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January 2012

Microwave Journal

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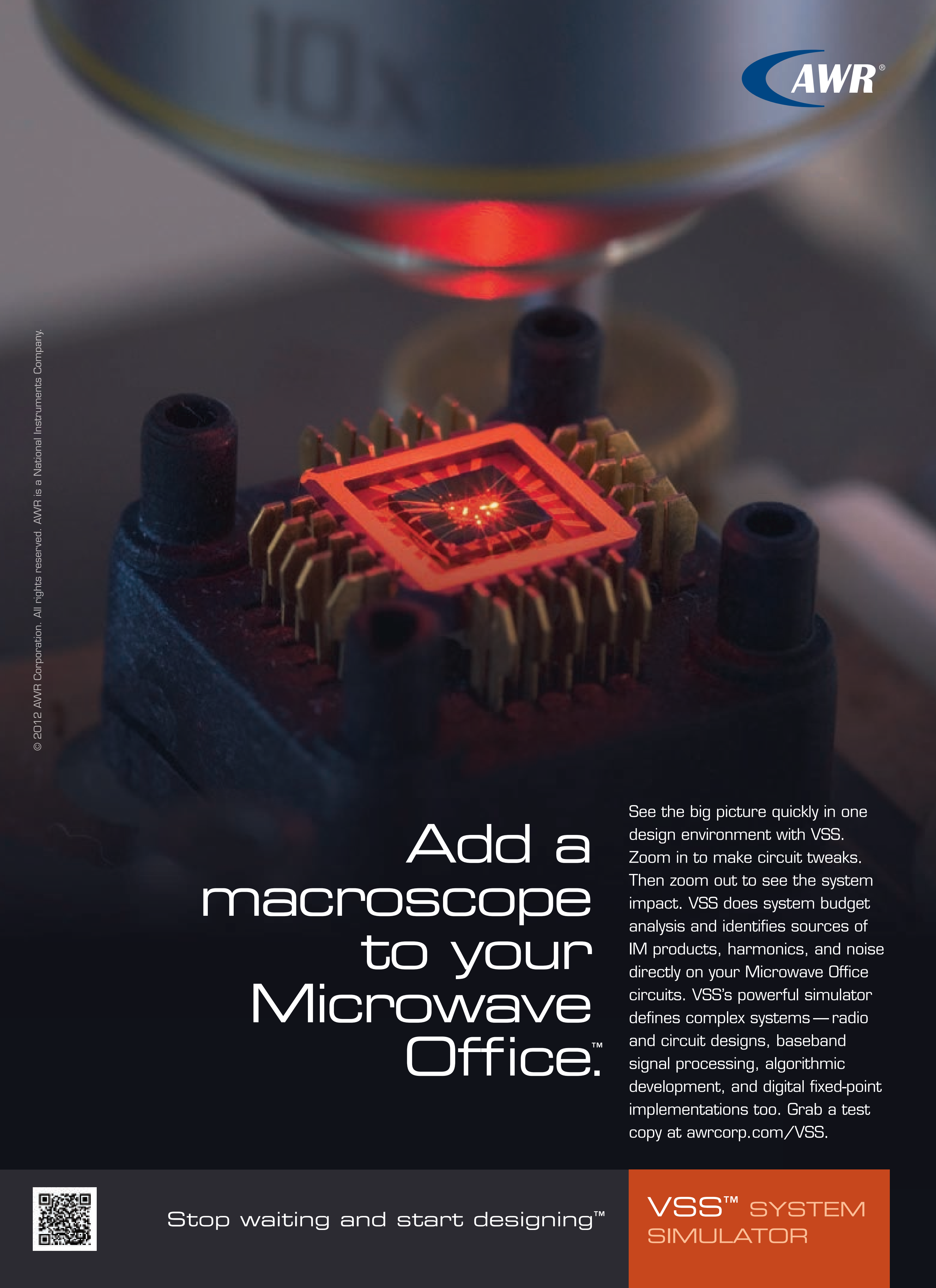
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An Ideal RF Power Technology for ISM, Broadcast and Commercial Aerospace Applications
White Paper, Freescale Semiconductor

Strategies for Signals Intelligence from Antennas to Analysis
White Paper, National Instruments

Wideband 400 W Pulsed Power GaN HEMT Amplifiers
Poulton, Krishnamurthy, Martin, Landberg, Vetury and Aichele, RFMD

Calibration Basics and Best Practices
White Paper, Tektronix

Executive Interviews

Greg Peloquin, President of Richardson RFPD, talks about global market trends, customer support, new suppliers the company is representing and what products to look for in 2012.

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Ergun Bora, CEO of the Radar and EW Group, Aselsan, elaborates on the company's expansion from primarily serving the Turkish Armed Forces into a multi-product defense electronics business serving global markets.

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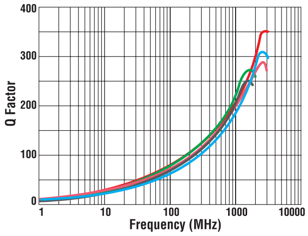

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29	30	31	1	2 **Webinar: Innovations in EDA** Agilent Technologies	3	4
5	6 (NATE 2012, 6–9)	7 NATE 2012 International Exhibition with Conference on Electromagnetic Compatibility Dusseldorf, Germany (7–9)	8	9 **Webinar: Agilent in Wireless Communications** Agilent Technologies	10	11
12	13	14	15	16 **Webinar: Agilent in Aerospace/ Defense** Agilent Technologies	17 Call for Papers Deadline	18
19 (ISSCC, 19–23)	20 (IWCE, 20–24)	21 ISSCC San Francisco, CA IWCE Las Vegas, NV	22 AUSA'S ILW Winter Symposium and Exposition Ft. Lauderdale, FL (22–24)	23 **Webinar: Agilent in LTE** Agilent Technologies	24	25
26	27 (Mobile World Congress, 27–1)	28 MOBILE WORLD CONGRESS	29 **MMS 2012 Call for Papers Deadline** **Webinar: Innovations in SA Series** Agilent Technologies	1	2	3

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Radio and Wireless Symposium
January 15–19, 2012 • Santa Clara, CA
www.rawcon.org

IEEE MEMS 2012
International Conference on Micro Electro Mechanical Systems
January 29–February 2, 2012 • Paris, France
www.mems2012.org

DesignCon 2012
January 30–February 2, 2012
Santa Clara, CA
www.designcon.com

FEBRUARY

NATE 2012 Conference & Exposition
National Association of Tower Erectors
February 6–9, 2012 • San Antonio, TX
www.natehome.com

International Exhibition with Conference on Electromagnetic Compatibility
February 7–9, 2012 • Dusseldorf, Germany
www.e-emc.com

ISSCC 2012
IEEE International Solid-State Circuits
February 19–23, 2012 • San Francisco, CA
www.isscc.org

IWCE 2012
International Wireless Communications Expo
February 20–24, 2012 • Las Vegas, NV
www.iwceexpo.com

AUSA's ILW Winter Symposium and Exposition
February 22–24, 2012 • Ft. Lauderdale, FL
www.ausa.org

MWC 2012
Mobile World Congress
February 27–March 1, 2012
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www.mobileworldcongress.com

MARCH

SATELLITE 2012
March 12–15, 2012 • Washington, DC
www.satellitetoday.com/satellite2012/

ISQED Symposium 2012
13th Annual International Symposium on Quality Electronic Design
March 19–21, 2012 • Santa Clara, CA
www.isqed.org

APRIL

ACES 2012
28th Annual International Review of Progress in Applied Computational Electromagnetics
April 10–14, 2012 • Columbus, OH
http://aces.ee.olemiss.edu/

WAMICON 2012
IEEE Wireless and Microwave Technology Conference
April 16–17, 2012 • Cocoa Beach, FL
www.wamicon.org

MAY

ICMMT 2012
International Conference on Microwave and Millimeter Wave Technology
MWIE 2012
Microwave Wireless Industry Exhibition
May 5–8, 2012 • Shenzhen, China
www.mws-cie.org

CTIA WIRELESS 2012
May 8–10, 2012 • New Orleans, LA
www.ctiawireless.com

JUNE

RFIC 2012
IEEE Radio Frequency Integrated Circuits Symposium
June 17–19, 2012 • Montreal, Canada
www.rfic2012.org

IMS 2012
IEEE MTT-S International Microwave Symposium
June 17–22, 2012 • Montreal, Canada
www.ims2012.org

79th ARFTG Microwave Measurement Symposium
June 22, 2012 • Montreal, Canada
www.arftg.org

AUGUST

IEEE EMC 2012
August 5–10, 2012 • Pittsburgh, PA
http://2012emc.org

SEPTEMBER

MMS 2012
12th Mediterranean Microwave Symposium
September 2–5, 2012 • Istanbul, Turkey
www.mms2102.org

OCTOBER

AMTA 2012
34th Annual Symposium of the Antenna Measurement Techniques Association
October 21–26, 2012 • Bellevue, WA
www.amta.org

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Microwave Journal 2.0

Carl Sheffres, *Microwave Journal* *Publisher*

I remember working on the design and development of the first Microwave Journal website some 20 years ago. It was an exciting time, as we navigated our way through those relatively new waters of the web. We felt as though we were on the cutting edge of this new frontier, by launching the first media site for the RF and microwave industry.

The cyber world has evolved dramatically since then, as have the tools with which publishers can now distribute content. Today, we offer an array of resources including blogs, webinars, whitepapers and video in addition to the standard technical articles, news, products, events and archives that have populated the site since its inception.

Microwave Journal has been active on the Social Media front as well. Several years ago, MWJ Technical Editor Pat Hindle launched the "RF and Microwave Community" group on LinkedIn and it now boasts more than 8500 members and grows by a steady 20 members per day. If you have not checked it out yet, I encourage you to do so. There are numerous active discussions going on at all times on a variety of industry related topics. The MWJ Facebook page has about 600 "likes" and that number is growing rapidly. MWJ staffers David Vye (@mwjournal), Pat Hindle (@pathindle), Mike Hallman (@mphallman) and Kristen Anderson (@KAatMWJ) are active on Twitter, and I am a recent addition to the group (@csheffres).

For a good part of the past year, the MWJ staff has been busy working on the latest version of our website, and I am pleased to announce that the brand new mwjournal.com will debut very soon. This new website will be hosted on a state-of-the-art Cloud platform developed specifically for publishers like Microwave Journal. It features the vast archive of content that we have accumulated over many years, in a contemporary, user-friendly, easy to navigate environment. You will find product/technology channels that aggregate specific content, making it easier for you to find information relevant to your interests. You will find a re-tooled Buyer's Guide, eLearning Center and enhanced video archive. Social media is integrated, expanding the opportunities for discussion and networking. I think you will find the site to be a valuable resource and a place to exchange ideas and interact with colleagues.

Watch for other exciting announcements during the year, including a mobile app for our IMS show issue. We will be Tweeting and posting it on Facebook and LinkedIn, so join our groups or follow our Tweets to stay up to date.

On the magazine side, I am excited about the editorial lineup that the editors are putting together. We will cover the latest technologies, the hottest new products and the major conferences as always, along with some unique market perspectives and special reports.

This issue features our cover story on "21st Century Radar: Challenges and Opportunities" and a Special Report titled "Beyond Next Generation Mobile Broadband: BuNGee". You will find additional articles on Radar Systems Modeling, Peak Power Measurements and a preview of the upcoming DesignCon show, just to name a few. You may also notice some subtle design changes, as we continue to evolve the print and digital editions of the magazine.

As always, I appreciate your support and I look forward to an exciting year ahead.

Happy New Year,
Carl Sheffres


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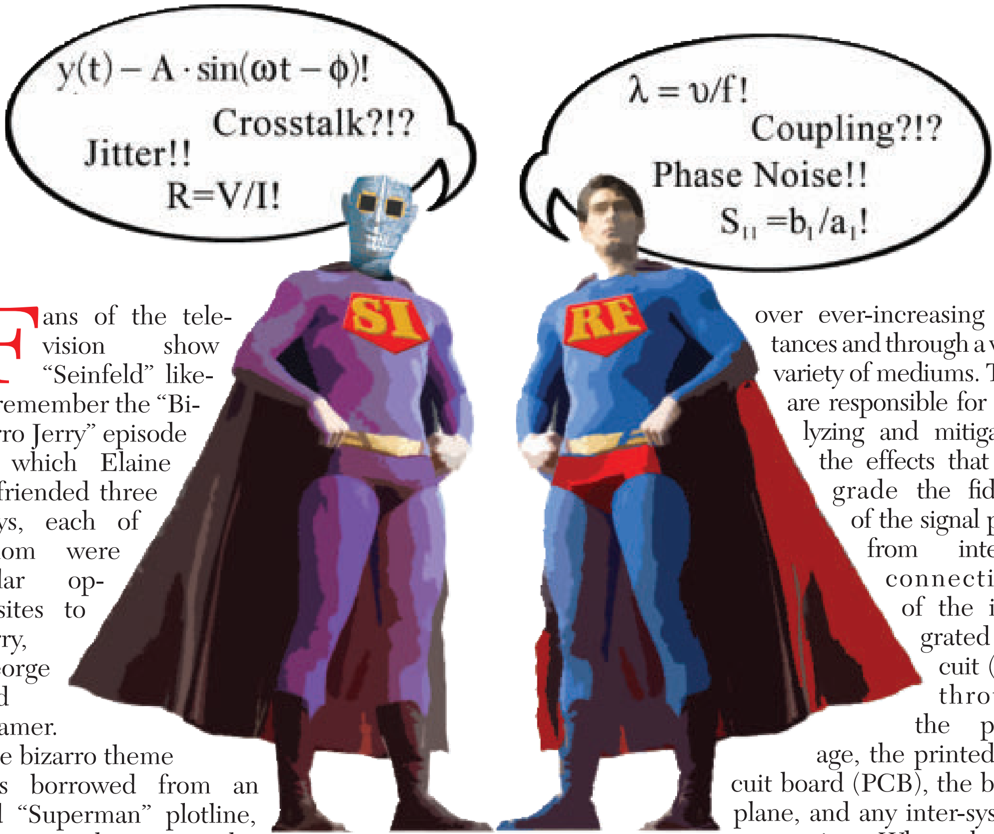
DesignCon Heroes



Fans of the television show "Seinfeld" likely remember the "Bizarro Jerry" episode in which Elaine befriended three guys, each of whom were polar opposites to Jerry, George and Kramer. The bizarro theme was borrowed from an old "Superman" plotline, satirizing characters who were very similar and yet very different from the show's regulars. In the technical world, the bizarro counterpart to an RF/microwave engineer might be the signal integrity (SI) engineer. Consider the following. They work with data in the 1/frequency (aka time) domain, they work to suppress circuit radiation, they refer to coupling as cross-talk and they have a large annual conference/exhibition, aka DesignCon, which takes place this year from January 30th through February 2nd at the Santa Clara Convention Center.

SI engineers work with digital signals commonly operating at multi-gigabit data rates, over ever-increasing distances and through a wide variety of mediums. They are responsible for analyzing and mitigating the effects that degrade the fidelity of the signal path, from internal connections of the integrated circuit (IC), through the package, the printed circuit board (PCB), the backplane, and any inter-system connections. Where the RF engineer is concerned with harmonics, intermodulation distortion, insertion loss, mismatch and noise figure, the SI engineer is concerned with ringing, ground bounce, distortion, signal loss, and power supply noise. While much of the terminology between RF and SI engineers are different, the physics of high speed signal transmission remains the same and so it is no surprise that many well known companies in the microwave industry participate in DesignCon every year.

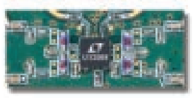
(Continued on page 26)

David Vye
Microwave Journal *Editor*

4G 4 U

Dual RF Mixer Needs Only 600mW

Actual Size



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LTC5591	1.3GHz to 2.3GHz	26.2	8.5	9.9/15.5	1260	5mm x 5mm QFN
LTC5592	1.7GHz to 2.7GHz	26.3	8.3	9.8/16.4	1340	5mm x 5mm QFN
LTC5593	2.3GHz to 4.5GHz	26.0	8.5	9.5/15.9	1310	5mm x 5mm QFN

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In particular, DesignCon attracts the leading RF test and measurement equipment manufacturers, including Agilent Technologies, Anritsu, LeCroy, National Instruments, Noisecom, Rohde & Schwarz and Tektronix; EDA and EM simulation vendors, such as Agilent EEsof, Applied Simulation Technology, ANSYS, AWR, Cadence, CST, Intercept Technology, Mentor Graphics, Synopsys, and Sonnet Software; as well as component and material manufacturers, such as ARC Technologies, Hittite Microwave, Huber + Suhner, Molex, Samtec, Rosenberger and Rogers Corp. The presence of these companies at DesignCon says a lot about the similar technical challenges faced by the microwave engineer and his SI counterpart. The engineering still comes down to design entry, characterizing the signal path (EM simulation), modeling the active devices, circuit/system simulation and optimization, fabrication and test.

And yet, these companies market familiar products in a slightly altered language at DesignCon. For instance, last year Agilent promoted the use of its ADS Momentum for solving power integrity problems on PCBs "complicated by heavily perforated power and ground planes." In SI and PI analysis, engineers characterize the signal path or interconnect channel using many of the same EM simulation tools used by the microwave community. For the microwave engineer, EM simulation tools provide the interconnecting transmission line or component's defining S-parameters and the designer is good to go. But for the SI engineer, interest lies in what happens to the data waveform as it passes through the signal path rather than the frequency behavior of the path itself. And so the SI engineer needs a model for the transmission channel that works in the time domain as well as representation of the waveform and all of the I/Os that will impact the waveform in the network under analysis. Rather than use RF compact or behavioral models, EDA products targeting DesignCon attendees such as Agilent's ADS, AWR's Microwave Office or ANSYS' SI Designer feature input/output buffer information specification algorithmic modeling application programming interface (IBIS AMI) standard. This standard allows IC vendors to share "executable datasheets" of the high speed digital SERDES without proprietary encryption.

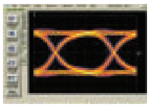
One of the on going challenges from a simulation perspective has been the use of S-parameter networks in signal integrity time domain analyses. The signal integrity analysis of high speed electronic designs requires that the interconnect models be valid over a wide bandwidth. Due to simulation or measurement errors, the S-parameters of interconnect structures can become non-passive. Although a number of simulators can perform transient simulation directly with S-parameters, they will often experience convergence problems if the measured or simulated data violates passivity. Perhaps for this reason, conference organizers are offering a special session on "How to Avoid Butchering S-parameters." Several software vendors address the issue with tools that provide data integrity checks, allowing users to verify and enforce the passivity, reciprocity and causality of S-parameters.

