly folding the sample, between -0.16 and +0.26 degrees/GHz. From this data, we can consider the phase stability with folding to be 0.42 degrees/GHz.

Traditionally, the cable twist test causes greater degradation and is, therefore, performed after the cable fold test. Applying a positive 180 degree physical twist to the test sample yielded a decrease in electrical length to +0.54 degrees/GHz. Relaxing the twist back to the neutral position shifted the phase to +0.71 degrees/GHz. Then applying a negative 180 degree physical twist expanded the electrical length to +0.45 degrees/GHz. Finally, relaxing the twist

TABLE 2

SAN-TRON (STI) TEST METHODS

STI 8.2.4-14 Setup 1: Network Analyzer Setup

1. Port 1 is the primary test port and will be selected for the least performing component.
2. Port 2 will be terminated through a high performance test cable.
3. Select upper frequency.
4. Set number of test points to a minimum of 25 × frequency range in GHz.
5. Set Transform to “Low Pass Step” with window set to minimum rise time.
6. Set Averaging = 6.
7. Perform a full two-port calibration based upon test port 1.
8. Display test parameters such as VSWR, S_{21} log magnitude and S_{21} phase.
9. After calibration, the test port cable may be secured with a 10 lb table vise to help prevent test data variation.

STI 8.2.4-14 Test-A1: Cable Fold Test, Insertion Loss, Phase and PIM Stability

The subject cable assembly is formed into a U-shaped loop with a 6" radius. The static test parameter is recorded in this neutral position. The test parameter is then recorded at each step of this test protocol as follows:

1. Wrap the loop 360 degrees about a 5" diameter mandrel.
2. Unwrap the loop to the neutral position.
3. Wrap the loop a negative 360 degrees about the 5" mandrel.
4. Unwrap the cable to the neutral position.
5. Repeat five times.

System stability is asymmetrical and is published as a range/GHz. Note: The 6" loop and 5" mandrel may be adjusted for larger sized cables or specific deployment scenarios.

STI 8.2.4-14 Test-B1: Cable Twist Test, Insertion Loss, Phase and PIM Stability

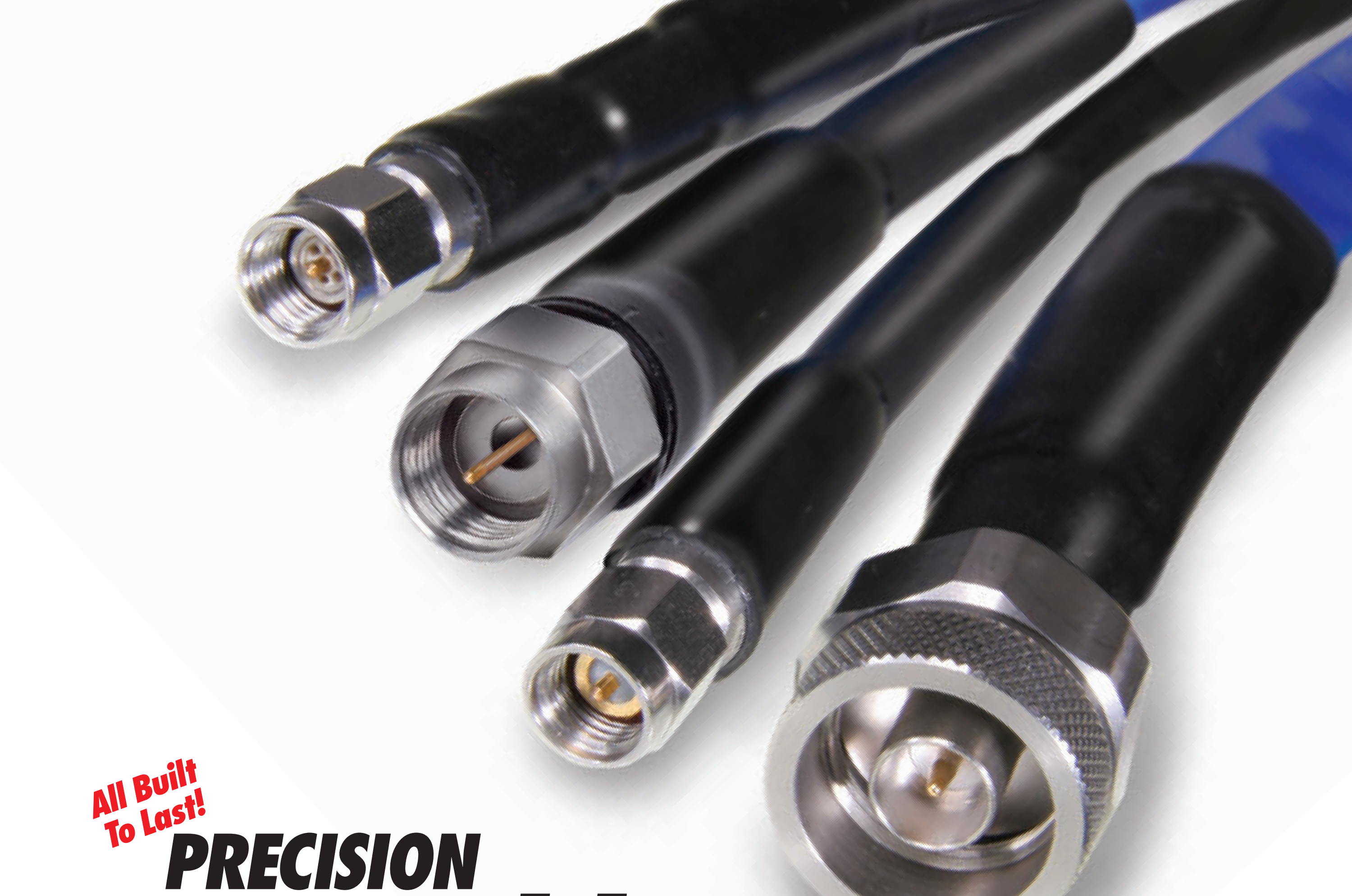
The subject cable assembly is formed into a U-shaped loop using the 5" mandrel as the base of the U-shape. The static test parameter is recorded in this neutral position. The test parameter is then recorded at each step of this test protocol as follows:

1. Rotate the loop mandrel 180 degrees about its symmetrical axis.
2. Rotate the loop mandrel back to its neutral position.
3. Rotate the loop mandrel a negative 180 degrees.
4. Rotate the loop mandrel back to its neutral position.
5. Repeat five times.

System stability is asymmetrical and is published as a range/GHz.

STI 8.2.4-14 Test C2: Cable Vibration Test, Insertion Loss and PIM Stability

1. The subject cable assembly is relatively straight. The static test parameter is recorded in this neutral position.
2. Vibration: 0.2" double amplitude, 17 Hz, 3 minutes.
3. System stability is reported as the initial, dynamic worst case and post-test parameter values.