THE CONFERENCE PROGRAM

Like the International Microwave Symposium, the technical program committee (TPC) consists of volunteers who conduct a peer review of submitted abstracts and papers. Unlike IMS, these reviewers are not members of a technical society, such as the MTT-S, but rather individuals from a broad collection of companies and universities that represent organizations at the forefront of the high speed electronics industry. This year's TPC is comprised of individuals from Cadence, IBM, Intel, Sigrity, Dell, Tektronix, the Mayo Clinic, Xilinx, nVidia, Apple, CST, Infineon and Cisco, to name just a few. The 2012 TPC consists of 146 reviewers from all areas of the high speed design spectrum.

The conference includes a number of sessions that will make an RF/microwave engineer feel right at home, including one on RF/Microwave Techniques for Signal Integrity. With a focus on the complete signal path, the conference organizers have the challenge of presenting a technical program that spans many mediums and several disciplines – from design, simulation, verification and test. This is reflected in the different design tracks available to attendees, including analog and mixed-signal design and verification, EMC/EMI, FPGA design and debug, high speed serial design, processing, equalization and coding, power integrity and power distribution network design as well as memory and parallel interface design. To address the challenges of designing high speed channels in different mediums, there will be sessions on chip-level design for signal/power integrity, PCB design tools and methodologies and a track on system co-design: chip/package/board. On the simulation, analysis and test side, there will be tracks on high speed timing, jitter and noise analysis, PCB materials, processing and characterization, and test and measurement methodology.

As signaling rates increase into the multi-gigabit-per-second range, SI engineers are forced to confront the phenomena that impacts circuit behavior at higher frequencies. Our SI counterparts will increasingly need the expertise and knowledge base of RF and microwave engineers to extend the range of the signal integrity toolkit. To participate in this exchange of knowledge or experience the SI world of our bizarro brethren first-hand, RF/microwave companies and engineers should make the journey to DesignCon 2012. As an SI engineer might say, "it is sure to be eye opening."



Chiphead image courtesy of DesignCon. Superman and Bizarro images courtesy of DC Comics.

COVER FEATURE
INVITED PAPER

21st Century Radar: Challenges and Opportunities

The extraordinary performance achievable by modern radars is delivered by a combination of advances in microwave and digital technologies, including miniaturization and increased performance of RF and microwave components, analog-to-digital and digital-to-analog converters, and the massively-parallel processing capability of Field Programmable Gate Arrays (FPGA). Much more will be required of each one to meet increasingly sophisticated threats, provide additional radar functions and operate in the increasingly electromagnetically dense signal environments of the future. This must be accomplished while reducing size, weight and power consumption (SWaP) in addition to lowering cost. This article discusses these challenges and provides insight into how the aforementioned technologies, devices and design methodologies will confront them, focusing on the receive path but also addressing the transmit path, as both must function together to provide a complete solution.

The capabilities of radar systems have exploded in many directions since World War II and every year the technology absorbs more functions. Today radar systems provide not just "detection and ranging" but imaging and, most recently, some elements of electronic attack (see ***Figure 1***). In defensive roles, radar is a highly capable adversary that is not easily fooled by the antics of Digital RF Memories (DRFM). In offensive roles, a radar system can determine in minute detail what it is "seeing" so that its operators can determine an appropriate course of action. In fire control scenarios, radars can, if so commanded, take the final step by ordering a barrage of ordinance to be directed at an approaching cruise missile as a last line of defense. Radars can function independently or within a sensor network, be aggregated to form a continents-wide network (or aperture), see through seemingly impenetrable foliage, cloud cover and structures, and function as imaging systems with graphical overlays. And this is just the short list.

Current radars are indeed impressive technological achievements but all this comes at a price – very high in the case of a large Active Electronically-Scanned Array (AESA), as shown in ***Figure 2***. These 21st century versions of the phased-array radar are extraordinarily complex assemblages of analog, RF and microwave and digital components along with software that orchestrates system functions. Control, signal distribution and especially timing require extraordinary precision in an AESA radar that includes hundreds or thousands of antenna elements. Each of these elements potentially contains capabilities for signal capture, downconversion, format conversion, RF power generation, timing and synchronization, control, and high speed communication both within and outside the radar.

GETTING THE COST OUT

Not surprisingly, the Department of Defense (DoD) has mandated that the cost of

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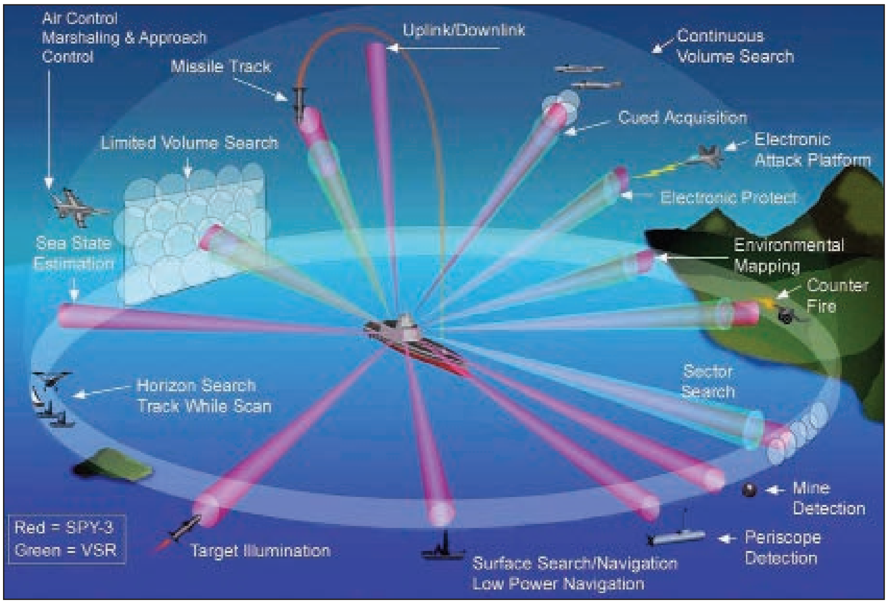


Fig. 1 Radar systems are taking on multiple functions.

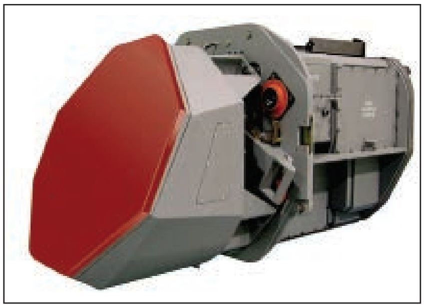


Fig. 2 Raytheon's AN/APG-79 AESA radar for the F/A-18/E/F Super Hornet employs advanced microwave and digital components and design approaches.

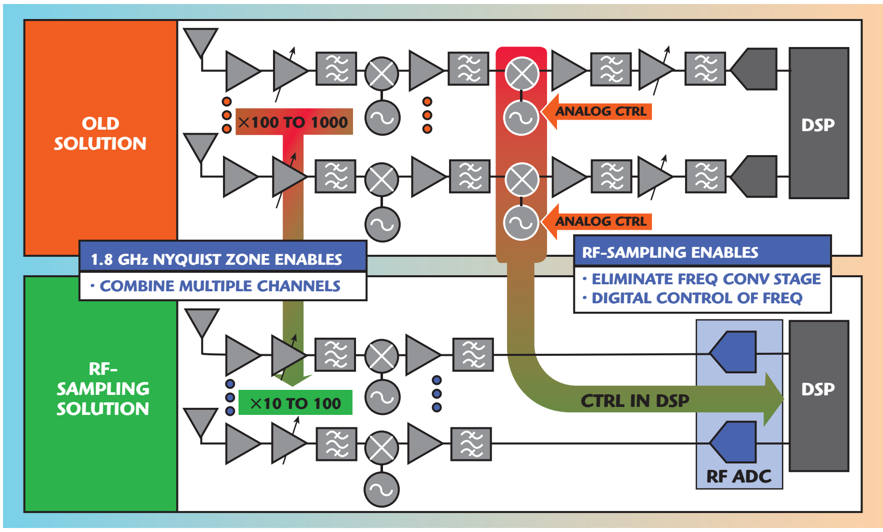


Fig. 3 The reduction in analog components is demonstrated in this diagram. (Courtesy of Texas Instruments–National Semiconductor).

future radar systems must be reduced through advancements at the device, subsystem and system levels, and with greater functional analog/digital integration, open and standardized radar architectures. Other cost-cutting strategies include use of Commercial Off the Shelf (COTS) or modified COTS components and more efficient delivery of higher RF output power in each element through solid-state devices, most likely gallium nitride (GaN) RF power transistors and MMICs. Since the first phased-array radars that combined transmit and receive functions at the element level, significant cost has been driven from the systems through elimination of the mechanical components required to steer the antenna beam.

At the highest level, the most cost reduction "for the buck" can be achieved by integrating within a single system functions, such as wide-area search, target tracking, fire control, jamming and perhaps weather monitoring, that currently require multiple systems. Networking them together with other sensors and systems allows the information the radar provides to be available in near real time over IP-based type networks to become key elements of the evolving Global Information Grid. Such multifunction systems are smaller, lighter and less power hungry and, when fully integrated, become easier for their operators to control.

THE HOLY GRAIL

The most widely held goal within DoD and prime defense contractors is to convert analog signal data to the digital domain as close to the antenna as possible. The reason is the same as for any signal processing environment, from consumer devices through radar systems: once a signal is digitized, it is vastly easier and faster to distribute, process, analyze and for its content to be modified. It also eliminates the problems associated with analog components, such as sensitivity to temperature and other environmental factors, and device tolerances. An example of this reduction is shown in ***Figure 3***.

The device most closely associated with achieving this goal is the ADC. It is the first major signal processing component in the receive path and has the critical responsibility of passing on to the next portion of the system (typically an FPGA or FPGAs) digital representations of the original analog signal with the highest fidelity and greatest dynamic range. Using existing merchant market devices, it is possible to directly receive an RF input signal with an instantaneous bandwidth of DC to 6 GHz, a sampling rate of 12 Gsamples/s and 7 bits of resolution. There are a variety of devices available that reach input frequencies greater than 3 GHz with resolution beyond 12 bits. In an L-Band or S-Band radar system, use of these devices makes it possible to eliminate an entire analog downconversion stage. If the devices are operated in higher Nyquist zones it is possible to directly capture analog signals at much higher frequencies. This results in a reduction in signal-to-noise ratio, but potentially eliminates another downconversion stage.

Another technique can be used to directly digitize RF input signals at

frequencies higher than an ADC can handle when operating in the first Nyquist zone, variously called band-pass sampling, harmonic sampling, IF sampling or direct IF-to-digital conversion. It allows higher IF frequencies to be employed, potentially eliminating additional analog down-conversion stages and their source, mixer and filter components. The signal of interest is band-limited to a single Nyquist zone (not necessarily the first Nyquist zone), and its image will always appear in the first Nyquist zone resulting from aliasing that occurs in the sampling process. The sample rate and the desired signal band must be placed where it is isolated to a single Nyquist zone using filters, and the sample rate must be at least twice the signal bandwidth.

Mercury Computer Systems used this approach and the frequency folding that occurs during the sampling process to good advantage in a 2 to 18 GHz digital Phase Modulation on Pulse (PMOP) detector in its 2 to 18 GHz instantaneous frequency measurement (IFM) receiver. The use of digital rather than analog techniques and devices reduced the size and weight of the circuit while providing greater flexibility. A high speed, track and hold device directly digitizes the 2 to 18 GHz RF input at 1 Gsample/s. All the frequency information folds in to the first 500 MHz Nyquist zone, but phase information is preserved.

As is invariably the case in electronic design, the choice of an ADC is not so simple. This is because it is not the converter's stated bits of resolution that is important, but rather the number of those bits that can effectively be used. The effective number of bits or ENOB is invariably less than what is stated on the device datasheet. This is a critical consideration because loss of a single bit translates into a reduction in the converter's signal-to-noise ratio by 6 dB. In radar as well as communications and EW systems, this is a very large number. Conversely, achieving 7 effective bits from an 8-bit converter can improve radar performance in almost every respect. Spurious-free dynamic range, linearity, power consumption and other specifications ultimately determine ADC and DAC performance, and must be taken into consideration and matched with the radar system's requirements.

Consequently, selection of an ADC for a radar application is invariably a trade-off between achieving a dynamic range of 60 dB or more that is typically required, RF input bandwidth, the number of the device's effective bits of resolution and the Nyquist zone it can operate in without significant performance degradation. Unlike their EW counterparts, radar systems are typically concerned with processing signals of considerably narrower bandwidths, although these bandwidths have been increasing on a regular basis thanks to the use of spread spectrum modulation techniques that extend bandwidth to perhaps 1 GHz. This allows ADCs with lower RF input bandwidths and higher resolution to be used.

In a large AESA radar with perhaps 1000 elements (or more), each one with its own ADC that delivers large amounts of data to the FPGAs following it, an astonishing amount of data will be collected in a very short period of time. For example, using the aforementioned ADC with 6 GHz of RF input bandwidth, the device will be streaming about 12.5 Gbytes/s to the FPGAs following it. In only 10 s, this veritable data fire hose will have communicated 125 Gbytes of data, which the FPGA will have to ingest, process and stream further back into the system where intense computation occurs.

This amount of data is much less when bandwidths are narrower, and a radar system generally determines at an early stage what signal content is important and discards the rest. Data reduction also has a direct impact on the transmit path, as the DAC employed to reconvert the digital data to its original or modified analog form is a less onerous task.

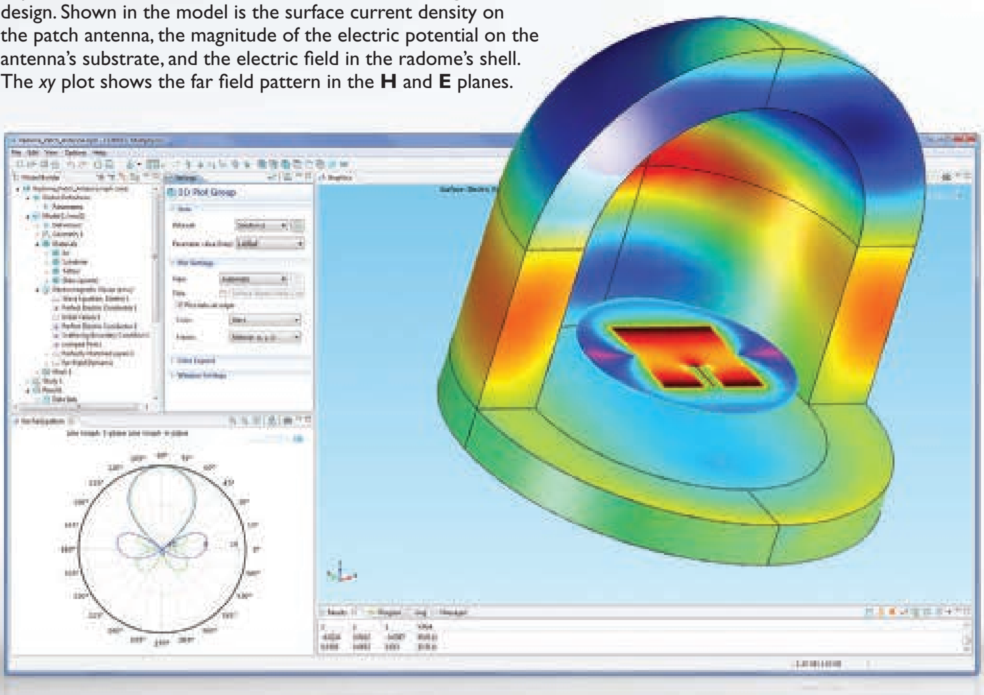
In addition, radars are beginning to take on electronic attack roles, appearing more as DRFMs, although typically covering narrower swaths of the spectrum. Within tens of nanoseconds, they must capture the analog signals and convert them to the digital domain, store them briefly, analyze and identify them if possible from a threat library and add "techniques." After this they must then reconvert the signal from digital to analog form, perhaps upconvert it and retransmit the signal, all within a frighteningly tiny time window, making the fidelity of the signal provided by the ADC even more critical.

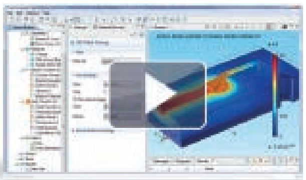
Once the ADC has captured and digitized the data, the next challenge is getting it into the FPGA without incurring a bottleneck. Fortunately, as one of the FPGA's initial functions was distributing data at high rates, the speed at which the device can do this per signal line has risen to 10 Gb/s. For those not particularly familiar with an FPGA, it consists of an array of configurable logic blocks with each cell of the block configurable (that is, programmable) to perform one of many functions. One of the most endearing attributes of the FPGA is that rather than being endowed by its manufacturer with a fixed set of functions, it is essentially a "blank canvas" when delivered to the designer, who can "paint" its desired functionality by programming it. This makes the FPGA extraordinarily versatile, as it can perform general-purpose computing, digital signal processing and high speed communication functions with little need for external resources.

The individual cells within an FPGA are interconnected by a matrix of wires and programmable switches. The logic cells become building blocks from which virtually any type of functionality can be created, from simple-state machines to complete microprocessors. The ultimate functionality that an FPGA will perform is created by programming the logic cells and selectively closing the switches in the aforementioned matrix of interconnect wires, and then combining these blocks to create the desired result.

FPGAs are extremely well suited for performing fixed-point arithmetic rather than floating-point arithmetic. Fixed-point arithmetic is typically less expensive to execute in hardware and is more efficient than its floating-point counterpart, but offers less dynamic range and requires values to be carefully scaled to avoid overflow or saturation. In contrast, in the floating-point format the position of the binary point "floats" depending on the magnitude of the number being represented. Floating-point arithmetic delivers high dynamic range and is very precise, but it comes with the caveat of being less frugal with power and more expensive to build. However, FPGAs are increasingly capable of performing both fixed and floating-point arithmetic, which further increases their usefulness in radar systems.

Although it is certainly possible to



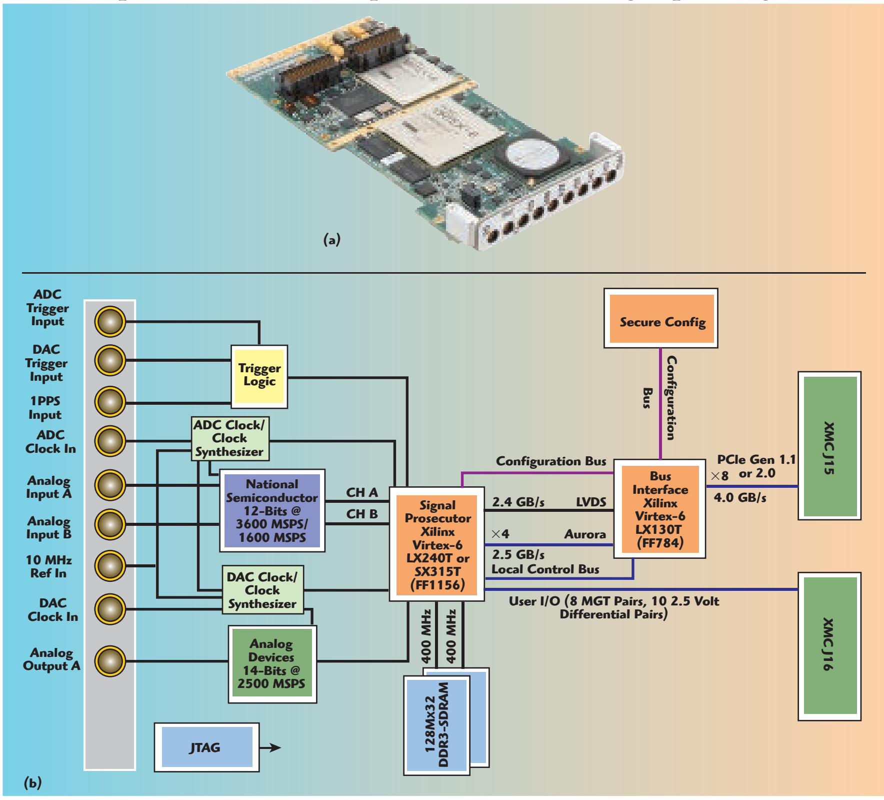


argue this point, it is a reasonable assumption that, along with the ADC, the FPGA has done more to advance the radar state-of-the-art than any other single advancement since the GaAs MMIC amplifier made solid-state T/R modules possible. Its ability to be programmed to perform a wide array of functions and its massively parallel processing make it the obvious choice for handling the increasingly vast amount of data that is sent from the ADC. Although FPGAs have integrated "soft" general processor cores, some of the latest devices have on board ARM processors that are well suited for use in the embedded computing environment of a radar system. They are also considerably easier to program than FPGAs and thanks to the widespread use of ARM processors in smartphones, there are far more engineers familiar with programming them than there are for FPGAs.

FPGAs tend to follow a development path similar to Moore's Law, with each succeeding generation delivering much greater performance. For example, the Xilinx Virtex-7, announced 18 months after the Virtex 6, provides two million logic cells, more than twice that of its predecessor, delivers up to 2.4 Terabits/s of I/O bandwidth and 4.7 TMACS of DSP performance. As touted by Xilinx in reference to radar systems, three Virtex-7 855T FPGAs can implement a 64-channel beamformer with an 80 percent reduction in board area with 24-channels per device, a 60 percent system cost reduction, and 90 percent FPGA power reduction. This type of doubling or more of performance is also typical of Altera's Stratix devices. The result is that radar designers have come to rely on the fact that the next generation of their chosen FPGA will give them more flexibility and performance at lower power than its predecessor.

In contrast, ADCs and DACs do not generate such headline-grabbing performance increases predictably in short times. The addition of a single "effective" bit may take five to 10 years to reach the market. However, the power afforded by this single additional bit, along with reduced power consumption, a higher sampling rate and thus high RF input bandwidth, is indeed a momentous event for radar designers.

Mercury's Echotek mezzanine module (see ***Figure 4***) is an example of a small-form-factor module that combines a high speed digitizer and



▲ *Fig. 4 The compact Mercury Computer Systems Echotek Series DCM-V6-XMC module (a) can directly digitize L-Band signals and integrates two FPGAs for signal processing and data movement and its core components (b).*

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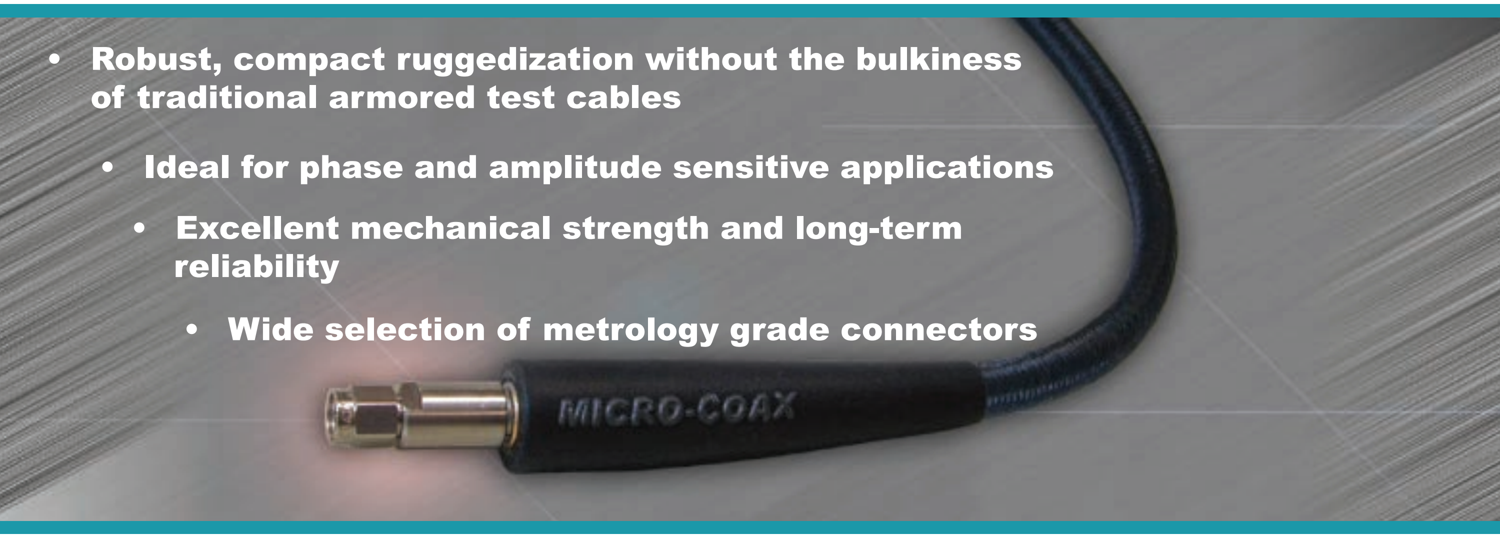

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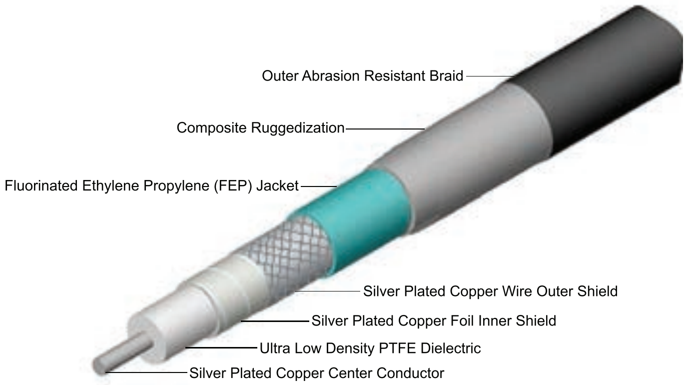
26.5 GHz	0.55	0.47
40 GHz	0.68	—



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processing solution, which can directly digitize L-Band signals up to 2.7 GHz. It uses two Xilinx Virtex-6 FPGAs along with one or two 12-bit ADCs that deliver sampling rates of 3.6 Gsamples/s in a single-channel or 1.6 Gsamples/s in a dual-channel configuration. Spurious free dynamic range (SFDR) at the input is 65 dB and signal-to-noise ratio is 57.5 dB. A 14-bit, 2.5 GHz DAC provides an analog output up to 2.5 GHz with an SFDR of 50 dBc and noise spectral density of -165 dBm/Hz.

In addition to FPGAs, designers are looking closer at graphics processing units (GPU) for their ability, among other things, to deliver extremely high resolution while also being significantly easier to program than FPGAs. In addition, as the graphics engines for a broad range of consumer electronics systems, programmers with expertise in GPUs are considerably easier to find than those who can program in VHDL.

GPUs are essentially fixed-point processors with massive arrays of single- and double-precision floating point units. They provide huge processing capability, but as a result also incur significant latency because of the data pipelines required for data transfer. FPGAs allow enormous flexibility in controlling onboard infrastructure, which allows the device to be optimized to reduce latency. However, GPUs require their application to essentially be fixed in the architecture. Finally, GPUs consume significant amounts of power and are not available in a variety of sizes as are FPGAs. That said, their positive attributes are making them appealing in certain circumstances.

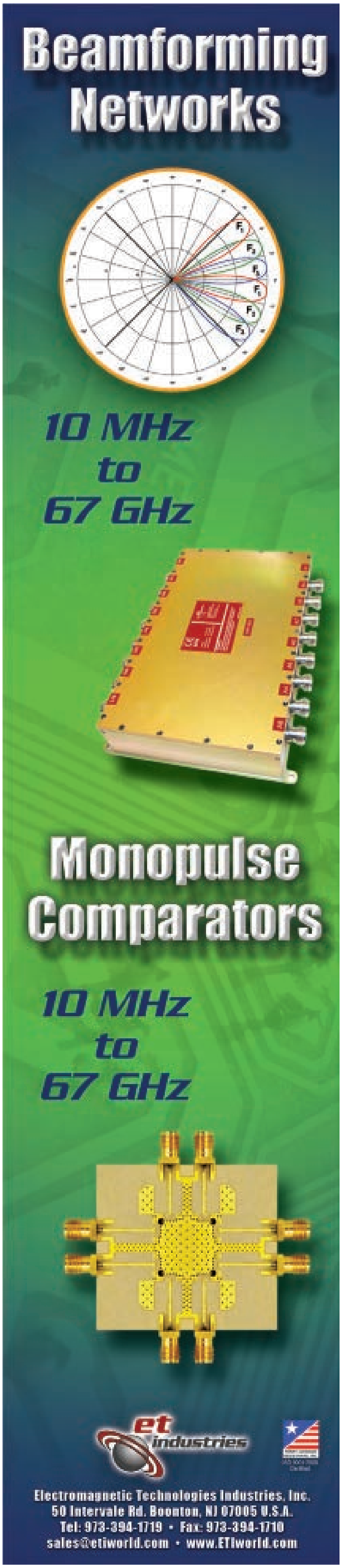
MICROWAVE TECHNOLOGY MOVES FORWARD

Although this article has thus far focused on the roles of ADCs, DACs and FPGAs for the advancement of radar systems, RF and microwave technology will obviously play an equally important role as radar systems evolve to face new threats. Just as GaAs MMICs broke new ground in the fabrication of T/R modules, their performance has increased and their cost has dropped dramatically, whether for small-signal applications such as low noise amplifiers, or RF power generation. Performance of both small-signal and RF power devices has improved in every important metric, from noise figure to linearity and efficiency, and in RF power devices with higher outputs at higher frequencies. All of these improvements are reflected in the capabilities of today's radar systems, and the roadmap for GaAs as well as silicon germanium (SiGe) technology is impressive.

However, around 2005, gallium nitride (GaN) RF power transistors and later MMICs began their rise as the "next big thing" in compound semiconductors for use in RF and microwave applications. The genesis was DoD's decision to use them for generating RF power in Improvised Explosive Device (IED) jammer amplifiers destined for Iraq and Afghanistan. Thus they were thrust from developmental to production status at an astonishing rate, even though at the time they were first employed, reliability and other benchmarks were far from proven. Nevertheless, the success of the Counter-Radio Controlled Improvised Explosive Device (RCIED) Electronic Warfare (CREW) program (now in its third generation), has made GaN a primary topic of conversation for use in other applications, one of which is radar systems.

An AESA radar can produce many sub-beams and can paint many targets over a very wide range of frequencies, but it can also concentrate all beams to produce the appearance of a single aperture. As a result, no single T/R module need deliver high RF output power, as the gain of the many antenna elements produces the desired ERP. As DoD's goal is to increase RF power output at the element level, this makes a compelling case for broadband, high power-density, GaN-based amplifiers.

GaN's power-added efficiency is equal to that of GaAs, but it has up to 10 times the power density (currently up to 11 W/mm of gate periphery), and a GaN-based power amplifier can deliver more than 100 W with 50 percent or greater efficiency. This supports the concept of a 1 kW CW pallet



through four- or eight-way combining depending on the power level of the building block. Not too long ago, GaN's ruggedness remained in question, but the ability to operate to a 10:1 VSWR is not unrealistic.

However, GaN's exceptionally high power density comes at the expense of large amounts of heat that must be dissipated both at the device, subsystem and system levels. In a radar system that has thousands of elements, each one with a GaN-powered amplifier, this is not a trivial concern. At the device level, one promising technology is the use of aluminum-diamond metal matrix composites in place of copper-moly-copper or other materials as a heat spreader.

Diamond, whether natural or synthetic, has the highest thermal conductivity of any substance, and at least twice that of its alternatives. It offers significant promise. However, it is still likely that radar, as well as EW and other systems employing high power, GaN-based amplifiers, will require some form of advanced cooling. Nevertheless, DoD is solidly behind the use of GaN, both in EW systems (of which the Next Generation Jammer is an excellent example) as well as radar systems. This virtually assures its increased use in defense applications.

CHALLENGES FOR THE FUTURE

DoD has long been frustrated that it must buy multiple radars to perform similar functions rather than a single one, as there is no standardized system architecture, which results in unique, proprietary designs. That is, if five radar systems are developed by different contractors, the result will almost invariably be five different, proprietary systems that essentially serve the same mission or missions, but are different in almost every respect.

In the domain of embedded systems, standards such as VPX have made enormous strides in providing commonality between products of various vendors, and have reduced cost and perhaps increased the number of suitable products. No such situation exists in the RF and microwave domain. The entire radio interface remains almost fully proprietary, which makes it exceedingly difficult for second-tier suppliers to develop products that deliver high performance and reduce cost, significantly reducing risk.

This is perhaps one of the reasons why RF and microwave content rarely finds its way into embedded systems as have signal processing, single board computer and other functions. The RF and microwave industry, as it relates to defense systems, is famous for being a wholly custom business and there are no rules with which this technology can be integrated within standards that today are typically used for digital embedded systems. This makes clock distribution, channelization and switching in the backplane virtually impossible to integrate and there is no switchable RF systems architecture that is compatible with the bladed architecture of embedded systems. There are no constraints on RF architecture in the backplane and thus little progress in achieving greater modularity. Without an open, standardized approach it is likely that this "one-off" approach to design will continue, frustrating efforts to reduce cost.

Fortunately, there is an initiative within DoD to create open radar architectures, creating reusable "plug-and-play" subsystems and facilitating the use of COTS components from a broad array of vendors, in order to enable fast technology refresh while lowering the cost of new radar systems. There are significant benefits, including integration of legacy radar systems, easier development of multi-function radars, rapid insertion of new technology, scalable architectures, enterprise-wide sharing of information and of course, cost reduction. This is the future of defense radar systems and its necessity has become even more obvious as impending and truly draconian reductions in defense spending become more likely.

There is also, as of November 9, 2011, a broad agency announcement (BAA) from the Defense Advanced Research Projects Agency (DARPA) for what it calls an "RF-FPGA," superficially at least an oxymoron. However, the BAA actually is, in DARPA's words, to "enable a common hardware architecture that facilitates reutilization of the same set of RF front-end components across disparate applications through programmability of the transceiver chain. RF-FPGAs will impact the areas of communications, electronic warfare radar, and signal intelligence by eliminating redundant and costly hardware development required for the adoption

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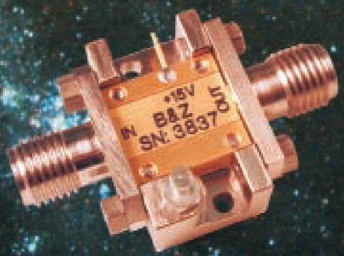

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BZ1826A	18	26	2.5	28	8	1.0	2.0:1	$875
BZP518A	0.5	18	2.7	30	10	1.8	2.5:1	$985
BZ0618B	6	18	1.8	30	10	1.5	2.0:1	$985
BZ0412B	4	12	1.6	28	10	1.5	2.0:1	$785
BZP506A	0.5	6	1.4	25	10	1.3	2.0:1	$875
BZP504F	0.5	4	1.3	30	17	1.0	2.0:1	$985
BZ0204F	2	4	1.0	30	17	0.5	2.0:1	$685
BZ0102F	1	2	1.0	30	17	0.5	2.0:1	$685

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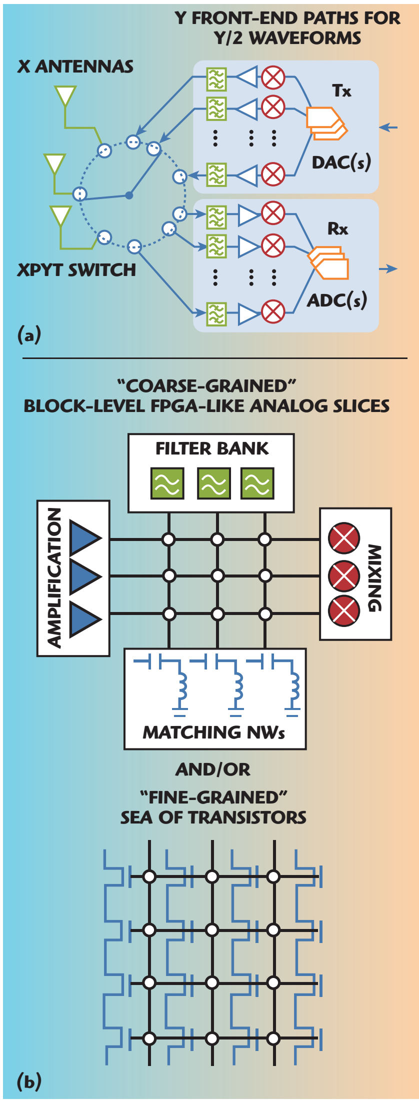
or recognition of a new wireless function or waveform" – in other words, RF standardization. Hardware resulting from the program will be dynamically-programmable analog and RF blocks similar in purpose to a digital FPGA slice (see ***Figure 5***). It aims to demonstrate working blocks of reconfigurable components and programmable transceivers capable of configuring for a variety of wireless applications while maintaining near optimal performance. Proposals are due January 26, 2012.

CONCLUSION

The many challenges discussed in this article are formidable, but achievable. They include producing higher levels of integration at the element level of the array, miniaturizing both digital and RF and microwave circuits, reducing power consumption, increasing resolution, delivering greater RF output power, increasing signal processing performance and ultimately converting signals from analog to digital form as close to the antenna as possible. In concert with an effort to provide a standards-based, open radar architecture and a similar effort for RF circuits, they are virtually certain to produce systems that meet the requirements of the future. ■



▲ *Fig. 5 The current state of the art in design (a) is in marked contrast to DARPA's proposed RF-FPGA approach (b).*

Ian Dunn *is Vice President and General Manager of Mercury Computer Systems' Microwave & Digital Solutions Group. He was previously the company's Chief Technology Officer responsible for technology strategy and R&D projects. Dunn joined Mercury Computer Systems in 2000 as a systems engineer upon completing his doctorate at Johns Hopkins University in Electrical Engineering. As a doctoral student there, he consulted for Disney Imagineering and Northrop Grumman on distributed automation and various high performance computing projects. Dunn has 20 years of experience designing and programming parallel computers for real-time signal processing applications and has authored many papers and a book on designing signal processing applications for high performance computer architectures.*

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Passive intermodulation (PIM) is a growing issue for cellular network operators. PIM issues may occur as existing equipment ages, when co-locating new carriers or when installing new equipment. It is a particular concern when diplexing new carriers into old antenna runs.