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Model Family	Freq. (GHz)	Connectors (male)	Lengths† (ft)	Temp (°C)
NEW Extra Flexible (FLC)	DC-26	SMA	1.5-6	-55/+85
Precession Test (CBL)	DC-18	SMA‡, N	1.6-50	-55/+105
Precession Test 75Ω (CBL)	DC-3	N, F	2-6	-55/+105
Armored (APC)	DC-18	N	6.0-15	-55/+105
Low Loss (KBL-LOW)	DC-40	2.92	1.5-6.6	-55/+85
Phase Stable (KBL-PHS)	DC-40	2.92	1.5-6.6	-55/+85

All models 50Ω except as noted.

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

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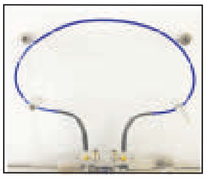

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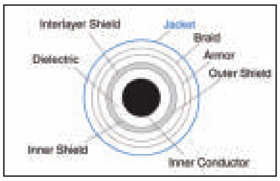

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TABLE 3
CURRENT RF STANDARDS PER IEC PUBLICATIONS
IEC-60966-1 Radio Frequency and Coaxial Cable Assemblies, General Specification
1. Insertion Loss Stability, paragraph 8.4
2. Stability of Electrical Length, paragraph 8.6
• Bending
• Twisting
3. Phase Variation with Temperature, paragraph 8.8
IEC-62037-2 Measurement of Passive Intermodulation in Coaxial Cables
1. Dynamic axial offset of 1 cable diameter +10 mm, 3 revolutions about the central axis, 5 seconds/ revolution
IEC-62037-4 Measurement of Passive Intermodulation in Coaxial Cable Assemblies
1. Clamped Cable Loop, paragraph 5.2, dynamic displacement ±20 mm, 3 cycles/orthogonal plane, 5 seconds/cycle
2. Flexing Tool, paragraph 5.3

TABLE 4
EARLY METHODOLOGIES PER MIL-STANDARDS
MIL-STD-202, Vibration, High Frequency per Method 204, Condition B
MIL-PRF-39012, 15g, 10 to 2000 Hz, 20 minute exposure, 12 times/3 orthogonal planes
MIL-T-81490A(AS) Transmission Lines: Transverse Electromagnetic Mode
• Insertion Loss and VSWR Stability
• Vibration
• Flexure
• Torque
• Tensile Load

back to the neutral position decreased the electrical length to +0.74 degrees/GHz.

Notice that when the cables are relaxed, the phase shift does not revert back to zero; we see a range between +0.08 (for the fold test) and +0.74 (for the twist test) degrees/GHz. The fold and twist tests exhibited phase shifts of -0.16 to +0.26 and +0.45 to +0.74 degrees/GHz, respectively. Combining these variations, from -0.16 to +0.74, specifies a phase stability range of 0.90 degrees/GHz.

Multiple mechanisms generate instability. Twisting a cable causes different changes than simply folding the cable. We also see that the effect of twisting decreases the electrical length, where folding can both elongate and constrict phase length. By modeling the intended application and applying tests in a progressive protocol, we can develop a test flow and parameter, such as degrees/GHz, to estimate the measurement uncertainty and cable variation and how the product will perform in the field.

COMPARING CABLE ASSEMBLY TEST METHODS

The above example showed that no single test can identify all latent failure modes. With the initial cable design described previously, the prototype passed the fold test, yet the twist test surfaced an anomaly. The vibration test confirmed that the assembly possessed a latent defect that would manifest failures in the field. By defining a test protocol to evaluate and qualify the design and assembly processes, the SRX™ product line was deployed with performance characteristics never before realized in fully flexible cable assemblies.

The San-tron test methods are summarized in ***Table 2***. These tests require multiple cycles of physical stress, at least five times to determine if the measured parameters vary over the repeated cycles. If variation is observed, personnel can decide if additional testing is warranted. San-tron has found these tests to be extremely cost effective. Other than the VNA, they require a minimum investment in test fixtures, apparatus and training. They are easily duplicated and can be implemented in the field for on-site testing and validation.

For comparison with the San-tron test methods, ***Table 3*** summarizes the IEC publications. These test methods are also economical and require a minimum of tooling. They are an excellent source for training engineers and test technicians, especially the General Specifications of IEC-60966-1. It offers an overview of RF cable assemblies and performance parameters. However the IEC methodology only requires a single test cycle for the stability validations (paragraphs 8.4 and 8.6) and could be improved by requiring multiple cycles of the physical stresses. More development in the processes of IEC-62037-2 and IEC-62037-4 is warranted.

The U.S. military standards (see ***Table 4***) were the genesis of the IEC and San-tron test methods. However, many of the tests are ineffective in identifying potential failure modes, and the required Qualified Products List (QPL) methodology is expensive. It requires significant investments in personnel, test samples, test equipment and the supporting fixtures. Nevertheless, the MIL-STDs define the most comprehensive characterization and are justified for military deployments where lives are at risk.

CONCLUSION

Adequately testing and qualifying a cable assembly design and assuring product quality in manufacturing requires a test methodology that is tailored to the application and will identify potential failure modes before they can occur in the field. The methodology must subject the cable assembly to multiple cycles of physical stress, including folding, twisting and low frequency vibration. The tests and flow developed by San-tron have proven to achieve these goals – it is cost effective and can be performed in the field. ■


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INVITED PAPER

Coax Connector Design Above 110 GHz

Anritsu Co.
Morgan Hill, Calif.

Historically, coaxial connectors have had two methods for center conductor mating, the hermaphroditic contact and the male pin/slotted female contact. The non-sexed connectors have many advantages, the main being that only one connector type is required. As frequencies got higher, connectors became smaller in order to remain single mode. The success of the SMA connector foretold the end of the non-sexed connectors. Mechanically it is difficult to make butt type connectors. The pin depth tolerances are very critical and the small size makes it difficult to make a resilient contact. These factors raise the cost of the connectors well above the simple male pin/slotted female contact.

As connectors became smaller and reached higher frequencies, the male/female contact design became the standard. A slotless female design was introduced for metrology applications, but this became impractical above the 50 GHz, 2.4 mm connector. A four-slotted contact is much more resilient. The 3.5 mm connector, designed to mate with SMA, incorporates a four-slot female contact and an air interface. This results in a higher precision design, but with a problem. Since they have to be compatible with the SMA connector, the size of the male pin was set at 0.914 mm (0.036"). The center conductor size of the 3.5 mm connector is 1.52 mm (0.060"). Therefore, the wall thickness of the female fingers is 0.3 mm (0.012"); this is quite thick for such a small diameter. After slotting, the fingers are closed and the part is heat treated. If they are closed too little, the contact will be unreliable. If they are closed too far, the insertion force required to mate the connectors will become quite high. This introduces excess wear and may even distort the support beads holding the center conductors in place. The large wall thickness also introduced more pin gap reflection. The impedance of the gap section is 80 ohms.

The 40 GHz, 2.92 mm K connector, introduced in 1985, addressed many of these problems. A short male pin ensures that the outer conductor parts align the two connectors before the center conductors engage, so the male pin will not damage the female by being inserted at an angle. The center conductor diameter of the K connector is 1.27 mm (0.050") leading to a finger wall thickness of 0.18 mm (0.007"). This means that the fingers are more flexible and the insertion pressure is greatly reduced. As a result, K connectors are rated for 4000 connections.