High speed digital data communications make PIM testing critical. As cell usage and throughput grows, the peak power produced by the new digital modulations increases dramatically, contributing heavily to PIM problems.

For these reasons, Anritsu Co. has developed the MW8209A PIM Master. The new analyzer has been designed specifically to support the 900 MHz band to address the growing need to measure PIM in E-GSM networks, including UMTS Band VIII and LTE Band 8.

Field engineers and technicians can use the MW8209A to help ensure optimum performance of UMTS Band VIII and LTE Band 8 networks by locating PIM faults before intermodulation distortion adversely affects signal transmission. The MW8209A has been designed to be integrated with many of Anritsu's handheld instruments – the S332E/S362E Site Master™ cable and antenna analyzers, MS2712E/MS2713E and MS272xC Spectrum Master™ handheld spectrum analyzers, MT8212E/MT8213E Cell Master™ handheld analyzers and the MT8221B/MT8222A BTS Master™ handheld analyzers.

Field personnel can use the PIM Master to generate two high power tones in the transmit band of a base station, and use any of the compatible handheld analyzers to measure the 3rd, 5th, or 7th order intermodulation products in the receive band that travel down the same cable. Using the GPS option available on all the analyzers, the location of the measurement can be recorded, as well.

INNOVATIVE PIM TECHNOLOGY

Anritsu's patented Distance-to-PIM™ (DTP) is a standard feature on the MW8209A. DTP helps field engineers, technicians and contractors pinpoint passive intermodulation faults, eliminating the unknown of whether the PIM source is from the antenna system or surrounding environment. Simple, immediate and accurate, DTP simultaneously informs the user of the distance and magnitude of all the PIM sources, both inside the antenna system and beyond the antenna.

DTP testing provides the detail and insight that can expedite repairs, control repair costs and help plan budgets. Historical data can be used to monitor a site and determine if corrections need to be made before a failure results in dropped or blocked calls.

2 X 40 W PIM TESTING

Many PIM problems can be intermittent. This is often the case in the early stages of a PIM issue, and can be caused by light corrosion, high traffic loading or changing weather conditions activating environmental diodes. High power levels can help show these intermittent PIM sources more clearly than a standard 20 W tester. Also, testing at 40 W more closely duplicates the power levels found in today's multicarrier, heavily loaded base stations. This allows the technician to find PIM problems and microscopic arcing that could go unnoticed with a 20 W PIM tester.

With 40 W of power and Distance-To-PIM, the MW8209A can help the operator find all sources of PIM, minimizing trips to the site and giving him maximum data throughput for his customers.

VENDORVIEW

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Morgan Hill, CA,
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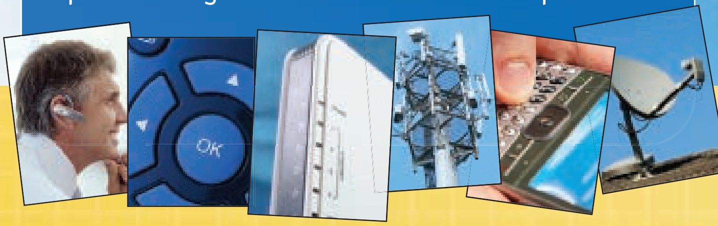

Anaren's newly expanded line-up of subminiature Xinger®-brand couplers, power dividers, baluns, and RF crossovers are the *reliable* solution for today's compact infrastructure equipment and point-of-use wireless devices.

From analog-to-digital conversion and pre-distortion receivers, transceivers, and low-power amplifiers – to handsets, handhelds, laptops, Bluetooth® devices, set-top boxes, and other broadcasting equipment – this family of parts offers:

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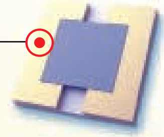
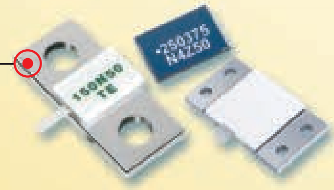
> **Low insertion loss** and excellent power handling for their size

> **Suitability for a wide range of bands and protocols,** including WiFi, WiMax, Bluetooth®,





Lockheed Martin AMF JTRS Team Successfully Demonstrates New Communications and Tactical Sharing

A Lockheed Martin team recently demonstrated how software-defined radios can extend the Army's tactical network by connecting disparate ground troops with the Airborne and Maritime/Fixed Station Joint Tactical Radio System (AMF JTRS). During a recent Army exercise, AMF JTRS demonstrated the system's range and capability by successfully relaying a combination of voice, data and imagery from a test bed AH-64 Block III Apache helicopter to ground forces over the Internet-Protocol enabled Soldier Radio Waveform (SRW).

AMF JTRS is a software defined radio that is capable of providing Internet-like connectivity with a secure infrastructure for joint forces to send data, imagery, voice and video. "The recent aerial demonstration of the JTRS capability in an Apache helicopter represents a significant step forward in maturing the tactical network and providing a significant force multiplier for our warfighters," said Colonel Raymond Jones, Assistant Joint Program Executive Officer, JTRS. "By continuing to build out the aerial layer of the network, we will be providing enhanced range, over the horizon capability and situational awareness to our soldiers on the ground."

"The recent aerial demonstration of the JTRS capability in an Apache helicopter represents a significant step forward in maturing the tactical network and providing a significant force multiplier for our warfighters."

During the exercise, a pre-engineering development model AMF JTRS Small Airborne radio in the Apache allowed pilots to communicate directly with six disparate ground elements using JTRS Handheld Manpack Small (HMS) Form Fit Rifleman Radios. The Apache first provided an aerial network extension for ground-based communications between troops who were separated by mountainous terrain and long distances. Using AMF JTRS, the Apache provided an automatic relay without having to deviate from its assigned mission of providing close air support for ground forces, and during the same mission, enabled forces using HMS Rifleman Radios to communicate by voice and data with the Apache over greater distances. The Apache was able to break all connections in the network and then rejoin all units in the JTRS network without major delay or information loss.

"The Apache's participation not only emphasized the significant benefits of extending the network to the air, it also showcased the power of the network in linking the capabilities of the Apache directly to soldiers on the ground," said Colonel Shane Openshaw, Apache Program Manager. "Soldiers depend on Apaches every day and this exercise successfully demonstrated that we are on the right path to improving the ability of aviation forces to support our ground soldiers."

The Apache and the ground forces were communicating using joint tactical radios enabled with SRW. By using mission applications on the AMF JTRS radio, ground nodes in the tactical operations center were able to markup imagery and re-distribute to users connected by the JTRS network. Throughout the simulated mission, Apache pilots, using AMF JTRS, were able to seamlessly exchange command and control and situational awareness messages with six groups of disparate ground forces (each equipped with JTRS-enabled radios).

"Our team is delivering capability, and moving forward in creating a mobile, secure and affordable network that will provide an enormous operational benefit for our forces for many years to come," said Mark Norris, Vice President of Lockheed Martin's AMF JTRS program. Lockheed Martin's AMF JTRS team includes General Dynamics, Northrop Grumman, Raytheon and BAE Systems.

Raytheon Awarded $241 M Contract to Continue Work on SM-3 Block IIA

The Missile Defense Agency awarded Raytheon Co. a $241 M contract modification for continued engineering design and development work on the Standard Missile-3 Block IIA. The SM-3 Block IIA is a co-development effort between the US and Japan and the cornerstone of phase three of the administration's Phased Adaptive Approach. The SM-3 Block IIA's larger rocket motors and advanced kinetic warhead will allow for a greater defended area, protecting both the US and its allies from ballistic missiles.

"The co-development of the SM-3 Block IIA with our Japanese allies continues to be an industry-leading example of global partnership," said Wes Kremer, Vice President of Raytheon Missile Systems' Air and Missile Defense Systems product line. "The SM-3 Block IIA is on track for a 2018 deployment."

SM-3 is being developed as part of the Missile Defense Agency's sea-based Aegis Ballistic Missile Defense System. The missiles are deployed on Aegis cruisers and destroyers to defend against short- to intermediate-range ballistic missile threats in the midcourse phase of flight. Raytheon has delivered more than 130 SM-3s to US and Japanese navies ahead of schedule and under cost.

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Northrop Grumman to Provide Combat Electromagnetic Environment Simulator

Northrop Grumman Corp. has been awarded a contract to provide a Combat Electromagnetic Environment Simulator (CEESIM) system to support maintenance of the US Air Force E-3 Airborne Warning and Control System (AWACS) Electronic Support Measures Operational Computer Program software. The contract was awarded by Defense Microelectronics Activity (DMEA). Northrop Grumman will deliver the CEESIM to Tinker Air Force Base Avionics Integration Support Facility (AISF), located in Oklahoma City, OK. The CEESIM provides navigation and pulse data generated from customized scenarios. It enables AISF software engineers to model a real-world environment and to test software changes by injecting pulses into the avionics hardware.

"The flexibility of the AWACS CEESIM system allows for adaptation to a wide variety of both system-under-test and existing laboratory external control interfaces," said Joe Downie, President of Northrop Grumman's Amherst Systems Business Unit. "This flexibility provides a cost-effective transition from the existing simulator to a state-of-the-art, supportable, modern simulator capability, in support of fifth-generation electronic warfare systems."

The AWACS CEESIM system will replace an Advanced Multiple Environment Simulator (AMES) system that has been operating at Tinker Air Force Base for 14 years. The CEESIM replacement unit allows automatic conversion of legacy AMES emitter files to CEESIM emitter files for seamless reuse of AISF threat data and test scenarios. The simulator also demonstrates the CEESIM versatility allowing for direct stimulation using radio frequency, intermediate frequency and digital outputs.

"The flexibility of the AWACS CEESIM system allows for adaptation to a wide variety of both system-under-test and existing laboratory external control interfaces."

DMEA is a Department of Defense applied engineering facility charged with keeping microelectronics components in military systems operational and technologically current. DMEA works in cooperation with both defense prime contractors and the commercial semiconductor industry to ensure that the full range of military systems, developed over 40 years, are supportable and operationally ready to perform their mission.


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European Researchers Drive Semiconductor Technology

Europeans continue to rise to the challenge of advancing communication, imaging and radar integrated circuits to work at high frequencies. A team at Interuniversitair Micro-Electronica Centrum Vzw (imec) in Belgium has developed the fT/fMAX 245/450 GHz SiGe:C heterojunction bipolar transistor – a sophisticated device that will help facilitate future high volume millimetre-wave low power circuits to be used in automotive radar applications. The study was funded in part by the Towards 0.5 terahertz silicon/germanium heterojunction bipolar technology (DOTFIVE) project, which received €9.7 M under the Information and Communication Technologies theme of the EU's Seventh Framework Programme (FP7).

In order to secure the ultra-high speed requirements, sophisticated SiGe:C HBTs require additional upscaling of the device performance. For the most part, thin sub-collector doping profiles are considered a must for this upscaling. The collector dopants are typically introduced at the start of the process and are, therefore, exposed to the complete thermal budget of the process flow. Because of this, the accurate positioning of the buried collector is harder to obtain.

In a statement, the imec researchers pointed out that performing in situ arsenic doping during the simultaneous growth of the sub-collector pedestal and the SiGe:C base allowed them to introduce both a thin, well-controlled, lowly doped collector region close to the base and a sharp transition to the highly doped collector, without further complicating the process.

This led to a significant increase in the overall HBT device performance: peak fMAX values above 450 GHz are obtained on devices with a high early voltage, a BVCEO of 1.7 V and a sharp transition from the saturation to the active region in the IC-VCE output curve. According to the researchers, the collector-base capacitance values did not rise much even though they performed aggressive scaling of the sub-collector doping profile. They said the current gain is well defined, with an average around 400; the emitter-base tunnel current, visible at low VBE values, is limited too.

The DOTFIVE Project

DOTFIVE aims to establish a leadership position for the European semiconductor industry in the area of SiGe HBTs for millimetre-wave applications and involves semiconductor manufacturers, including STMicroelectronics and Infineon Technologies. In addition to evolving markets, DOTFIVE technology sets out to be a key enabler for silicon-based millimetre-wave circuits penetrating the THz gap, enabling enhanced imaging systems with applications in the security, medical and scientific area.

Global Mobile Connections Soar in Asia-Pacific to Three Billion

Asia-Pacific added nearly one billion global mobile connections from two years ago – growth that is fueled by rapid economic development in the region, where increased rollout of mobile network infrastructure, citizen prosperity and affordability of mobile handsets have encouraged adoption, according to ABI Research.

Less than 18 percent of the three billion connections in Asia-Pacific are 3G and 4G enabled, but that is expected to change quickly.

China successfully surpassed 100 million 3G subscriptions in September 2011…

"Mobile broadband connections will experience rapid growth over the next two years, driven by 3G network rollouts in India and China and 4G deployments in Japan and South Korea," said ABI Research Practice Director Dan Shey.

China successfully surpassed 100 million 3G subscriptions in September 2011, just 10 percent of its total mobile population.

"Subscription growth for the China-developed TD-SCDMA standard has been slow due to lack of compatible handsets, but 16 million new connections over the past two quarters suggest growth is accelerating," commented Research Analyst Fei Feng Seet. TD-SCDMA subscriptions are forecast to hit 100 million by the end of 2013.

3G adoption is expected to ramp up in India as well, where 3G networks went live in 2010. India's largest operator by subscribers, Bharti Airtel, launched early in 2011 and gained three million 3G customers in less than six months of operation. Low-cost smart feature phones are already entering these markets to drive 3G connections among consumers.

ITU, Industry Partners Form Global Coalition on ICT and Climate Change

The International Telecommunications Union (ITU), together with a coalition of industry partners, is working to advance the call to harness the power of information and communication technology (ICT) to promote mitigation and adaptation to climate change. The ITU and the Global e-Sustainability Initiative (GeSI) have initiated the Global Coalition on ICT and Climate Change. Organizations in the coalition include the UNFCCC Secretariat, the UN Global Compact, TechAmerica, as well as high level representatives from the governments of Ghana, South Africa and Egypt.

The coalition's message is simple: ICTs such as smart grids, intelligent transport systems and the "Internet of things" have extraordinary potential to reduce the green-

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house gas (GHG) emissions of other high energy-consuming industry sectors, and must be included in any meaningful climate change policies at the global, regional and national level.

"It is imperative that our massively inter-connected world also becomes a greener, more sustainable world. 'Smart' technologies will help to bridge the digital divide and improve the lives of millions – billions, even – of people," said Dr. Hamadoun Touré, ITU Secretary General. "Look at the benefits, which can be achieved with intelligent transport systems, or through the digitization of goods, processes and services. We need to move now to take advantage of the powerful tools already in our hands."

UK's Small and Medium Enterprises Get £75 M to Help with Innovations

Incentives to spur companies to innovate and grow, including £75 M of additional funding targeted at small and medium-sized businesses, form part of the UK government's Innovation and Research Strategy. The strategy announcement reveals that some of this funding, including the additional support for small and medium enterprises (SME), will be delivered to businesses by the UK's innovation agency, the Technology Strategy Board.

"A good deal of the innovation that happens in the UK comes from SMEs, and with innovation comes business growth," said Iain Gray, the Technology Strategy Board's Chief Executive. "This new package of measures will help to put these businesses at the forefront of the country's economic recovery. This package enables the Technology Strategy Board to do even more to stimulate business-led innovation in its leading role as the UK's innovation agency."

"…with innovation comes business growth."

Additional funding will be made available for the Smart scheme – previously Grant for Research and Development. Smart offers funding to small and medium-sized enterprises to engage in R&D projects from which successful new products, processes and services could emerge.

The SBRI programme, which uses the power of government procurement to drive innovation by providing opportunities for innovative companies to engage with the public sector to solve specific problems, will also receive additional funding. SBRI enables the public sector to engage with industry during the early stages of development, supporting projects through the stages of feasibility and prototyping.

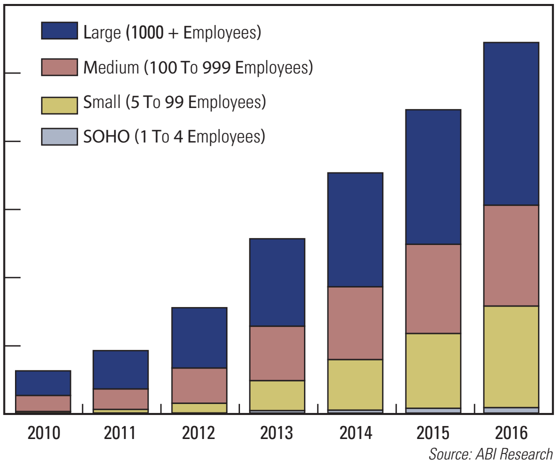
Dan Massé, Associate Technical Editor

Enterprise Mobility Management Services will Grow to $11 B by 2016

AT&T, Motorola Mobility, Samsung Mobile – these are the latest companies announcing their intent, or actual products and services, for managing mobility in the enterprise. Enterprise mobility management services, which include services to manage mobile apps, devices, content, network services, expenses, policy, and security, will grow to $11 B worldwide by 2016.

ABI Research's "Enterprise Mobility Management Services for Smartphones and Media Tablets" provides five-year enterprise mobile management subscriber forecasts by delivery channel, size of business, device type, platform type, and for corporate-liable and individual-liable employees across seven world regions The report provides extensive reviews of leading suppliers and the supplier ecosystem, including analysis of Apple and Google. The report also provides telecom expense management subscriber and revenue forecasts. It is part of ABI Research's Enterprise Mobility research service.

Mobile Device Management Services Subscribers
World Market, Forecast: 2010 – 2016



EJL Wireless Research Announces Second Report Focused on BTS Transmission Lines

EJL Wireless Research is announcing the second report within its new and proprietary series of research reports focused on the RF transmission lines market that connects wireless macro cell base stations (BTS) and the BTS antennas. The second report focuses on the global jumper cable market, which is the primary solution that interfaces the feeder cables and remote radio units (RRU) to the BTS antenna.

"Similar to our findings in the feeder cable report, the jumper cable market dropped 27 percent year over year in total volumes (measured in units of cables) in 2010. In terms of jumper cable lengths, the 2 to 5 m jumper cable product segment remained the largest in 2010, followed by the < 2 m and the > 5 m segments," said Founder and President Earl Lum.

"Our research confirms that the 7/16 DIN straight male-male jumper cable segment remains the predominant jumper cable configuration at 69 percent of total shipments in 2010."

Weak end-market demand in Asia-Pacific (China and India) and Africa offset strong demand in North America in 2010. "In revenue terms, the 1/2" superflex jumper cable market accounted by 65 percent of overall market revenues in 2010 followed by the 1/2" standard jumper cables. Our research confirms that the 7/16 DIN straight male-male jumper cable segment remains the predominant jumper cable configuration at 69 percent of total shipments in 2010," Lum said.

Report Predicts Surge in LTE Subscribers

New forecasts from TeleGeography predict massive growth in the global LTE market in the coming years, with more than 400 million subscribers expected by the end of 2016. While the US is currently the leader in subscribers, it is predicted that by 2016 the US will have been pushed into second place behind the APAC region, while Western Europe will be in third position.

"…ensuring these users receive good service will heavily depend on operators executing a successful rollout – something that did not happen when, for example, 3G was rolled out in the UK."

Murat Bilgic, Advisor, CTO Office at EXFO, a network evolution specialist, made the following comments:

"While these forecasts predict enormous subscriber growth, ensuring these users receive good service will heavily depend on operators executing a successful rollout – something that did not happen when, for example, 3G was rolled out in the UK. A recent report from Ofcom further demonstrates this issue, illustrating just how poor 3G coverage is in much of the UK, with vast swathes of the country either still relying on 2G, or receiving a patchy 3G service resulting in dropped calls and lack of mobile broadband availability. Such issues hint at a poorly planned rollout – something European and Asian service

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providers must be careful to avoid as they try to catch up with pacesetters in the US.

"With 4G evolution looming, future revenues depend on operators getting rollout right, the first time. LTE networks are surrounded by a similar amount of hype that greeted their 3G predecessors, but present a new proposition on a number of levels. The all-IP nature of LTE is an issue that needs to be taken into account as it requires a completely new, more granular approach to test and measurement. This will be especially important when voice becomes another service delivered over IP as its quality has to be ensured while serving other types of data traffic over the same radio network at the same time. Using IP and Ethernet all the way to the cell site will also require new monitoring and troubleshooting tools to ensure deployment is right first time."

Mobile Experts Predict 7 Million LTE Macro Transceivers Shipments in 2016

A new forecast released by Mobile Experts predicts a shifting market for mobile communications base stations, with new technologies driving growth in the number of radio transceivers deployed annually. The forecast predicts that more than 14 million radio transceivers will be installed during 2016, with more than half deployed for LTE services.

"Despite the rise of small cells, the macro infrastructure market will remain strong," said Joe Madden, Principal Analyst at Mobile Experts. "In particular, rising data traffic demand will drive a need for ongoing investment in the macro layer, especially for 3G, TD-LTE and LTE-FDD systems."

"Despite the rise of small cells, the macro infrastructure market will remain strong."

"Because of the complexity of LTE systems, the number of transceivers per base station is much higher than 2G or 3G systems," Madden said. "MIMO architectures are driving two to four transceivers per sector, and Active Antenna Systems (AAS) will drive an even higher numbers of radios. Everything is changing in the base station: Power levels are changing, frequency bands are fragmenting, RRH units are growing and the OEM mix is changing rapidly. Our forecast gets into the details."

2 GHz Clock Generator

CG635...$2995 *(U.S. list)*

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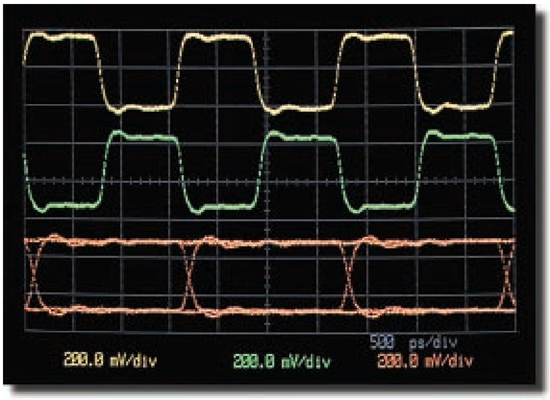

Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

The CG635 generates clock signals—flawlessly. The clock signals are fast, clean and accurate, and can be set to standard logic levels.

How fast? Frequency to 2.05 GHz with rise and fall times as short as 80 ps.

How clean? Jitter is less than 1 ps and phase noise is better than –90 dBc/Hz (100 Hz offset) at 622.08 MHz.

How accurate? Using the optional rubidium timebase, aging is better than 0.0005 ppm/year, and temperature stability is better than 0.0001 ppm.

You would expect an instrument this good to be expensive, but it isn't. You no longer have to buy an rf synthesizer to generate clock signals. The CG635 does the job better—at a fraction of the cost.

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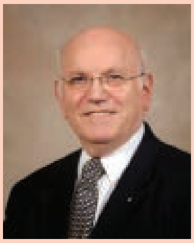
Around the Circuit

Kerri Germani, Staff Editor

INDUSTRY NEWS



▲ Roger Pollard

Roger Pollard, IEEE Secretary and former Dean of the Faculty of Engineering at the University of Leeds, died December 3. He was a member of the IEEE Board of Directors and a long-time volunteer. He previously served IEEE as Vice President of Technical Activities, as Chairman of the United Kingdom-Republic of Ireland Section (one of IEEE's largest), and as President of the IEEE Microwave Theory and Techniques Society. Pollard retired in 2010 from the University of Leeds, where he also held the Agilent Technologies Chair in High Frequency Measurements. For the past 30 years, he was a consultant to Agilent Technologies, Santa Rosa, CA. His highly respected research on microwave instrumentation and measurement led to his elevation to IEEE Fellow and Membership in the Royal Academy of Engineering (UK).

Agilent Technologies Inc. and **Accelicon Technologies** announced they have signed a definitive acquisition agreement. Accelicon, a privately held company, provides device-level modeling and validation software for the electronics industry. The transaction is expected to be completed in 60 to 90 days. Financial details were not disclosed. The acquisition is led by Agilent's EEsof EDA organization. The majority of Accelicon's 30 employees are located in Beijing, China. As a result of this acquisition, Agilent's device modeling R&D and services will expand in Asia, a growing region, where many leading foundries reside.

CTS Corp. and **Valpey Fisher Corp.** announced that they have entered into a definitive merger agreement providing for the cash acquisition of Valpey Fisher by CTS. Upon closing of the transaction, Valpey Fisher will operate as an indirect wholly owned subsidiary of CTS. Pursuant to the terms of the definitive agreement, CTS will acquire 100 percent of the issued and outstanding equity of Valpey Fisher for $4.15 per share for a total purchase price of approximately $18 M. Valpey Fisher has $3 M of cash and is essentially debt free. Valpey Fisher's Board of Directors has unanimously approved the merger and recommends that Valpey Fisher's stockholders vote in favor of the transaction. The transaction is subject to customary closing conditions and approval of Valpey Fisher's stockholders. The transaction is expected to close in January 2012.

DragonWave Inc. plans to acquire **Nokia Siemens Networks'** microwave transport business, including its associated operational support systems (OSS) and related support functions. Under the terms of the "Master Acquisition Agreement," as well as acquiring the business, DragonWave would also become the preferred, strategic supplier to Nokia Siemens Networks of packet microwave and related products, and the companies would jointly coordinate technology development activities. Nokia Siemens Networks and DragonWave believe the proposed acquisition and supply agreements would accelerate innovation in backhaul products, supporting world class microwave solutions for mobile operators. The companies aim to complete the planned acquisition and supply agreements in the first quarter 2012.

API Technologies Corp. announced that is has completed the acquisition of substantially all of the assets of **Commercial Microwave Technology Inc.** (CMT) for a total purchase price of $8.2 M in cash. Based in Rancho Cordova, CA, CMT was founded in 1997 and is a leading manufacturer of RF and microwave filters to the satellite and commercial industries. CMT's customers include many Fortune 100 companies as well as industry-leading providers of public safety products, and wireless and broadband communication services. Product lines feature off-the-shelf and custom-designed lumped element filters, cavity filters, combline filters, and waveguide filters, for use in a variety of applications, including satellites, surveillance, remote metering and interference mitigation.

Skyworks Solutions Inc. and **Advanced Analogic Technologies Inc.** announced that the two companies have amended their previously announced merger agreement. Under the terms of the revised merger agreement, Skyworks will acquire all of the outstanding shares of AnalogicTech for $5.80 per share in cash through a tender offer that Skyworks intends to commence within seven business days. The companies expect the transaction to be completed in January 2012.

Giga-tronics announced an agreement with **Liberty Test Equipment** to offer rental and distribution of Giga-tronics' high performance RF and microwave test and measurement equipment in the US and Canada. Liberty Test Equipment will provide rental and distribution of Giga-tronics RF and microwave test solutions, including fast-switching microwave signal generators, microwave power amplifiers and high accuracy power meters and sensors. The partnering agreement will include options for integrated promotion, advertising and sales of test solutions.

Intercept Technology Inc., a leader in PCB/Hybrid/RF electrical engineering applications, has joined the **IPC-2581 Consortium**. Intercept has always been a strong supporter of open data transfer, and continues to support such efforts with its commitment to provide the IPC-2581 file format. As one of the few vendors that still utilize open ASCII formats for all of its output files, the IPC-2581 will be added to Intercept's suite of ASCII manufacturing output options within the next year. Intercept strongly supports vendor collaboration for the promotion of improved design and manufacture practices.

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HIGH POWER PRODUCTS

POWER DIVIDERS

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

◊ In excess of theoretical split loss of 3.0 dB
◦ With matched operating conditions

HYBRIDS

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

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] ◦	Package
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322

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

Unless noted, products are RoHS compliant.

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Around the Circuit

OEM Worldwide LLC announced an organizational name change to **Onyx EMS LLC** as it outlines strategies for future growth. In conjunction with the name change, Onyx is completing an $11 M expansion and improvement project to its manufacturing and engineering facilities over the next four years. The company broke ground on a 50,000 square-foot expansion to its existing headquarters in Watertown, SD, on September 20, 2011. The expansion will double the company's system-build and warehousing capacity. Onyx will also upgrade and replace automated printed circuit board assembly equipment to increase current manufacturing capacity and prepare the company for expansion. Additionally, in February 2011, the company opened a new Twin Cities Technical Sales office in MN with engineers available to respond to design and engineering needs for the company's growing customer base.

Interconnect Devices Inc. has been awarded a **Raytheon** 3-Star Supplier Excellence Award. Raytheon presented the award to 39 companies for supporting the company's Space and Airborne Systems. They were chosen for meeting standards in the areas of quality and delivery performance, customer satisfaction and total business and financial health.

LPKF, a manufacturer of laser and electronic systems, announced that it has been awarded a Global Technology Award in the category of Assembly Tools for its MicroLine 1000 S. The award was presented to the company on November 15 during the awards ceremony at the New Munich Trade Fair Centre in Munich, Germany, during Productronica 2011. The MicroLine 1000 S presents a compact and cost-effective method for UV-laser depaneling of thin-rigid and rigid-flex assembled PCBs.

Anritsu Co. announced that its ME7834 Mobile Device Test Platform, BTS Master and Cell Master handheld analyzers have made the finalist list for the LTE North America Awards 2011. The test solutions are finalists in the Best Network/Device Testing Products for LTE, one of 10 categories that comprise the awards. Anritsu is one of only five test companies to be shortlisted in the respective category. Anritsu is also one of only two companies who received multiple nominations in any of the 10 categories that comprise the award competition. The ME7834A/L Mobile Device Test Platform is a scalable system for protocol conformance and carrier acceptance testing of 2G, 3G, and 4G/LTE wireless technologies.

TriQuint Semiconductor Inc. was named to Fortune Magazine's™ annual 100 Fastest-Growing Companies list, featuring innovators in all aspects of the global economy. TriQuint ranked 49th in profit growth based on several financial performance metrics over a three-year period. TriQuint's growth was due in part to significant design wins across several high growth markets, including smartphones, tablets, 3G/4G base stations, optical networks and cable systems.

M/A-COM Technology Solutions Inc. has honored **WIN Semiconductors Corp.** with its Foundry Supplier of the Year Award for 2011. WIN Semiconductors provides M/A-COM Tech with market leading GaAs MMIC foundry services across a broad range of HBT and PHEMT technologies. The superior level of support and comprehensive technology portfolio provided by WIN Semiconductors' advanced foundry services has facilitated M/A-COM Tech's development and introduction of new products in many of its markets. This award recognizes WIN Semiconductors for its outstanding performance in quality and service, technology development and strategic collaboration.

Microwave Marketing has expanded its microwave design and manufacturing operations under **Linwave Technology** from an initial staff of six in 2003 to a level exceeding 45 today and has begun work on a new joint headquarters with the purchase of a 1.5 acre site in Lincolnshire, UK. The facility will satisfy design/manufacturing requirements for Linwave Technology and office/warehouse requirements for Microwave Marketing. It will initially extend over 11,000 square feet with additional land retained for further business expansion in the future.

CONTRACTS

Cobham has been awarded two contracts totaling more than US $72 M during the next six years through its newly acquired **Trivec-Avant** business, which has become part of the Antenna Systems Strategic Business Unit. The US Navy Space and Naval Warfare Systems Command (SPAWAR) has issued a $60.7 M contract to add options and contract extensions for the purchase of commercial off the shelf (COTS), small ship variant, ultra-high frequency (UHF) satellite communication antenna systems and mobile user objective systems, with associated spares and subassemblies. A six-year purchase agreement was also recently signed with **Thales Communications Inc.**, to supply a variety of SATCOM antennas in support of Thales' Integrated Waveform rollout for its AN/PRC-148 Joint Tactical Radio System Enhanced Multiband Inter/Intra Team Radio (AN/PRC-148 JEM). The agreement could result in revenue of up to $2 M per year.

Dynamics Research Corp. (DRC) announced that its High Performance Technologies Group has been awarded a $14.7 M contract with the Department of Veterans Affairs' Office of Information and Technology. Under the terms of the contract, DRC will operate, manage, and enhance the Budget Tracking Tool, a web-based government application that allows the Department of Veterans Affairs to streamline reporting processes, support management functions and automate business processes.

Micronetics Inc. announced that it has been awarded a production contract release, valued at approximately $3.9 M, from a leading US Department of Defense (DoD) prime contractor for the supply of high performance broadband microwave subsystems. The company also has been awarded an initial production order valued at approximately $2.4 M from a leading precision antenna system manufacturer for the supply of high performance microwave subsystems.

ASC Signal Corp. has been awarded a $3.8 M sub-contract by **L-3 Communications Systems-West** to build a dual-band antenna system to support global data collection and dissemination worldwide for the US Navy

Around the Circuit

MQ-4C Broad Area Maritime Surveillance Unmanned Aircraft System (BAMS UAS) program. The advanced antenna terminals will be designed to meet the stringent ARSTRAT (Army Forces Strategic Command) standards required to operate with the US Department of Defense's Wideband Global Satcom (WGS) constellation, a high capacity satellite system deployed across the Pacific, Indian and Atlantic Ocean regions that supports BAMS and other military platforms.

RF Industries' RadioMobile Division announced the award of a $2.6 M contract from the Los Angeles County Fire Department for the implementation of a wireless system upgrade to the County Fire Department's existing remote communications equipment. RadioMobile has the unique ability to replicate the county's existing technology and simultaneously implement a high speed data solution satisfying FCC Narrowband requirements.

API Technologies Corp. announced that it has received a new order, valued at $1.3 M, for an Integrated Microwave Assembly (IMA) to be used in Navy ships, submarines and shore stations. The new system is designed to provide naval commanders and sailors with greater data throughput capacity and improved protection against enemy intercepts. API's RF Solutions division was awarded the order by a Fortune 500 defense contractor.

Advantech Wireless has been awarded a contract to supply point-to-point microwave radio equipment to **Pittsburgh International Telecommunications**. Transcend™ 800 is Advantech Wireless' second generation microwave system that is capable of transmitting MPEG data directly from broadcast equipment through Transcend 800 integrated DVB-ASI interfaces over the microwave link. The DVB-ASI interfaces support standard definition, high definition, and Digital 3D broadcast applications with capacity of 214 Mbps per ASI stream. Transcend 800 fully supports SFN networks and various ISDB standards. In addition, Transcend 800 can simultaneously carry native IP and native TDM traffic.

Cobham's HGA-7001 SATCOM high gain antenna subsystem has been selected by **Virgin Atlantic** for the airline's Boeing 747 cabin upgrade programme to commence in 2012. Virgin Atlantic will retrofit seven of its Boeing 747 aircraft with the Cobham antenna, which will enable Inmarsat SwiftBroadband (SBB) SATCOM connectivity into the cockpit and cabin. Cobham's antenna subsystem will be retrofitted to the fleet of seven Boeing 747-400 aircraft through an independent Supplemental Type Certificate (STC).

PERSONNEL

Agilent Technologies Inc. announced that **Ron Nersesian** has been appointed Executive Vice President and Chief Operating Officer. Nersesian has been President of Agilent's largest business, the Electronic Measurement Group (EMG), since 2009. Nersesian, 52, will have day-to-day responsibility for Agilent's three businesses, Electronic Measurement, Chemical Analysis and Life Sciences.


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Around the Circuit

▲ Ron Nersesian

Nersesian first joined Hewlett-Packard, Agilent's predecessor company, in 1984. Since then he has served in various management positions, including Vice President of the Wireless Business Unit, before being named EMG President. Nersesian holds a bachelor's degree in electrical engineering from Lehigh University and an MBA from New York University's Stern School of Business.

▲ John Schroeder

Tampa Microwave has named **John Schroeder** as Vice President for Army Programs. This is a new position established to broaden the awareness of Tampa Microwave's family of small, light and extremely capable satellite communications terminals and specialized test equipment. Schroeder received an undergraduate degree in Economics from the Catholic University of America in Washington, DC. He has held business development positions with Intelsat General Corp., Iridium LLC, MCI, Sprint and Harris CapRock Communications.

ANADIGICS Inc. announced that **Thomas Shields** had resigned from the positions of Chief Operating Officer, Executive Vice President, Chief Financial Officer and Secretary to pursue career advancement opportunities outside of ANADIGICS. **Terrence Gallagher**, who had served as Vice President, Finance and Controller, has been promoted to the positions of Vice President and Chief Financial Officer. Shields has agreed to provide consulting services to the company for a period of time to ensure an orderly transition of all of his current responsibilities.

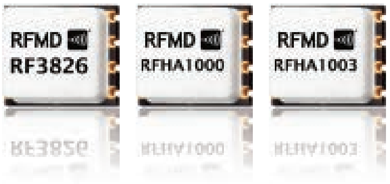
Harris Corp. has named two senior company representatives to lead its RF Communications US Department of Defense (DoD) and International tactical communications businesses. **George Helm**, Vice President of the long-term evolution (LTE) business for the Public Safety and Professional Communications business, has been named President of Harris RF Communications' DoD business. He succeeds **Brendan O'Connell**, who has been named President of Harris RF Communications' International business.