The 50 GHz, 2.4 mm and the 65 GHz, 1.85 mm connector interfaces were introduced by HP/Agilent (now Keysight). The 2.4 mm connector was required with introduction of their 50 GHz VNA. With improvements of V connector bead design, the VNA frequency moved up to 65, then 67, and now 70 GHz.

The 110 GHz, 1 mm connector was introduced by Agilent (now Keysight). Anritsu introduced the 110 GHz W connector with the introduction of their 110 GHz broadband VNA. Anritsu has also introduced a 0.8 mm connector as part of the 70 kHz to 145 GHz VNA and is working on even higher frequency connectors.

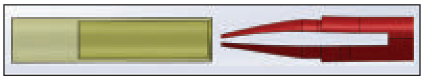

Fig. 1 "Lobster claw" high frequency connector design.

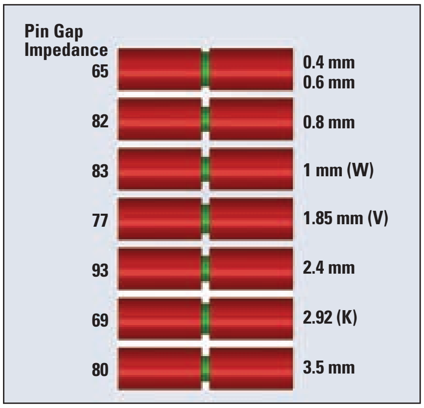

Fig. 2 Pin gap impedance values.

TABLE 1

MECHANICAL AND ELECTRICAL PROPERTIES OF VARIOUS CONNECTORS (# and* SHOWS COMPATIBLE CONNECTORS ** SHOWS DESIGNS UNDER DEVELOPMENT)

Connector	Air Frequency Cutoff F_{co} (GHz)	Max Rated Frequency (GHz)	Pin Gap Impedance	Size of Center Conductor (mm)	Size of Bead (mm)
TYPE N	19.4	18		3.04	
SMA #	N/A	18	N/A	1.27	N/A
3.5 mm #	38.8	33	80	1.52	3.6
2.92 mm K #	46	40	69	1.27	3.05
2.4 mm*	56	50	93	1.042	2.1
1.85 mm V*	73	70	77	0.803	1.5
1 mm W	133	110	83	0.434	1.15
0.8 mm	166	150	82	0.347	0.559
0.6 mm	TBD**	TBD**	65	0.26	0.406
0.4 mm	TBD**	TBD**	63	0.174	0.28

THE SLOT PROBLEM

If the dimensions are reduced by 50 percent for a higher frequency connector, the slotted female contact would be very fragile. If a thin walled design was used, the insertion force would be very slight, but so would the contact pressure. If a thick walled design was used, the contact pressure would be greater but the finger flexibility would be minimal. So a slotted female contact seems out of the question. An out of the box comment supplied the answer. "Don't slot the female, slot the male pin. What would that look like?"

We can make the female wall very thin so there are no slots. Therefore the male pin could be large, closer to the main center conductor size, as shown in ***Figure 1***. This pin could be made with a 0.05 mm slot. Also since the slotted portion is contained inside the un-slotted hole, it would be quite robust with no tendency to spread out like the standard slotted female contact. The impedance of the pin gap is 65 ohms, much less than lower frequency designs. This makes the connector less sensitive to pin depth reflections (see ***Figure 2***). ***Table 1*** provides information on existing connectors and those in design. The current plan is to use the new slotted male design (called the "lobster claw") in the sub-0.8 mm connector designs. Notice that the center conductor of these connectors quickly approach 1/20th the size of the N connector center conductor.

CONNECTOR SIZES AND IDENTIFICATION

Traditionally, connectors moving up in frequency get smaller. Anritsu decided to keep the coupling nuts of new connectors the same size as the 1 mm connector. Smaller than that makes the connectors difficult to work with. Also, the threads are different. The 1 mm connector has a course thread and the higher frequency connectors have a fine thread. It is critical that all of the sub-1 mm connectors cannot be connected in a destructive manner.

The connectors are identified by a laser engraved number that shows the connector size. The number is also etched on the coupling nuts. The 1 mm male coupling nut is plain, the 0.8 mm coupling nut has a single groove and smaller connectors have sequentially additional grooves.

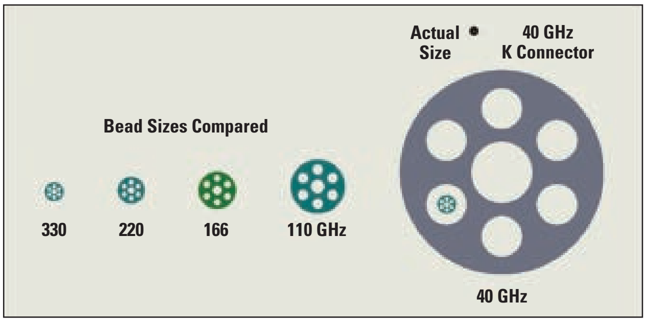

Fig. 3 A comparison of sizes of the beads since the K connector.

SUPPORT BEADS

The connectors above the 1 mm connector have a maximum rated frequency that is the same as the F_{co}, the air dielectric cutoff frequency. The lower frequency connectors have support beads that are larger than the air outer conductor size. This means that they have an F_{co} that is substantially lower than the air F_{co}. The cutoff frequency is inversely proportional to the square root of the dielectric constant of the material between the center conductor and the outer conductor. The new designs have support beads that are substantially smaller than the size of the air outer conductor. They are designed to have an F_{co} that is the same frequency as the air F_{co}. They are also much smaller, as shown in ***Figure 3***.

A major problem with making the bead size smaller than the air dielectric outer conductor size is how to captivate the bead. The old designs, where the bead is larger than the air outer conductor, allowed a mechanical capture in both directions. The solution was a sleeve that contained the bead and had an outer diameter about the same size as the air outer conductor. The sleeves have very thin lips on both ends and are swaged to hold the bead in place (see ***Figure 4***). The as-

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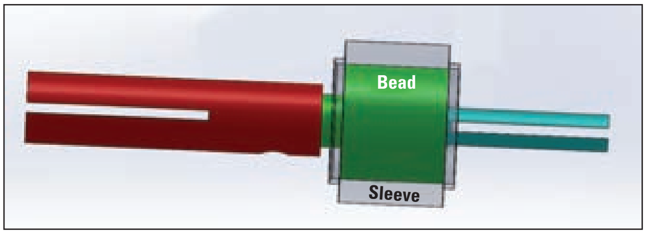

Fig. 4 Swaged bead sleeve drawing.

sembly can then be soldered in place, due to the use of high temperature plastics.

ASSEMBLY DETAILS

Figure 5 shows a 0.8 mm connector and does not have the lobster claw design. The backside of the connector is a Coplanar Waveguide (CPW) design similar to a wafer probe. The center conductor is common, but the outer conductor end cap can be configured to accommodate different CPW designs. Figure 5 also shows how the bead sleeve is soldered into the outer conductor.

A feature of the design is the ability to adjust the position of the back side CPW interface. Correct positioning of the connector to the substrate is critical to performance. Holes are centered at the edges of the flange. A tapered pin allows the flange to be moved up and down as well as left and right. When the connector is properly connected to the CPW substrate, the flange screws are tightened.