▲ Daniel Dillon

Trilithic Inc. has named **Daniel Dillon** as Director of Product Marketing for its Mobile Systems Applications within Trilithic's Broadband Instruments Division. In his new expanded role, Dillon will be responsible for product development and marketing of all mobile devices and software for the Broadband Instruments group. Dillon Joined Trilithic in 2006 as a Technical Writer and was quickly promoted to Product Coordinator, providing support to Trilithic's product management group. Dillon is a graduate of Purdue University (West Lafayette, IN) in electrical engineering.

RFMD®

High-Power GaN Power ICs



RFMD's GaN Power ICs (PICs) are wideband power amplifiers designed for continuous wave and pulsed applications such as military communications, electronic warfare, wireless infrastructure, radar, two-way radios, and general purpose amplification. Using an advanced high power density Gallium Nitride (GaN) semiconductor process, these high-performance amplifiers achieve high efficiency, flat gain, and power over a large instantaneous bandwidth in a single amplifier design. These GaN discrete amplifiers are 50Ω input-matched, packaged in a small form factor 5 x 6mm SOIC-8 outline air cavity ceramic package that provides excellent thermal stability through the use of advanced heat sink and power dissipation technologies. Ease of integration is accomplished through the incorporation of optimized input matching network within the package that provides wideband gain and power performance in a single amplifier. An external output match offers the flexibility of further optimizing power and efficiency for any sub-band within the overall bandwidth.

SPECIFICATIONS

Freq Range (Min) (MHz)	*Freq Range (Max) (MHz)*	*Gain (dB)*	*OP3dB (dBm)*	*Power Added Efficiency (%)*	*V_D (V)*	*I_D (mA)*	*Package*	*Part Number*
30	2500	11.0	39.0	40	28	55	AIN SOIC-8	RF3826
50	1000	16.0	41.3	53	28	88	AIN SOIC-8	RFHA1000
30	512	18.5	39.5	70	28	55	AIN SOIC-8	RFHA1003

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FEATURES

- Advanced GaN HEMT technology
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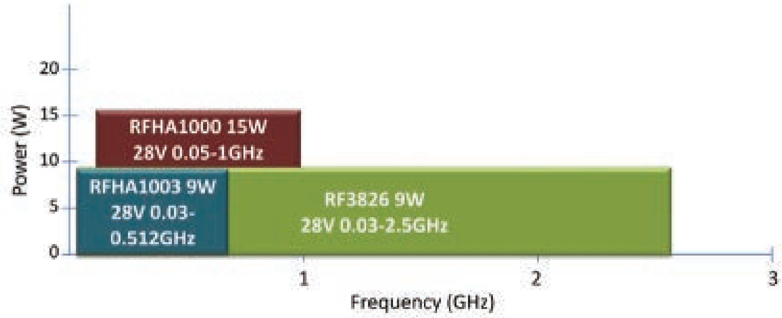

RFMD®

Mobility. Connectivity. Energy.

Around the Circuit

REP APPOINTMENTS

In order to continually grow its business internationally, **A1 Microwave Ltd.** has announced new appointments of representatives for its filters and waveguide assemblies. They are: **Gigacomp GmbH** for Germany, Austria and Switzerland, **ASD Technology** covering Australia and New Zealand, **Alfa Micronde** for Italy, **Orion Space** for Spain and **New Tech Venture** covering Singapore, Malaysia and Indonesia.

Analog Devices Inc. has entered into a worldwide sales distribution agreement with **Richardson RFPD Inc.** Richardson RFPD will support the design-in of ADI's high performance RF ICs along with the company's full range of analog, mixed-signal and digital signal-processing products. ADI's RF ICs and signal-processing technology are available now through Richardson RFPD's North and South America offices and are expected to be available through Richardson RFPD's offices in Europe, Middle East, Greater China, Asia Pacific and Japan in the first half of 2012.

A.T. Wall Co. announced that it has appointed KS-based **Midtec Associates Inc.** as manufacturers' representatives for its products in KS, MO, NE, IA and southern and central IL. Midtec will handle A.T. Wall's complete product line, including waveguide, precision metal stamping, precious metals and glass to metal seal products.

Florida RF Labs & EMC Technology announced a new partnership with **Acetec Inc.** to represent the company's board-level RF and microwave components and single conductor cable assemblies in the southern CA territory. Acetec maintains offices in San Diego, Los Angeles and northern Los Angeles County areas. For 16 years, Acetec has represented top quality lines of RF/microwave active, passive and interconnect assemblies, focusing on the commercial, Hi-Rel and space markets.

L-com Inc. announced that its connectivity products will be distributed by **CMS plc** from Farnborough, Hampshire in the UK. The partnership allows CMS to sell the complete line of L-com products. The L-com connectivity product portfolio includes an extensive range of copper and fiber products for use in audio, data and telecom applications. CMS plc is one of the UK's largest distributors of IT infrastructure and cable management products. In addition to CMS, L-com recently partnered with **Bertek**, a Brazilian telecom importer, after it received homologation for 20 HyperLink branded antenna products for sale in Brazil.

Modelithics Inc. has signed **RDT Equipment and Systems Ltd.**, as its new representative in Israel. Larry Dunleavy, CEO Modelithics, and Avi Tiv, General Manager of RDT Systems, have signed a comprehensive agreement designed to support Israel's market for high accuracy RF and microwave simulation models and characterization services. RDT Equipment and Systems (www.rdtest.co.il) is an Israeli supplier of solutions and services for a wide range of professional industries. Founded in 1963, it has been at the forefront of the electronics industry for more


San-tron
SERIES

Around the Circuit

than 40 years, representing international leading manufacturers of test products and services.

Mouser Electronics Inc. announced its global distribution agreement with ultra-low power (ULP) RF specialist ***Nordic Semiconductor ASA***. Design engineers and buyers will now have access to Nordic's portfolio of 433/868/915 MHz and 2.4 GHz ISM band SoCs and transceivers, single chip ANT™ protocol solutions, and Bluetooth® Low Energy connectivity ICs.

In order to better serve customer demand for smaller and inexpensive quartz crystals, oscillators and real time clocks (RTC) and round off its broad-based portfolio of clock generators and RTCs, **MSC Vertriebs GmbH** has signed an agreement to distribute **Micro Crystal AG's** quartz crystal and real time clock products throughout Europe. The Swiss company is a leading international developer and manufacturer of miniature and energy-efficient quartz crystal devices for use in a variety of consumer and industrial applications.

Vaunix Technology Corp. has announced the hiring of a new sales representative, **BQ Microwave**, to handle customer relationships in Germany, Austria and the Netherlands. A technical sales agency, BQ Microwave provides sales representation for manufacturers of high tech RF/microwave components and systems. BQ Microwave has more than 30 years of professional sales experience in the Germany, Austria, Switzerland and Western Europe electronics industry. BQ Microwave President, Dion Gallinat, can be contacted via e-mail, info@bq-microwave.de, or phone, +49 7191 1878106.

Electro Rent Corp. announced that it has been named the exclusive reseller for certain models of **Communication Components Inc.'s** (CCI) passive intermodulation measurement (PIM) products throughout the US and Canada. Electro Rent will exclusively distribute CCI's lab-based PiMPro Rack Mount (RM) products through its existing Agilent Technology Partner sales channel. Additionally, Electro Rent will sell CCI's complete line of PIM products, as well as offer customers rental and other flexible financing options. Electro Rent (www.electrorent.com) is one of the largest global organizations devoted to the rental, leasing and sales of general purpose electronic test equipment, personal computers and servers.

Richardson RFPD Inc. has entered into a global distribution agreement with **RECOM Power Inc.**, a leading provider of DC/DC and AC/DC converter modules, switching regulators, and constant current LED drivers. A high quality manufacturer for more than 35 years, RECOM's DC/DC converter modules are used by power electronics design engineers around the world. Richardson RFPD's worldwide field sales engineering teams are now assisting circuit designers in integrating RECOM converter modules into inverter designs. For technical information or to buy RECOM products, visit the RECOM storefront on the Richardson RFPD website.

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Need to protect a low-noise receiver that will be operating in a hostile environment? These limiters offer excellent protection against ESD, power surges and unwanted high-level signals—without the tradeoff of high insertion loss. And these limiters react nearly instantaneously (as fast as 2 ns response time, 10 ns recovery time) and work over a very broad band.

With an insertion loss as low as 0.23 dB typical, these hi-rel, wide-band limiters provide protection against high level signals from +5 dBm to +36 dBm input. The power out of the limiter is as low as 0 dBm typical, thus protecting the sensitive devices connected to the limiter output. *The surface mount RLM series* is housed in a miniature plastic case, 0.25" x 0.31" x 0.17", while the *VLM SMA connectorized series* is housed in a rugged, patented unibody package for easy connection to sensitive devices following the limiter.

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THE MASTERS OF MIMO SERIES

Beyond Next Generation Mobile Broadband: BuNGee

The BuNGee Project[1] – "Beyond Next Generation Mobile Broadband" – is a project partially funded by the European Commission (EC) to develop an innovative mobile network system with hugely increased capacity over present systems. It forms part of the EC's Seventh Framework Program of funded or partially funded communications projects. Nine academic and commercial partners are responsible for its development over a period of months until mid-2012.

According to the official BuNGee website, "BuNGee's goal is to dramatically improve the overall infrastructure capacity density of the mobile network by an order of magnitude (10×) to an ambitious goal of 1 Gbps/km^2 anywhere in the cell – thereby removing the barrier to beyond next-generation networks deployment." The present LTE and WiMAX rates are of the order of 100 Mbps/km^2.

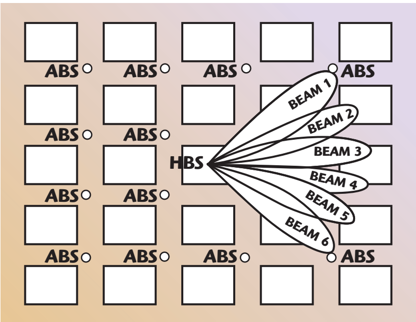


Fig. 1 Typical "Manhattan Grid" configuration showing the single Hub Base Station (HBS) and the Access Base Stations (ABS).

BuNGee is intended to exploit new access and backhaul procedures over both licensed and unlicensed parts of the spectrum and develop the concept of intelligent MIMO radio techniques. The Hub Base Station antennas are of a novel construction, which is necessary to exploit the digital processing techniques being developed in parallel by other BuNGee consortium members. They have been designed and developed by the only dedicated antenna partner in the consortium, Cobham Antenna Systems – Microwave Antennas (previously European Antennas), near Newmarket in England.

The main antenna is dual polar, slant linear polarization, with a construction capable of projecting six separate beams of each polarity covering a 90° arc. Thus by positioning four antennas in a square formation at a hub site, complete 360° coverage is achieved using 24 dual-polarized beams in total.

The multi-beam antenna itself is designed to produce six individual beams each with a half-power beamwidth of 15°, such that each pair overlap at the half-power point, which is considered sufficient to provide contiguous coverage over the complete 90° sector. ***Figure 1*** shows a single Hub Base Station (HBS) antenna in the middle of a typical urban "Manhattan Grid" configuration, showing the 90° azimuth spread of six beams. Three further antennas

COBHAM ANTENNAS
Newmarket, UK, on behalf of the BuNGee Project Consortium

will be installed at the center of the square to provide the remaining 270° required for full coverage. The Access Base Station (ABS) antennas are situated below roof level at the corner of each block.

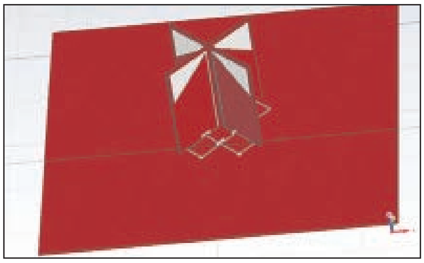
The whole antenna array comprises eight high gain sector antennas, which are spaced a half-wavelength apart. This spacing provides reduced azimuth sidelobe levels when the sectors are phased together to provide a slewed high gain beam. The individual sectors have been designed to provide a 110° azimuth beamwidth. Each sector is composed of eight tiers of elements spaced about 0.7 wavelengths apart to provide the required elevation pattern.

In order for the six narrow (15°) high gain beams to be formed to cover the 90° arc, two (8×8) Butler matrix beamforming devices[2] are used to feed the separate ports of each antenna. By a mechanism of fixed phase shifters and couplers the Butler matrices provide defined sets of phases into each of the eight antenna elements, which results in two sets of eight "skewed" beams. Note that only the inner six of these beams are used to cover the 90° area required for the defined architecture.

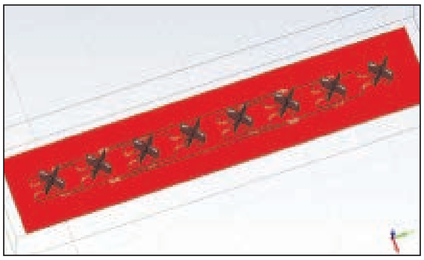
The proposed multiple input multiple output (MIMO) radio system feeds each of the six pairs of (dual slant 45°) beams into the matrices through a total of twelve separate inputs. A potential further system benefit can be achieved by "amplitude weighting," which requires the outer antenna ports to be attenuated. Using this technique, although the gain of the main beams will be slightly lower, the azimuth sidelobes are further reduced giving an improvement in relative sidelobe level, which may result in greater system efficiency.

THE SINGLE ELEMENT AND SECTOR ARRAY

The antenna element, originally modeled in a commercial simulation software package, is based on a single cross-dipole assembly, etched on a standard PCB substrate. The dipoles, in this case optimized to work at a center frequency of 3.5 GHz, are physically interlocked and soldered to a motherboard in a configuration that provides a slant dual polar beam (see



▲ *Fig. 2 Modeled individual slant 45° cross-dipole element for Hub Base Station antenna.*



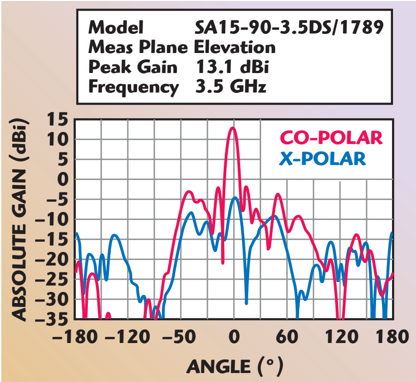
▲ *Fig. 3 Modeled eight-element single tier elevation array.*

Figure 2). In the model, the tracks cross over, using a surface bridge. The final design uses plated-through holes to short bridging tracks on the underside of the board. High sector gain requires eight sets of these assemblies to be fed in phase through a stripline feed to create the fundamental (110° azimuth) sector antenna, which forms the basis for the array. Each dipole pair is mounted on the motherboard spaced 0.7λ apart; the interconnecting tracks of one polarity passing via plated-through holes to short tracks on the underside of the motherboard at the points of crossover. Although the underside of the motherboard has a continuous ground plane, this is relieved locally to accommodate the bridging tracks. To maintain phase fidelity, the tracks of the opposite polarity, which remain on the topside of the motherboard, are lengthened to provide the same electrical length and compensate for these diversions (see ***Figure 3***). The positions of the feed tracks dictate the phase to each element pair and thus the down-tilt; the number of elements controls the gain and the elevation beamwidth.

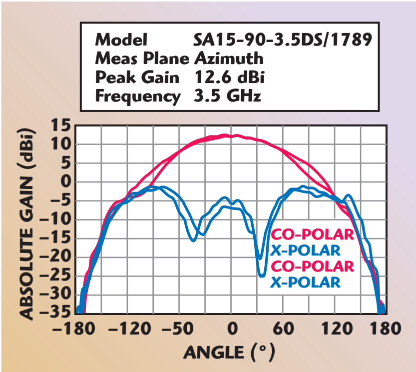
The 110° HPBW sector pattern produced by an individual dipole pair, even when combined into the single sector using eight elements, provides the basis for the overall pattern to be achieved with the final array. In this formation, the elevation beamwidth has been reduced from a single ele-

ment of 110° to 10° through the "array-factor." By varying the amplitude and phase to each element pair in the vertical array, it is possible to introduce features to the elevation pattern such as electrical (down) tilt, sidelobe-suppression and null-fill, which may be beneficial to the system. These elevation pattern parameters have no effect on, and are independent of, the multiple azimuth beams.

In this antenna, the down tilt is a nominal 2° across the band of interest, that is 3.4 to 3.6 GHz, with an elevation beamwidth of 10° at the half-power point (see ***Figure 4***). The gain is a function of beamwidth; the more elements in parallel, the higher the gain and thus the narrower the elevation beamwidth. ***Figure 5*** shows the measured azimuth patterns for the eight element single tier sector array, with the +45° and –45° polarizations (in red) superimposed at midband. The two polarizations overlap very well over the center 90° over which the six narrow beams will be arrayed. The cross-polar signals (in blue) are better than 15 dB below the co-polar signals over the center 90° sector.



▲ *Fig. 4 Measured elevation pattern for eight-element single tier array +45° port (red), the cross-polar signal (blue) are better than 15 dB below the co-polar pattern.*

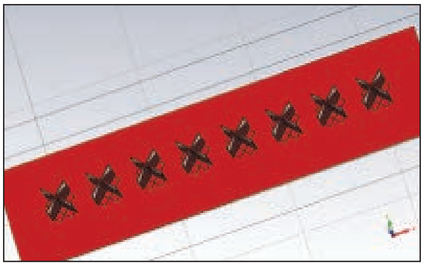


▲ *Fig. 5 Measured azimuth pattern for an eight-element single tier sector array.*

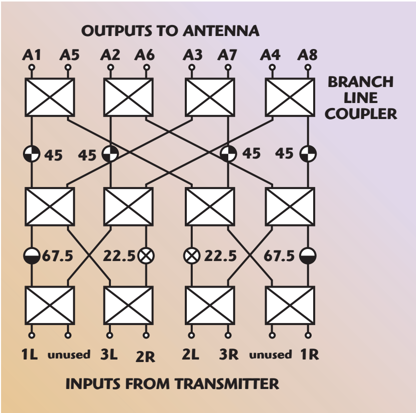
MULTI-BEAM AZIMUTH ARRAY

The next step was to use the model of the single element, as modified by iterations of the design, to determine the horizontal spacing of the single dipole pair and the fixed phase shifts necessary across eight elements to provide the "steer" for the beams in the right directions. It remained necessary to cover the 90° arc with six equal (15°) beams, while maintaining the patterns shapes and without introducing high azimuth sidelobes. The principal requirement from the system is that the nearby beams retain a high level of isolation from each other, by becoming narrower and of course benefitting from the higher gain that goes with reducing the beamwidth. This would allow a high level of frequency re-use needed for the required data rates.