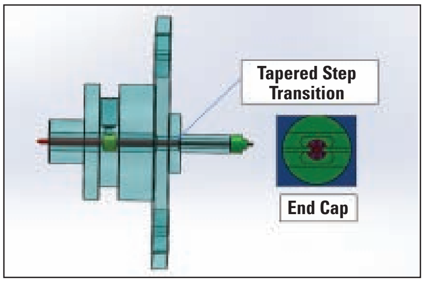

Fig. 5 0.8 mm connector design.

These types of connections are mostly used to connect high frequency VNA modules to a wafer probe that in turn will be used to measure CPW substrates over a very large bandwidth. VNA technology is now available from 70 kHz to 145 GHz using 0.8 mm connectors. Waveguide modules extend that coverage to 1.1 THz. These "lobster-claw" connectors are intended to extend the broadband coverage from 70 KHz to 332 GHz.

CONCLUSION

What will be the last connector in a long string of higher and higher frequency connectors?

In 1983, a 40 GHz coax connector was considered unlikely. Today we are designing a connector that reaches almost 10 times higher in frequency. Circuit designers seem to be able to create devices that operate at ever-higher frequencies, and some kind of connection is always needed to make these devices useful. Let's not limit our imagination. ■

Spring-Mounted Measurement Adapter Saves Costs

SPINNER GmbH
Munich, Germany

The mobile industry is under cost pressure. What can be done to reduce product cost beyond R&D and product design? Manufacturers have not fully tapped into savings from RF fine-tuning during product assembly or test and measurement during product qualification.

When tested, RF products are usually mated manually. Traditional push-pull adapters cannot be used for automated testing, as they are not self-centering and require manual feeding. SPINNER's EasyDock can significantly reduce costs by automating RF measurement and quality tests, testing faster without sacrificing quality or measurement precision.

For conventional push-pull mechanisms, the measurement adapters are manually fed to the test device. This is unsuitable for automated movement processes, since the positioning of the test device to the adapter is not guaranteed to be 100 percent aligned. A certain amount of tolerance cannot be avoided, which the measurement adapter has to reliably compensate for.

These requirements are met entirely by the EasyDock, a spring-mounted measurement adapter that guarantees perfect contact and reliable operation, even when the axes of the test device and the adapter are not perfectly aligned. Also, the precision of the measurement process is not affected by mechanical tolerances.

PRECISION MATING

The EasyDock tolerates deviations in all planes and directions. The conical intake ensures that the adapter and the test device slide together reliably, even if they are not centered and aligned. Moreover, they do not have to meet each other at a right angle, since the adapter compensates for tilt, and the spring-loaded mounting evens out variances in distance. These mechanical compensations are crucial for automated testing, as they protect the devices and measurement interfaces.

When testing, the EasyDock first centers itself within the test device. Then the devices are tightened together for mating. Over the entire mating process, the EasyDock ensures a constant contact pressure of 80 N, which maintains a correct and reproducible electrical contact for the measurement and ensures consistent data.

The ability to compensate for misalignment enables the EasyDock to test RF products with

Fig. 1 The EasyDock portfolio includes 7-16, 4.3-10, 4.1-9.5 and N measurement interfaces.

more than one interface. Devices such as couplers, diplexers, base stations and antennas can be tested within one stroke, provided multiple EasyDock adapters are installed on a dedicated measurement frame.

The EasyDock is available for all common mobile industry interfaces. The portfolio (see ***Figure 1***) includes 7-16, 4.3-10, 4.1-9.5 and N interfaces and hosts 7-16, 4.3-10, N and 3.5 mm interfaces on the rear, contacting the measurement cable or device. The adapter can be mounted on a front panel or housing, either as a bulkhead or four-hole flange.

PIM MEASUREMENT

Since passive intermodulation (PIM) is one of the most crucial aspects for the mobile communication industry, SPINNER has designed the EasyDock 7-16 and 4.3-10 measurement interfaces for PIM measurements. While a contact pressure of 80 N is sufficient for PIM measurements on a 4.3-10 interface, it is not sufficient for a typical 7-16 interface. To address this, the 7-16 EasyDock interface was adapted to ensure proper PIM measurement with 80 N contact pressure. This allows simultaneous PIM tests of devices with many connectors and is also suitable for products with a high connector density, such as antennas.

An EasyDock adapter featuring either a 7-16 or 4.3-10 measurement interface (front or rear) supports PIM measurements up to -162 dBc IM3. The EasyDock can be combined with SPINNER's low PIM switch and low PIM rotary joint for automating test systems where movement and rotation are required or where test procedures switch between PIM and VSWR measurements.

COST SAVINGS

Tests with the EasyDock have shown significant savings – up to 80 percent compared to manually mated test procedures. Design to cost measures have improved the CAPEX position of manufacturers. Now, EasyDock adds OPEX savings to significantly reduce production costs.

VENDORVIEW

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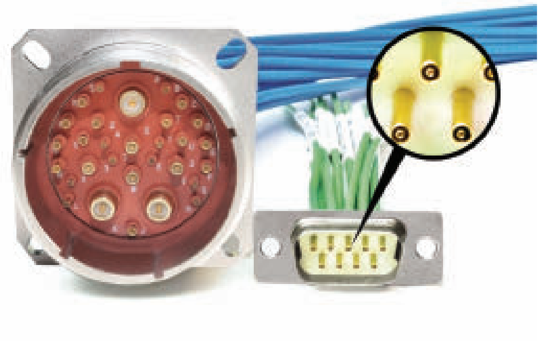


Next Generation Interconnect Cabling

Southwest Microwave Inc.
Tempe, Ariz.

Electronic equipment has evolved significantly over recent decades, both in terms of performance and packaging. A myriad of advancements in device engineering in the commercial, military and scientific sectors have contributed to components and end systems that are more sophisticated and much smaller than their predecessors. For example, today's unmanned vehicles have greater range as a result of optimized energy sources and reduced craft size. Satellites that communicate from deep space are constructed from compact, lightweight materials to reduce launch costs. Surgical procedures are more minimally invasive through robotics and microscopic tools.

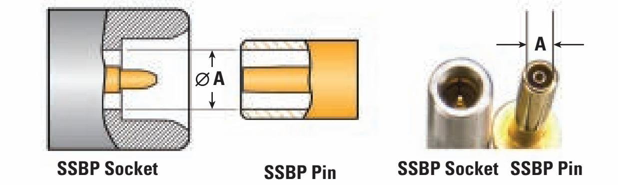
Yet as end solutions evolve in function and form, microwave coaxial connector solutions have been slow to keep pace with the complex interconnect cabling requirements to support these new generation technologies. In an age of miniaturization, legitimate concern exists relative to the heavy weight and extensive space needed for individual connector mounting, between-connector spacing, and manual mating of each connector and cable. If intricate harnesses are developed to organize a maze of interconnections, system cost grows. If not, field maintenance is extensive and expensive. Finally, the range of connectors commonly needed to address the varying frequency demands of today's electronic products further increase PCB or panel area and project budget.

There are also interconnect quality issues that can negatively affect reliability. Standard push-on RF connectors can separate under the vibration or shock of a harsh environment. Poor connector grounding equals poor RF performance and shorter system mean time between failures (MTBF). Similarly, without a built-in stress release, a soldered center conductor is a failure point for many of today's coaxial cable assemblies. In a spec where the potential for mismating of cables is prohibited, reverse-sex plug-jack combinations, polarized (keyed) connectors or pairing of dissimilar connectors can solve the problem, but at high cost.

As systems expand in capability but shrink in size, there is a distinct need for multifunctional microwave interconnect solutions that support higher RF frequencies, greater bandwidth, improved survivability, easier servicing and a more compact footprint.

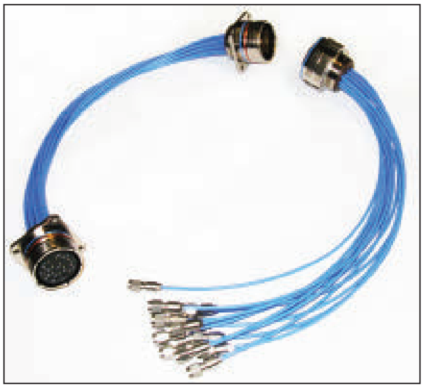
THE SSBP ADVANTAGE

To provide a reliable alternative to the packaging challenges of traditional interconnect cabling, Southwest Microwave has developed a family of SSBP RF and microwave coax contacts. SSBP coax contacts conveniently seat in cavities designed for signal (non-coax) contacts



SSBP Size:	SSBP-20	SSBP-20HD	SSBP-16	SSBP-12	SSBP-8
"A" Diameter: (reference only)	0.9 mm	0.9 mm	1.2 mm	1.7 mm	3.3 mm
Max Frequency: (calculated)	150 GHz	150 GHz	108 GHz	76 GHz	40 GHz

▲ *Fig. 1 SSBP size (using signal contact sizing terminology) vs. millimeter wave transmission line diameter "A". The maximum frequency depends on contact size and cable application.*



▲ *Fig. 2 SSBP high performance coax contacts for use in standard MIL-DTL-38999 and other multiport connectors solve the space, weight and performance challenges of standard interconnect cabling.*

in off-the-shelf multiport connectors that use M39029 contacts. For maximum design flexibility, SSBP contacts for special applications, including discrete coax installations, can be arrayed in custom envelopes. Seating or removal of SSBP contacts is achieved using standard MIL-I-81969 insertion and extraction tools.

SSBP coax contacts achieve a single, high performance connection to device cabling that can be easily connected and disconnected as needed, rather than mating an array of individual RF connectors. This simplifies interconnections and cabling, especially in tight or hard to reach spaces, dramatically reducing field maintenance or system test requirements and contributing to reductions in end-system cost. The miniaturized SSBP RF packaging format enables significant space and weight savings, versus discrete connectors and cables, by reducing the necessary area and volume of interconnections.

SSBP solutions offer higher RF performance and greater bandwidth than a corresponding array of individual connectors. Coax contacts of varying frequencies can easily be housed in one multiport connector or mixed with DC power, signal and fiber optic contacts to optimize multi-functionality, packaging design flexibility and project cost savings.

For circular connector applications, SSBP size 20, 16, 12 and 8 contacts are available to seat in standard MIL-DTL-38999 connectors with size 20, 16, 12 and 8 contact cavities. In rectangular connector applications, SSBP size 20HD coaxes seat in size 20 contact locations in standard MIL-DTL-24308 D-Subminiature connectors. SSBP 20HD assemblies used in D-Sub applications are also used in low profile, ruggedized, board-launchable MIL-DTL-83513 Micro-D type connectors in 3, 6 or 9-pin configurations. ***Figure 1*** shows the SSBP size versus millimeter wave transmission line diameter "A". The maximum frequency depends on contact size and cable application.

For miniaturized applications, SSBP contacts retrofit into Glenair Mighty Mouse® Series 79 and 80 connectors, and can be designed for use in other types of multi-pin connectors. SSBP high performance coax contacts for use in standard MIL-DTL-38999 and other multiport connectors (see ***Figure 2***) solve the space, weight and performance challenges of standard interconnect cabling.

SSBP coax design ensures exceptional RF performance and longevity, particularly in harsh environments. Pin and socket construction offers built-in contact stress relief during mating, as does a positive, three-step mating sequence in the host connector that accurately aligns the contact's outer conductor prior to engaging the center conductor, which guarantees matched impedance and EMI-tight, repeatable mating. Spring-loaded contacts maintain a constant ground path through shock or vibration and have no exposed spring fingers or slots that could be damaged or allow EMI emissions. Termination of SSBP contacts does not involve soldering of the cable center conductor to the socket contact, preventing breakage due to cable movement.

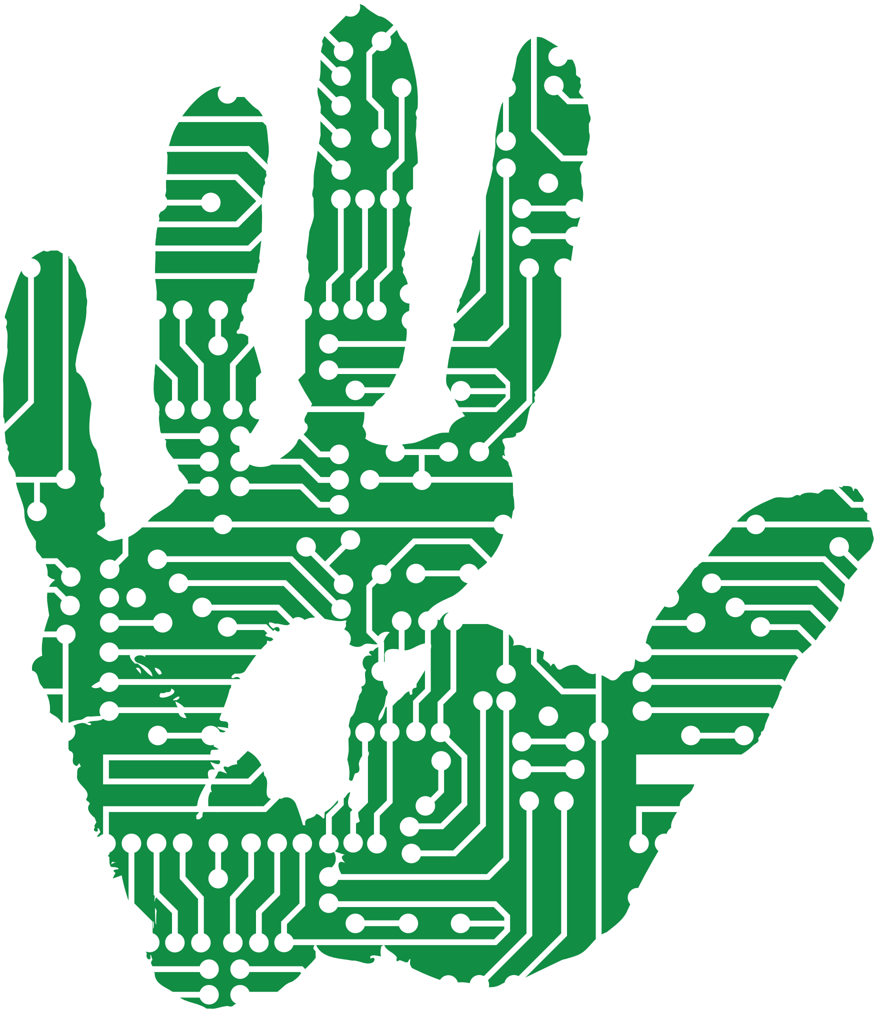
MIL-HDBK-217F, Notice 2 outlines that coaxes in multi-pin connectors are predicted to have higher reliability, or longer MTBF, than groups of equal numbers of discrete coaxes. Coupling this data with the highly positive outcomes of SSBP coax testing for vibration, shock, mating/unmating durability, EMI shielding effectiveness and typical microwave performance reinforces the viability of these solutions for hi-rel or harsh environments.