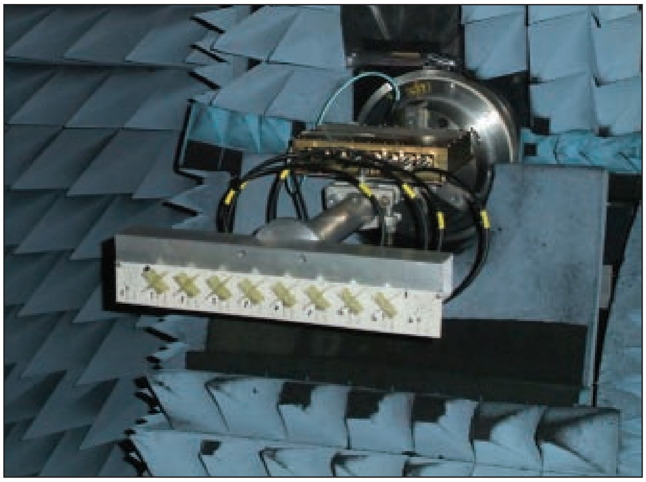
The modeling showed that half a wavelength (λ/2) spacing of the ele-



▲ *Fig. 6 Modeled single tier azimuth array.*



▲ *Fig. 7 Typical Butler matrix showing the 90° branch line couplers and interconnections showing phase shift in each combination of connections.*



▲ *Fig. 8 Single tier azimuth array and fixed-phase beamformer (behind, connected with phase matched cables).*

ment with relevant phase-shifts would provide optimum results. The element had been designed such that this close proximity of adjacent dipoles (in the 45° configuration) would not have any effect on the return loss or pattern fidelity, which was critical for the success of the array. A set of single cross-dipole elements was fixed to a motherboard in a horizontal array to demonstrate the beam-form principle (see ***Figure 6***). Unlike the elevation array which only has two terminations, –45° and +45°, the azimuth array has 16 because all the dipoles are independently fed, although in tests only eight of one polarization were used. Like the elevation array, a prototype was built up and tested in Cobham Antennas' anechoic chamber, which, after processing, allowed full far field radiation patterns to be created.

Early modeling showed a possible need to use dummy elements at either end to further control beam direction, which in practice proved unnecessary. This discovery paved the way to eventually develop the 8 × 8 element array with all the elements electrically functional.

THE BUTLER MATRIX

The Butler matrix is a passive (unpowered) beamformer, the principles of which were first described by Butler and Lowe[2] in 1961 and depend on achieving even increments of phase shift at the outputs, according to which one of successive inputs is fed.

The beamformer specified for BuNGee is designed using stripline technology and proprietary crossover circuitry (see ***Figure 7***). It uses six inputs and eight outputs. Using Input 1 causes a phase shift of 22.5° per output port, 67.5° per output port when using Input 2, and 112.5° per output port when connected to Input 3. The three remaining input ports produce phase shift in the opposite direction, that is –22.5°, –67.5° and –112.5°, respectively. When connected to the azimuth array, using accurately phase-matched cables, the beams can be "steered" in six 15° increments from 37.5° to the left to 37.5° to the right simply, according to which of the six inputs has been activated. When the half-power beamwidth of 15° per beam is taken into account, it gives the desired azimuth coverage of 90°. One Butler matrix is used for each antenna polarization, so two are fitted per complete array.

Figure 8 shows the Butler matrix connected to the prototype azimuth array using eight carefully phase-matched cables and positioned in

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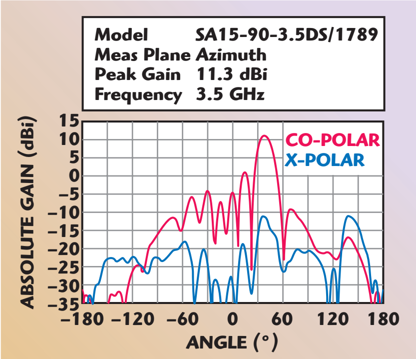


▲ *Fig. 9 Measured mid-band azimuth pattern for eight-element single tier array −45° polarization showing 37.5° beam steering.*

Cobham Antennas' near field spherical test chamber. Using this with dedicated software allows a complete sphere of far field data to be extracted and, as each antenna test takes about 20 minutes or less, it is practical to conduct many tests in a working day.

The plot in ***Figure 9*** was extracted from one of these tests, showing clearly the predicted 37.5° azimuth beam shift, when a signal was applied to "Input 3, Right Hand" on the Butler matrix. Many of the modeled parameters of the final antenna are demonstrated as measured. The beamwidth is close to the predicted 15°, in this case 15.8°. The main sidelobe is practically 12 dB below the main beam and the cross polar level comfortably exceeds the −15 dB minimum specified.

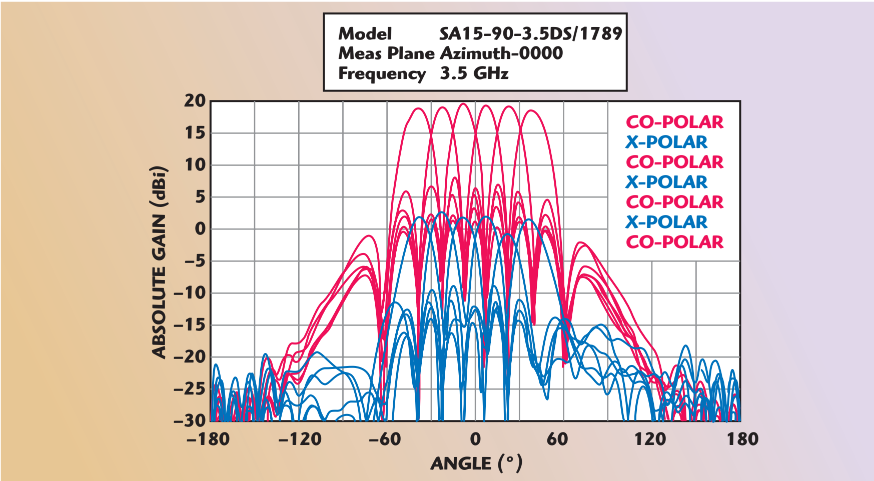
THE COMPLETE ANTENNA

Having combined the principles of the cross polar topography and the Butler matrix, it was possible to develop the 8×8 element antenna. The simulated model was interpreted into a practical array, using the same design features of the original elevation and azimuth tiers. The model predicted a theoretical peak gain of 19 dBi with the essential 15 half-power beamwidth in azimuth and 10° in elevation. However, some losses were to be expected in the Butler matrix and phase matched cables, but the assembly had proven the principles.

The superimposed beams measured in one polarization are demonstrated in ***Figure 10***. The 90° azimuth spread, from −45° to +45° can clearly be seen with the 3 dB (half-power) points coinciding with the handover points between adjacent beams. Near 0° the gain is 19 dBi and even at the beam extremities never drops below 17.5 dBi.

CONTROL OF AZIMUTH SIDE-LOBES THROUGH AMPLITUDE WEIGHTING

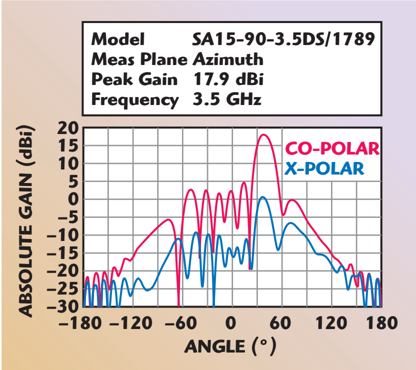
The highest first sidelobe for any beam falls at least 12 dB below the main beam and typically the level is nearer 13.5 dB, but even this can be improved upon if amplitude weighting is introduced. This is a technique using low value series attenuators in line with the Butler matrix outputs to the antenna. The two central columns are typically left unattenuated, but to preserve phase fidelity 0 dB attenuators are fitted of the same electrical dimensions as the attenuators connected to the outer tiers. Working outwards the next two columns may either have 0 dB or perhaps 1 dB



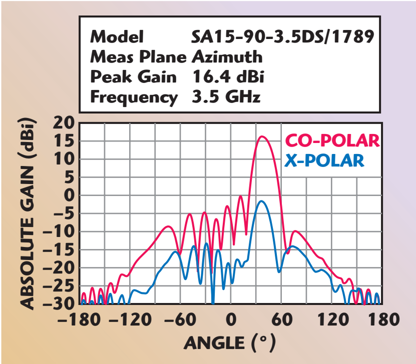
▲ *Fig. 10 Overlaid beams from −37.5° to +37.5° over a 90° azimuth spread using the 8×8 array.*

attenuators connected, while the remaining tiers have progressively larger value components fitted such that the greatest attenuation occurs on the outermost extremities of the array. While the effect is almost unnoticeable in the elevation cut, except for a slight decrease in overall gain, the sidelobe levels in azimuth are significantly reduced relative to the loss in gain of the main beam.

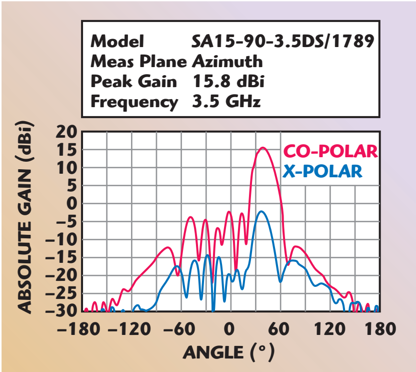
Figures 11, ***12*** and ***13*** illustrate the progressively lower sidelobe levels as the amplitude weighting is increased on the same antenna array. For a drop in main beam gain of 2 dB, an improvement of 5 dB in relative sidelobe level can be achieved. This may be a valuable trade-off and option for the system designers to use, although there comes a point, of course, beyond which the drop in main beam gain is undesirable, which dictates the limit.



▲ *Fig. 11 +37.5° azimuth beam using the 8×8 array without amplitude taper.*



▲ *Fig. 12 +37.5° azimuth beam using the 8×8 array with 0, 0, 2 and 5 dB attenuators.*



▲ *Fig. 13 +37.5° azimuth beam using the 8×8 array with 0, 1, 3 and 5 dB attenuators.*

ANTENNA DEPLOYMENT

The Hub Base Station antenna described above is intended to be deployed within an urban "Manhattan Grid" formation, affording coverage through 360° by virtue of positioning four antennas just above roof-top height, each covering a 90° sector, and working in the 3.4 to 3.6 GHz band. These communicate with line-of-sight, or virtually line-of-sight dual-slant linear Hub Subscriber Station antennas, sited below rooftop

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SMP1302-085LF	High power (50 W) handling, shunt	Land mobile radio, LTE base station, and more
SMP1325-087LF	High power (35 W) handling, series	Land mobile radio, LTE base station, and more
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SMP1330-005LF	Clean-up limiter, +30 dBm input power, +13 dBm flat leakage power, up to 2.5 GHz	Land mobile radio, military, infrastructure, and more
SMP1330-085LF	Low loss, high power, +30 dBm input power, +13 dBm flat leakage power, up to 4 GHz	Land mobile radio, military, infrastructure, and more
CLA4603-085LF	Medium power, low loss, +33 dBm input power, +13 dBm flat leakage power, up to 10 GHz	Land mobile radio, military, infrastructure, and more
CLA4606-085LF	Medium power, low loss, +35 dBm input power, +18 dBm flat leakage power, up to 10 GHz	Land mobile radio, military, infrastructure, and more
CLA4609-086LF	Course limiter, high power handling, +43 dBm input power, +41 dBm flat leakage power, up to 6 GHz	Land mobile radio, military, infrastructure, and more

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SMS7621-005LF	Excellent sensitivity, low capacitance, series pair	Infrastructure, smart energy, infrastructure, and more
SMS7630-061	Best sensitivity, zero bias, 0201, performs up to 100 GHz	WLAN, military, infrastructure, and more
SMS7630-040LF	Best sensitivity, zero bias, 0402	WLAN, military, infrastructure, and more
SMS3922-079LF	Medium barrier, high breakdown voltage	Infrastructure and more

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SMV1247-040LF	Low capacitance (7 pF @ 0.3 V, 0.7 pF @ 4.7 V), high Q (1500)	Automotive, smart energy, WLAN, test and measurement, infrastructure, and more
SMV1249-079LF	Medium capacitance (31 pF @ 0.3 V, 2.6 pF @ 4.7 V)	Automotive, smart energy, WLAN, test and measurement, infrastructure, and more
SMV1255-079LF	High capacitance (64 pF @ 0.3 V, 5.2 pF @ 4.7 V)	Automotive, smart energy, WLAN, test and measurement, infrastructure, and more
Abrupt Diodes		
SMV1405-040LF	Ultra high Q (3200)	Automotive, smart energy, WLAN, test and measurement, infrastructure, and more
SMV1413-079LF	Low resistance, high Q	Automotive, smart energy, WLAN, test and measurement, infrastructure, and more

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within the grid and sharing their location with (different frequency) Access Base Station antennas. These, in turn, point up and down streets to communicate with (personal) mobile terminals. The installations in both cases are intended to be cost effective. Multi-beam technology will be much more efficient to install where antenna mounting considerations, such as weight, wind speed, and thus mast/roof-top rental are paramount. Re-use of the spectrum for this dense data-rate means lower license fees for operators per bit of data transmitted. Below-rooftop deployment and co-location of the Hub Subscriber Antenna/Radio and Access radio/antennas reduces the cost of installation. Carefully controlled antenna beamwidth and intelligent MIMO techniques, (being developed separately within the BuNGee project), as well as judicious positioning of neighboring Hub Base Station multi-beam antennas, reduce interference within the system, increasing signal to noise ratios. A nominal peak gain per antenna of 19 dBi, while providing useful penetration also produces a well-defined beam set with the extra advantages of dual polar technology at both ends of the link (2×2 MIMO).

SUMMARY

The multi-beam antenna, developed by Cobham Antenna Systems to be deployed in the BuNGee communications project, is a novel approach to dual polar, beamforming technology. The use of a Butler matrix to produce a set of beams spanning a wide sector allows for a significant increase in the data throughput when compared with a wide beam antenna of sufficiently high gain, and is more compact than having the equivalent of six separate narrow beam antennas. This rewards the user with reduced installation and deployment costs, while being able to control individual beams where needed. ■

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2. Butler and Lowe, "Beam-Forming Matrix Simplifies Design of Electronically Scanned Antennas," *Electronic Design*, Vol. 9, April 1961, pp. 170-173.


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Advances in Radar Simulation Design

Advances in modern radar systems include specialized active antennas, microwave circuits and devices, agile beam steering and shape and digital space-time signal processing. While the pace of radar technology continues to march forward, two fundamentals remain constant. The first is that the electromagnetic properties of antennas, radomes and the installation platform are governed by the underlying and unwavering physics. The second is that engineers designing these systems will push the limits of simulation, based on that underlying physics, to solve ever-larger and more complex electromagnetic radiation and scattering problems. While the physics does not change, the numerical methods engineers and scientists apply continues to advance, built upon the fundamental principles and theorems of electromagnetics.

The technological needs of the radar system designer or antenna designer are to provide understanding of the radiation and scattering performance. A phased array radar antenna, for instance, does not operate in free-space. On the contrary, it may be mounted on the front or side of an aircraft. That aircraft is likely constructed of both metallic and composite materials. The antenna is covered by a radome that likely contains a frequency selective surface (FSS). Understanding the radiation and scattering performance of such a system requires a very comprehensive simulation capability.

Performance of the system and interaction among the various components and subsystems are often not discovered until expensive production of prototypes and testing in the integration lab. What is needed is a full system solution that allows engineers to assemble complex 3D systems and predict system performance and electromagnetic effects using the appropriate global and local simulation technology. ***Figure 1*** depicts a typical phased array radar antenna system. Within that system there is an individual antenna element (flared notch or Vivaldi) assembled into an array. The array antenna is mounted within an aerodynamic radome, which itself may have a FSS applied within its surface. Finally the radar system itself is mounted onto an aircraft.

NUMERICAL TECHNIQUES

Modern electromagnetic simulation must handle 3D systems that are physically complex, have a large range of physical dimensions and are assembled based on models from disparate

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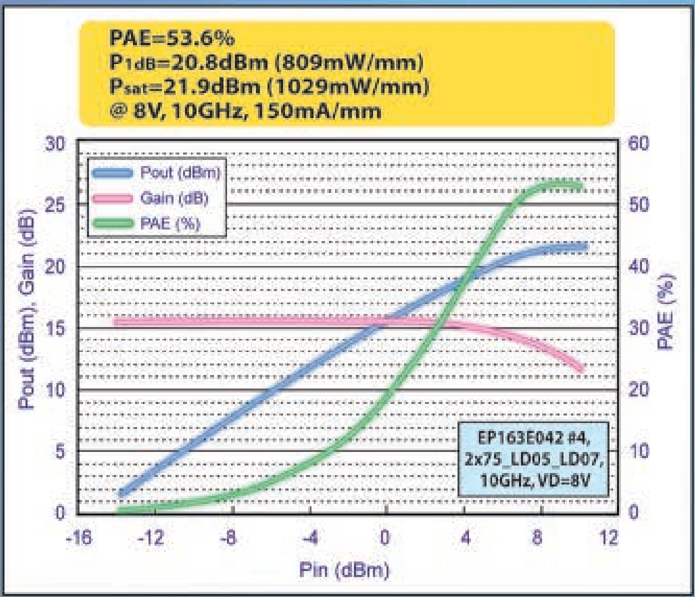

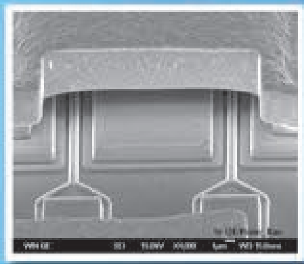

Comparison Table for 0.1µm, 0.15µm, 0.25µm and 0.5µm pHEMT

	PP10	PP15	PP25-21	PP50-11
Vto (V)	-0.9	-1.2	-1.2	-1.4
Idss (mA/mm)	450	500	345	350
Idmax (mA/mm)	720	650	460	480
GM (mS/mm)	750	495	380	310
VDG (V)	9	10	19.2	20
ft (GHz)	130	85	65~72	32
Fmax (GHz)	175	180	160	85
PldB (mW/mm)	533.25 (3.5V)	670 (5V)	809 (8V)	587 (8V)
Psat (mW/mm)	764.3 (3.5V)	820 (5V)	1029 (8V)	851 (8V)
Gain (dB)	14.35	18.1	15.6	15.5
PAE (%)	53.57	55	53.6	53.5
Frequency	29 GHz	10 GHz	10 GHz	10 GHz

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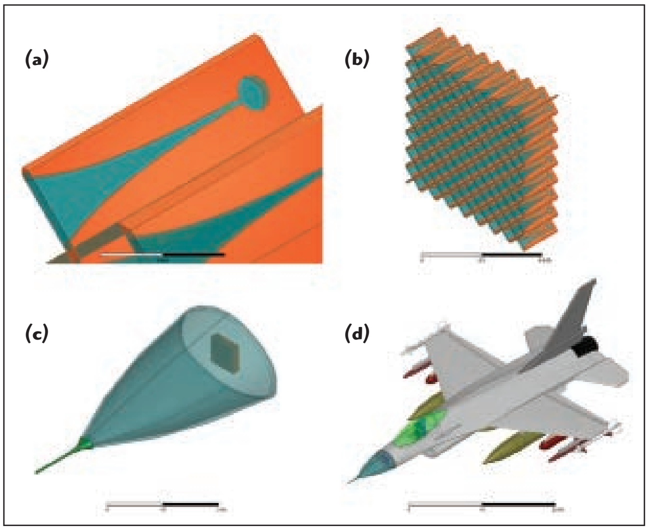
sources, which can include multiple 3D CAD and 2D layout design tools. In addition, it is highly likely that no single electromagnetic simulation technique (such as, Finite Elements, Method of Moments, Physical Optics) can solve the entire system to a desired level of accuracy. A proper and efficient solution requires the ability to apply the appropriate solver technology in a particular area(s) of the system.