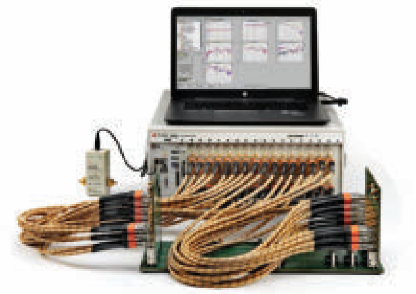
BROAD-RANGING APPLICATIONS

Systems with complex signal generation and routing requirements – such as communications, radar or missile defense systems – call for a high volume of RF interconnects. The higher the volume of RF interconnects, the more applicable the SSBP solution. The small footprint and reduced weight of numerous SSBP coax contacts housed in a multiport connector also make this solution ideal for interconnect applications where weight and space are concerns, such as the tight spaces of on-board computers, landing gear, microsurgical equipment or unmanned systems.

With the environmentally sealed, ruggedized packaging of the D38999 connector housing, SSBP contacts will withstand the shock and vibration inherent in aerospace or military applications. By facilitating instant and reliable mating of a complex array of interconnections with a single multiport connector, SSBP coaxes reduce the potential for mating error and connector damage, and add efficiency to highly-regulated electronic system performance testing applications, such as aircraft system testing, where the manipulation of individual interconnections adds extensive data logging and cost to the testing process.

Southwest Microwave Inc.
Tempe, Ariz.
(480) 783-0201
www.southwestmicrowave.com





RF/Microwave Cable Assemblies

Maury Microwave's Stability™ series RF/microwave cable assemblies are designed specifically for phase- and amplitude-stable applications, offering excellent measurement repeatability even after cable flexure. With a ruggedized, durable construction, Stability results in a reduced total cost-of-test. Stability's light weight, superior flexibility and small form factor make it ideal for daily use with VNAs, test instruments, bench-top testing, probe station integrations and ATE systems.

Stability low-profile cable assemblies are designed for high-density applications such as switch matrices and PXI/PXIe/AXIe cards, as well as wafer probe applications where traditional cable assemblies might cause interference due to cable and connector size. Stability low-profile cable assemblies offer the same electrical performance as Stability RF/microwave cable assemblies in a configuration that is 44 percent smaller and 66 percent lighter, and are available with 3.5 and 2.92 mm connectors.

For thermal vacuum applications, Stability TVAC cable assemblies have been designed for measurements in a thermal vacuum environment for space product testing. Stability TVAC cable assemblies offer the same electrical and mechanical performance as Stability RF/microwave cable assemblies with specialized vented 2.92 mm connectors that meet low outgassing requirements of ESA-PSS-01-702 with a TML < 1 percent and CVCM < 0.1 percent.

Stability Swept 90° cable assemblies are designed for applications requiring a fixed and stable bend where traditional cable assemblies may be inconvenient. With a bend radius of 1.43" and a cable-to-connector length of 3.3", Stability Swept 90° cable assemblies retain the electrical and mechanical specifications of the traditional assembly while removing stresses related to hand-formed bends.

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

Low Loss Hermetic Cable Assembly

GLA & GULA cable assemblies have been developed and produced for aircraft and cover the broad frequency range from DC to 18 GHz. These high quality, low loss cable assemblies deliver a low VSWR of 1.35:1, feature a self-locking connector and are protected by a Nomex and Kevlar jacket, which offers abrasion resistance.

MIL-T-81490 COMPLIANCE

As required by the aircraft sector, the GLA & GULA cable assemblies must be lightweight, small in size and not sacrifice performance. All cables are designed to meet statutory aircraft requirements and are in compliance with MIL-T-81490, which enables the cable to withstand harsh environments over a long period of time.

The GLA & GULA cable assemblies have been developed to meet stringent communication standards with a cable design that is crushproof and hermetically sealed. Another advantage is that the cable assemblies also enable the connection of an anti-rotation connector which is used in high vibration environment applications.

APPLICATIONS

GLA & GULA cable assemblies are also applicable to helicopter, trainer, UAV, military, communication, aircraft antenna systems, radar system, air reply system and satellite communication systems.

GigaLane Co. Ltd.
Gyeonggi-do, South Korea
(82)31-370-3517
sales@gigalane.com
www.gigalane.com

Self-Contained, Computer Controlled Measurement System

In-Phase Technologies announced availability of their Model PCT306 Microwave Vector Test System. The self-contained, computer controlled measurement system is used for testing RF and microwave passive devices utilized in helicopters, aircraft, ships, submarines and militarized vehicles. The 50 Ohm system, covering the frequency range of 30 KHz to 26.5 GHz, accurately measures all S-parameters, scalar insertion loss, VSWR and distance to fault (DTF) of RF and microwave cable assemblies under harsh environments. It is designed to withstand vibration, shock and varied temperature and humidity conditions. The system is packaged within a small transit case and is capable of running off its own internal battery supply, or can be connected to any AC outlet. The portable test set is ideal for rapid integrity checks or for troubleshooting coaxial cable runs, antennas and other passive devices on the flight line or in depot and field maintenance facilities.

The design of Model PCT 306 is based on field proven In-Phase cable test systems used over a decade within the CH-47 Chinook and V-22 Osprey rotorcraft production facilities. Each test set can be preprogrammed with scores of antenna, coaxial cable and other device performance specifications. These specifications are used by a test operator to test and verify the performance of critical cables and devices used in C5ISR avionic systems.

In-Phase Technologies
Bordentown, N.J.
(609) 298-9555
www.in-phasetech.com

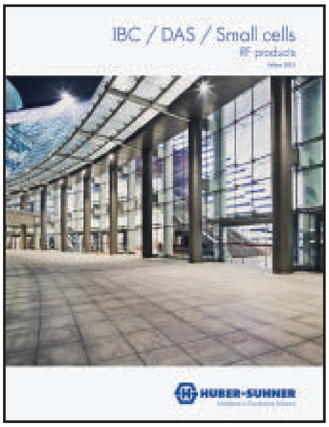
Cables and Connectors

Literature Showcase

RF/Microwave Signal Transmission

Cinch Connectivity Solutions offers a wide range of connectors and cable assemblies suited for RF/microwave signal transmission. Their products support wireless communications, data networking, test and measurement, broadcast, military and aerospace applications. Johnson offers a wide variety of RF connector types and board interfaces. Semflex offers a high performance, low attenuation bulk cable and custom, fixed length and semi-rigid cable assemblies to satisfy the most demanding requirements. Learn more at www.cinchconnectivity.com or call (800) 247-8256.

Cinch Connectivity Solutions
www.cinchconnectivity.com

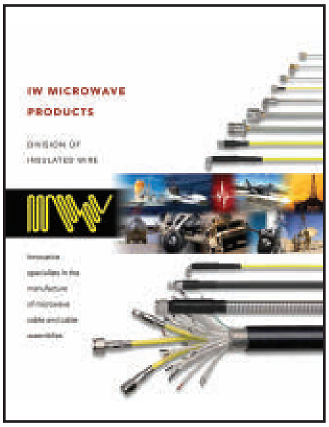


IBC/DAS/Small Cells Catalogue

VENDORVIEW

When it comes to availability and quality of wireless data communication services, the high coverage requirements apply equally both outside and inside buildings. With the implementation of dedicated solutions like distributed antenna systems (DAS), additional capacity for voice and data channels can be created as required. The new HUBER+SUHNER IBC/DAS/Small cells product catalogue contains a wide range of radio frequency solutions that support all applications in the deployment of the mobile communication network in urban environments. Visit HUBER+SUHNER's microsite at www.wireless-infrastructure.com/solutions for a closer look.

HUBER+SUHNER
www.hubersuhner.com



More Technical Content

IW's new 2015 catalog features a new data sheet format with increased technical content. Tabulated and graphical data for all cables includes stranded center conductor, expanded Re-Flex™ options, attenuation values in dB/m, plus useful cable handling instruction and new product specifications. IW introduces 0471, 170 series and RF250 following customer demand for smaller diameter cable, improved attenuation and extended frequency range for SATCOM applications, and the most versatile RG401 replacement available. IW–we're flexible!

Insulated Wire (IW)
www.iw-microwave.com

Kappa 331 UX

The Kappa 331 UX is a modular wire cut and strip machine capable of processing coaxial and triaxial cables with cross sections from AWG 24 to AWG 2. The Kappa 331 UX comes equipped with the TopTouch user interface that is extremely operator friendly and easily programmable. The Kappa 331 UX can be changed over quickly to increase efficiency and production rates. For more information, please contact your local Komax Wire sales representative or visit the company's homepage.

Komax Wire
www.komaxwire.com

Cable Assemblies

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

Maury Microwave Corp.
www.maurymw.com

Coaxial Cable Assemblies

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

MIcable Inc.
www.micable.cn

Cables and Connectors

Literature Showcase

Custom Rack Mount Test Equipment Guide

VENDORVIEW

Mini-Circuits' Custom Rack Mount Test Equipment Guide is a 52-page, full color brochure showcasing a wide selection of custom test solutions ranging from DC to 18 GHz including amplifiers, signal generators, routing and distribution systems, and more. The brochure highlights Mini-Circuits' ability to deliver affordable, reliable custom test solutions with turnaround times as fast as two weeks and also introduces the company's user-friendly control software, programming support and test accessories. To request a copy, email sales@minicircuits.com.

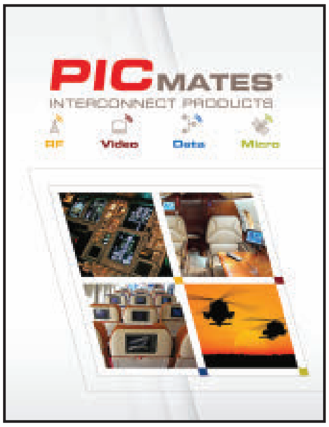
Mini-Circuits
www.minicircuits.com

V11.03 Update

VENDORVIEW

NI AWR Design Environment™ introduced new antenna measurement capabilities and a ready-built 3D parts library within its Analyst 3D FEM EM simulator, as well as user-configurable 3D PCells for custom parts creation. NI AWR software provides an intuitive use model that delivers an exceptional user experience and open design flow that supports third party tools, resulting in more compelling solutions. These unique aspects of NI AWR software solutions maximize user productivity by eliminating errors and design redundancies and quickening the pace to market. Learn more about additional enhancements for V11.03 at www.awrcorp.com/whatsnew.

National Instruments
www.ni.com



PICMATES Interconnect Products

The PICMATES family of cables and connectors offers solutions for high frequency/microwave applications plus network/communications, data transfer and entertainment demands. The company's brochure highlights their broad selection of specialized coaxial, triaxial, high speed data and custom cable options. In particular, MicroMATES are designed to advance interconnect technology for Ku- and X-Band assemblies supporting satellite communications and onboard connectivity in aircraft. Visit www.picwire.com/pdfs/PIC_Overviews/pic_wire_picmates_overview.pdf for more in-depth information.

PIC Wire & Cable
www.picwire.com

Precision Coaxial Connectors

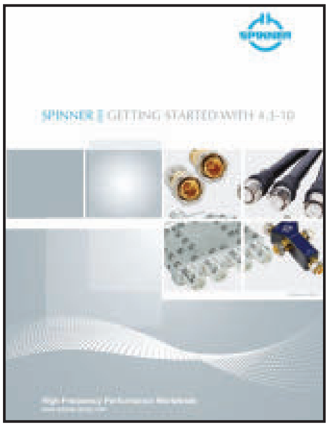
SGMC Microwave is a registered ISO 9001:2008 manufacturer of precision coaxial connectors including cable connectors, receptacles and adapters. The company's product catalog along with their newly revamped website showcases their extensive line of readily available products which includes these series: 1.0 mm, 1.85 mm, 2.4 mm, 2.92 mm, 3.5 mm, SMA, N, TNC and SSMA. Quality, performance, and reliability you can count on.

SGMC Microwave
www.sgmcmicrowave.com

Hermetically Sealed Adapters

Spectrum's new brochure features numerous updates to their product line. 2.4 and 1.85 mm units were added to their N, TNC, and 2.92 mm series. The standard Hermeticity specifies 10^{-8} atm. cm^3/s minimum. As several applications do not need this high class Hermeticity, more economical priced products with Hermeticity of 10^{-5} atm. cm^3/s were also added. All adapters use fused in glass seals between center contact and outer conductor. The adapters are normally used at vacuum chambers testing products that are undergoing tests for outer space applications.

Spectrum Elektrotechnik GmbH
www.spectrum-et.com



Getting Started with 4.3-10

VENDORVIEW

SPINNER GmbH's 4.3-10 portfolio is consistently growing. New offerings include calibration kits and easy dock for test & measurement; connectors, adapters and jumpers; loads and attenuators; plus couplers and splitters. The SPINNER Group has been setting standards with its RF technology products for more than 65 years. The company's high quality standards of design, material and manufacturing ensure the best possible connectivity, optimized installation and failure-free operation, even under the toughest environmental conditions. For more information visit the company's website at www.spinner-group.com.

SPINNER GmbH
www.spinner-group.com

Cables and Connectors

Literature Showcase

DAS Coaxial Cable Products

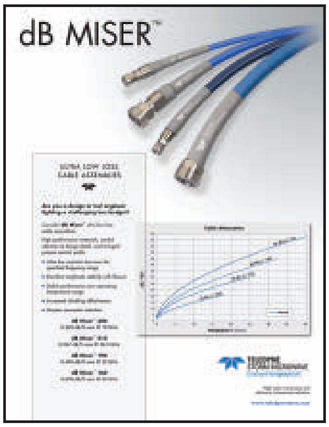
Superior Essex offers a broad portfolio of cable products and accessories for the modern wireless heterogeneous (HetNet) network, including coaxial, fiber, power, hybrid and category cables, as well as connectors and jumpers used for both cell towers and Distributed Antenna Systems (DAS). Superior Essex DAS coaxial cable products offer industry-leading electricals, with low attenuation across 30 to 4000 MHz, guaranteed voltage standing wave ratio (VSWR) less than 1.25 dB, and passive intermodulation (PIM) less than -155 dBc. With manufacturing facilities throughout the U.S., Superior Essex offers short lead times to help meet your wireless installation needs faster.

Superior Essex
www.superioressex.com

Comprehensive Product Catalog

SV Microwave released their latest, most comprehensive product catalog that features all of their distribution items categorized by series. Additionally, every part number in SV Microwave's digital copy has a hyperlink to its own landing page on the company's website with series information, data sheets and inventory availability. Please visit www.svmicrowave.com/resources/catalogs to download your copy today.

SV Microwave
www.svmicrowave.com



dB MISER Brochure

The clear choice for engineers facing challenging system gain or signal-to-noise requirements, dB Miser™ assemblies exhibits ultra low loss, excellent amplitude stability with flexure, stable performance over temperature and exceptional connector retention. Teledyne Storm Microwave's recently updated brochure provides data for the full line of dB Miser™ cables (0.160", 0190", 0.210" and 0.299" diameters) including cable specifications, construction, connector options, armoring and ruggedization options, plus full ordering information. Visit the resource center on the company's website to view and download a copy.

Teledyne Storm Microwave
www.teledynestorm.com

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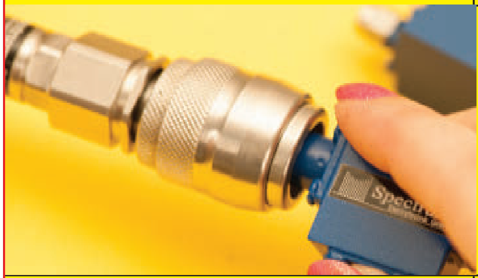
Procedure for how to use the N, TNC and 7/16 Push-On male. Push-On Connectors mate with any standard female connector of the same connector style.

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

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

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

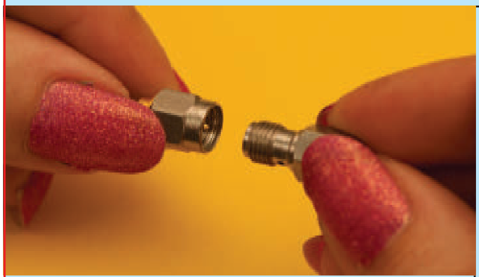


4. The Connection has been completed, easy and fast. The connector has been locked on safely.

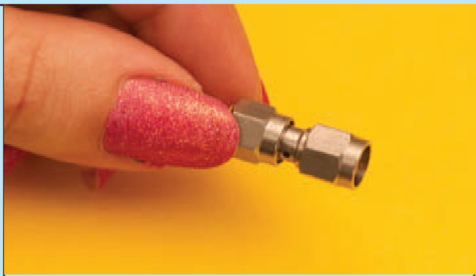
5 . To unlock (when "Back Nut" is in unlocked mode) push the "Lock Nut" forward and stop reverse movement by setting your fingers onto the "Back Nut".

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

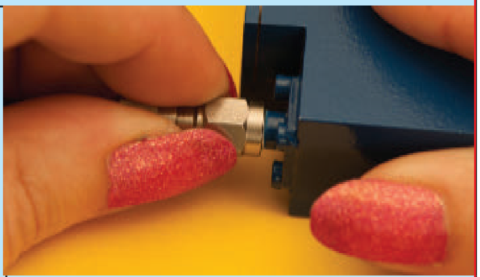
Procedure for how to use the SMA male and SMA female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.



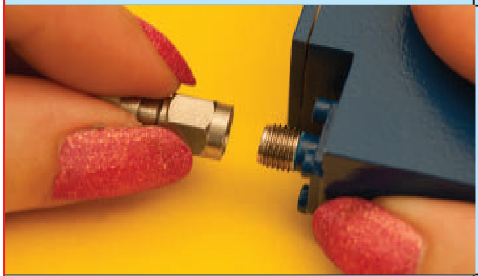
1. Convert your standard cable assembly into a Push-On Assembly by threading the standard female side of the adapter onto the male connector of the assembly.



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



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

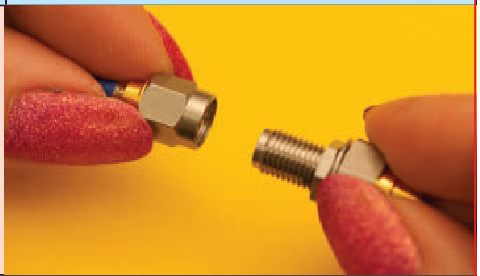


4. To disconnect, just pull the connector off.

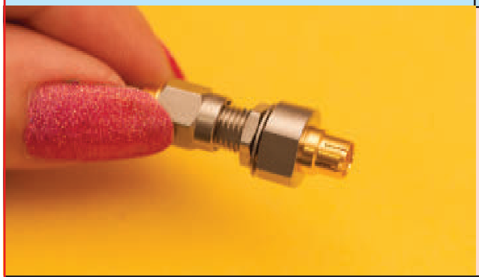
Spectrum Elektrotechnik GmbH

Please contact us at:
www.spectrum-et.com
Email: sales@spectrum-et.com
Phone: +49-89-3548-040
Fax: +49-89-3548-0490

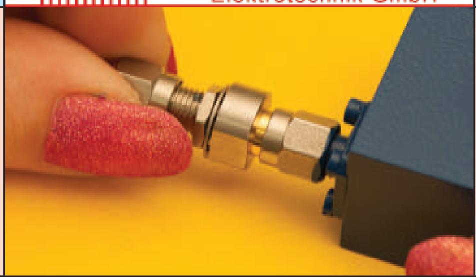
Spectrum Elektrotechnik GmbH



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



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



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

4. To disconnect, just pull the connector off.

Delta's 4.1/9.5 Mini DIN series of coaxial connectors were developed to meet the growing demands of today's high performance mobile communications systems.

The **4.1/9.5 Mini DIN** has an operational frequency range of DC-14 GHz, offers excellent VSWR performance and Low Passive Intermodulation (Low PIM) < -165 dBc, making it ideally suited for use in **Base Stations, Distributed Antenna Systems (DAS)** and **Small Cell** applications.

Features

- IEC standardization
- 30% smaller and lighter compared to 7/16 series
- Reduced center to center spacing
- Albaloy plating

Benefits

- Global standard interface
- Increased package density
- Low PIM: < -165 dBc

Get your copy of our new **4.1/9.5 Mini DIN** catalog, contact Delta today!

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