Modern simulation methods available in ANSYS® HFSS™ take advantage of advanced computing hardware and novel numerical methods. High Performance Computing (HPC) methods allow large electromagnetic problems to be distributed across a network of computers (cluster) to solve large 3D volumetric problems, to perform material and geometry parametric sweeps, and to solve across frequency. A particularly interesting technique, the domain decomposition method (DDM),[1] divides a finite element problem into multiple domains, each of which is then solved on a different computer in the cluster allowing truly massive simulations to be performed.



▲ *Fig. 1 Components of a phased array radar system include many parts, such as (a) flared notch antenna element, (b) flared notch array, (c) antenna in radome and (d) aircraft platform.*

Table 1 provides a summary of numerical and computational techniques available in HFSS that can be leveraged by the design engineer and analyst to solve challenging electromagnetic simulations. The most general technique is the finite element method (FEM) that can solve virtually any geometry shape with complex materials and microwave ports/excitations. The transient (time-domain) FEM offers the additional benefit of providing temporal and spatial behavior of fields especially useful for identifying scattering centers. Other methods like the integral equation (IE) method and physical optics (PO) allow efficient simulation of much larger structures, especially those that are mostly metallic. Both use a surface mesh rather than the volume mesh used in finite elements. The IE method explicitly solves for the electrical current on each surface mesh element. Models that are primarily large surfaces are

TABLE I

NUMERICAL AND HIGH PERFORMANCE COMPUTING METHODS FOR RADAR SYSTEM AND RCS SIMULATION

Numerical Technique	Description	Applications
Finite Element Method	Most general; handles complex material and geometries; volume mesh and field solution; explicit, numerically exact solution	Open and closed microwave structures and antennas
Transient Finite Element Method	Most general time-domain solution; handles complex materials and geometries	Provides insight into models where temporal and spatial properties are critical; identification of scattering centers; ground penetrating radar
Integral Equation (Method of Moments)	Efficient solution for open radiation and scattering; currents solved on surface mesh; efficient when structures are primarily metal	Electrically large metallic open-space models, such as antennas placed on aircraft; RCS computations of aircraft/ missiles
Physical Optics	High frequency approximate solution; ideal for electrically large, smooth objects; currents approximated on illuminated regions and zero on shadow regions	Electrically very large smooth metallic models; useful for computing interaction of antennas and structures, such as aperture blockage due to aircraft wing, etc.
Hybrid FEBI	Combines finite element with integral equation methods; finite elements for regions of complex material/geometry, IE for efficient solution for open region/metallic objects; takes advantage of features from both methods to allow for more efficient simulations	Electrically large complex material models; antenna plus radome systems; composite aircraft models
Hybrid IE Regions	Extension of FEBI that allows uniform regions of free space or dielectric to be removed from the FEM solution; metal objects can be solved directly with IE solution applied to surface; dielectric regions can be replaced with an IE Region on the boundary of uniform dielectric material	Electrically large complex "separate" models; reflector antennas; ground penetrating radar; RCS
High Performance Computing	**Description**	**Applications**
Shared Memory Parallel	Multiprocessing allows a simulation model to solve faster	Solving traditional electromagnetics problems on a single computer that has multiple processors
Distributed Memory Parallel	Multiple computers allows a larger simulation model	Solving large electromagnetics problems on a cluster of computers with ability to use all memory on all machines

solved very efficiently using IE. PO is a high frequency (asymptotic) method where currents are approximated on illuminated surfaces of the model and set to zero in shadow regions. Necessarily the model must be illuminated by an external source, such as a plane wave or from a FEM or IE simulation. Typically a PO solver permits only first order interaction (single bounce). The beauty of the PO solver is that it can solve very large models quickly and hence provides quick performance estimates of electrically large problems.

While each of these methods is valuable as standalone solutions to radar antenna and scattering, an even more powerful solution may be had by combining the techniques in a "hybrid" solution. Some portions of a problem are best solved by FEM; other portions are best solved using IE or PO. For instance, the antenna aperture may include Vivaldi radiators with suspended stripline feed elements. FEM is ideal for solving that geometry for radiation and scattering. Once the antenna is placed in a radome, the IE method can be used to compute the Fresnel diffraction and refraction through the radome. In a hybrid technique, the entire problem is solved efficiently by using FEM for the antenna aperture and IE for propagation to and through the radome.

RADAR ANTENNA SYSTEMS

Finite-sized Phased Array Analysis

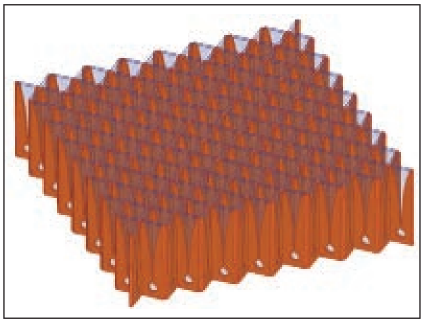
Modeling large, finite-sized phased antenna arrays are an extremely challenging simulation problem. Somewhat by definition these will be electrically large structures with complex geometries. No matter what technique is employed an explicit or a direct solution to the problem will be computationally expensive as the number of mesh elements, matrix unknowns and potentially the number of right hand sides (RHS or excitations), must be large.

The traditional approach for simulating large phased arrays approximates that behavior by assuming an infinitely large array. In such an approach, only the geometric description of a single unit cell is required. Then using a periodic boundary approximation approach a solution for this single unit cell can be developed assuming it is placed in an infinitely large array. Such infinite array analysis has been the staple of antenna array design where the solution for this single unit cell is multiplied by an array factor to determine an approximate behavior of the finite sized array. The approximate nature of this infinite array solution is a result of the fact that the environment, fields and coupling experienced by individual elements of the array vary according to their location in the array (interior, edge, corner, etc.). Lacking this element-level knowledge introduces challenges in finite-sized array design. The design of a corporate feed cannot assume that the active S-parameters of all elements are the same and has to allow for sometimes significant differences especially at the edges of the array. This effect can be mitigated by implementing a band of passive or "dummy" elements around the perimeter of the array. These would allow for the corporate feed of the active elements to assume a more equal input, but would obviously require a larger footprint for the array.

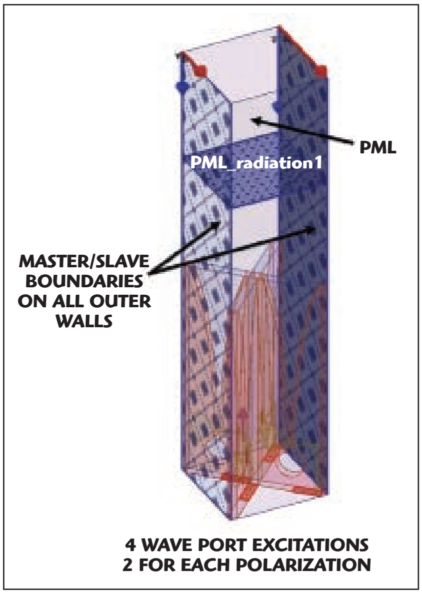
Figure 2 depicts a 256-element array of dual-polarized Vivaldi antenna elements. This array was simulated using two techniques. The first is a new DDM approach[2,3,4] that has been developed to effectively and efficiently model finite-sized arrays using distributed memory. The second is a direct solution using a single machine of high capacity as the baseline for computational effort.

Figure 3 shows the single unit cell used to simulate the array. The unit cell of the antenna array, including its automatically adapted mesh developed in a periodic boundary condition analysis, is virtually duplicated into the 256-element array geometry. The unit cell and its duplicates are each treated as individual domain solutions for a DDM solution to the entire finite antenna array. The electromagnetic interface between the individual cells is captured by a Robin transmission condition applied on the transverse faces of the cells. Also a continuous conformal tetrahedral mesh is effectively maintained across this interface through a master/slave mesh technique for the unit cell where an identical triangular mesh is enforced on parallel faces of the unit cell.

The calculation of the element domains can be simplified by exploiting the repetitive nature of the elements matrices, A, in the Ax=b calculation for each individual cell. However, not all cells of the array have the same matrix as edge and corner elements reside in a different environment depending on how the elements of the perimeter are terminated and thus corner elements and elements along an edge each have distinct A matrices. Ultimately, to describe a rectangular array, nine unique parent elements are required, one interior plus four edge and four corner. After the matrices for the individual cells are constructed, their solutions collectively become a pre-conditioner for an iterative solution process for the entire system performed at a host node. With this technique, the finite nature of the array, including edge effects, are captured since a unique set of fields are computed for all elements. In addition, this technique is highly parallelizable as the individual units cells can be analyzed across distributed computing cores.



▲ *Fig. 2 256-element phased array of cross-polarized Vivaldi elements.*

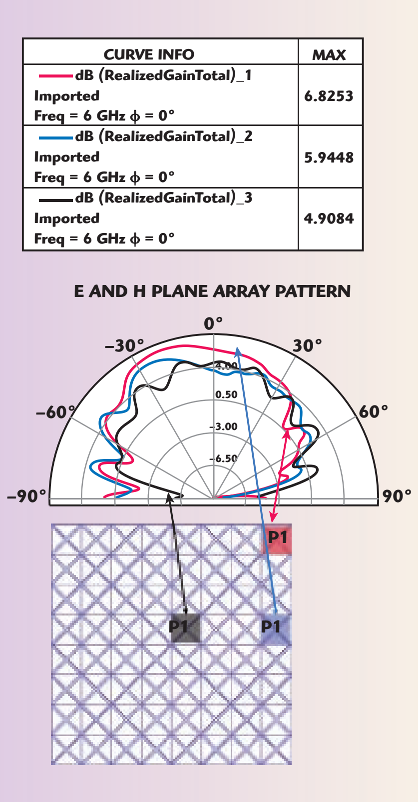


▲ *Fig. 3 Unit cell set-up for finite-sized array analysis using DDM.*

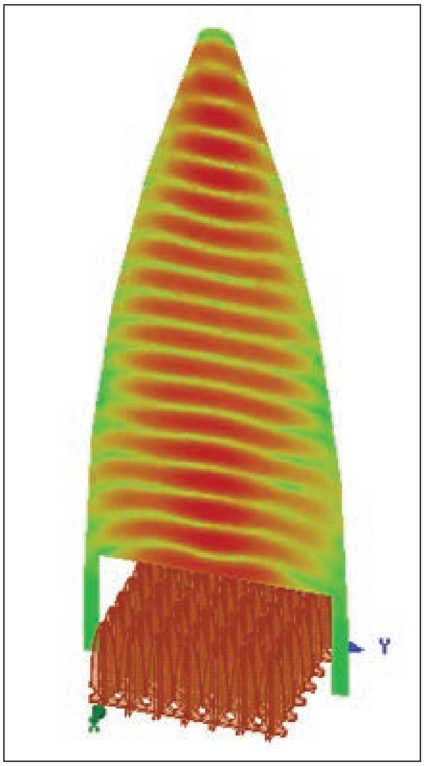
Figure 4 shows results from the analysis. As can be seen in the figure, the element pattern is highly dependent upon the element location in the finite-sized array. A direct simulation of the array required 211 GB RAM and over 122 hours to complete on a single machine. The new DDM simulation required 48.2 GB total RAM and 30 hours computation time on a cluster of 13 machines. That is 77 percent less RAM and 4.1 times faster.

ANTENNA IN RADOME

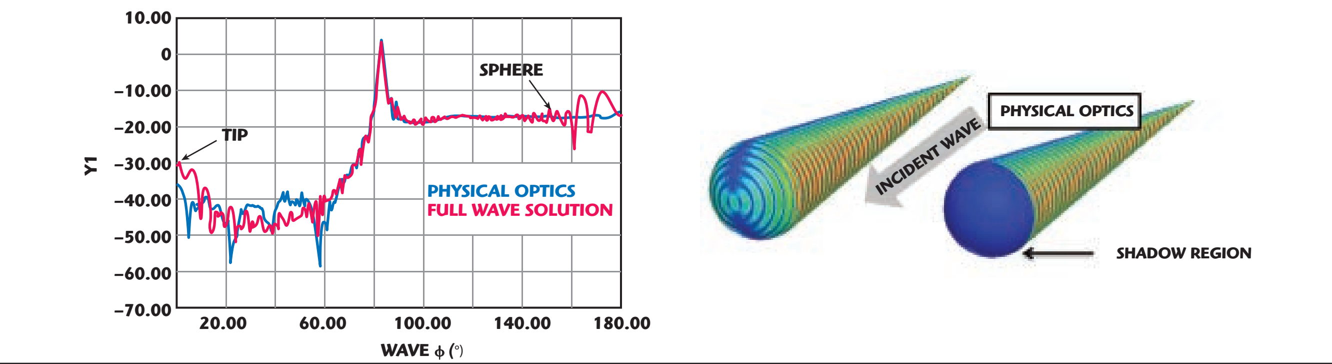
Once simulation and optimization of the array has been performed, the next simulation challenge is to observe array performance when placed within a radome. *Figure 5* depicts the electric field due to a simulation of the 256-element array placed in the radome. This simulation was performed using a hybrid solution technique that combines FEM with the IE method. The Finite Element Boundary Integral (FEBI) method allows the fields to be truncated into an absorbing boundary created by the boundary integral (BI) surface mesh. In Figure



▲ *Fig. 4 Array element pattern depends upon location in the array.*



▲ *Fig. 5 Simulation of a 256-element Vivaldi array placed within an aerodynamic radome.*



▲ *Fig. 6 Comparison of IE and PO solution for monostatic RCS of an electrically large "cone-sphere" model.*

5, the BI surface mesh is skin-tight up against the outer surface of the radome. Finite elements are used to solve the array and within the radome; the integral equation method is used to solve for the fields exterior to the radome.

PLATFORM RCS

Both the IE and PO methods are popular for RCS computations of electrically large models. ***Figure 6*** shows a comparison of monostatic RCS using the IE and PO methods for an electrically large "cone-sphere" model simulated at 9 GHz (note that for incident radiation toward the tip, the PO model has illumination on the cone due to shadowing). The model has radius = 2.947 inches (diameter = 4.5 wavelengths); length = 23.821 inches (18.15 wavelengths). As can be seen in the figure, the two simulation methods agree very well on broadside incidence near 82 degrees. The PO solution is in very good agreement for all angles but for near incidence on the tip (0 degrees) and for near incidence on the sphere (180 degrees). Creeping wave effects are not accounted for in the PO solution. This becomes apparent as incident angles approach the tip- and sphere-side of cone-sphere.

While that discrepancy may be important when ultimate accuracy is desired, the entire story is only told when we examine the computational resources required for each solution. When computing the RCS of the cone-sphere, using the IE and PO methods, the PO solution is roughly eight times faster, thus providing a rapid examination of the solution. This performance can be useful when first exploring a design and/or when optimizing a design. It can also be useful in more challenging computations of RCS of real targets, such as aircraft.

The bi-static RCS of a full-sized fighter aircraft at 5 GHz is depicted

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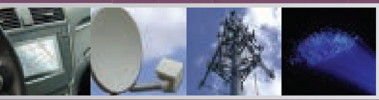

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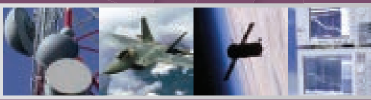

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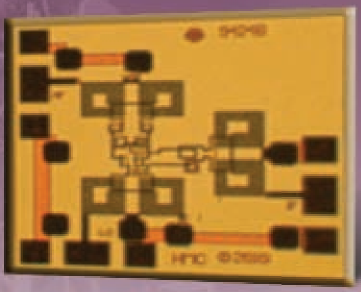

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	7 - 34	+13 LO, Double-Balanced	DC - 8	-11	35	+22	**HMC774LC3B**
	11 - 20	+13 LO, Double-Balanced	DC - 6	-7	46	+18	**HMC554LC3B**
	24 - 40	+13 LO, Double-Balanced	DC - 18	-8	35	+21	**HMC560**
	54 - 64	+13 LO, Double-Balanced	DC - 5	-8	30	+13	**HMC-MDB169**
	2.5 - 7	+15 LO, Double-Balanced	DC - 3	-7	48	+22	**HMC557LC4**
	5.5 - 14	+15 LO, Double-Balanced	DC - 6	-7	45	+24	**HMC558LC3B**
NEW!	26 - 32	+13 LO, Triple-Balanced	16 - 22	-10	45	+22	**HMC1015**
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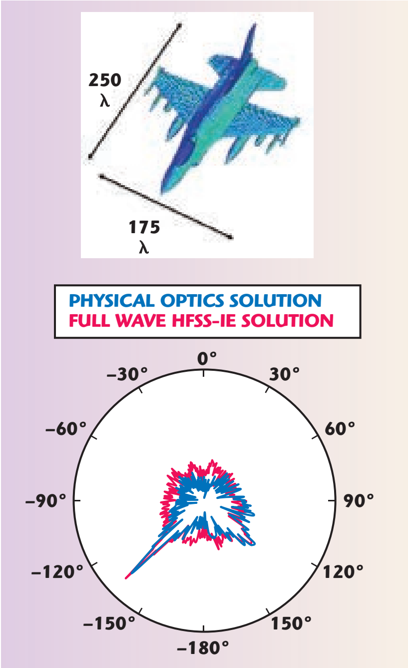
in ***Figure 7***. The aircraft is electrically large: 250λ by 175λ. The bi-static RCS was computed using both the IE and PO techniques. Of course, the IE simulation was quite computationally intense and hence an HPC solution was invoked. The large-scale simulation was so large that it was only possible using a computer cluster of 10 networked machines. The distributed IE solution used 32 GB of memory on each of the ten machines for a total of 325 GB. Solution time was 33.5 hours total. This rigorous solution provides a highly accurate computation of the true RCS of the aircraft in all regions, including the non-specular directions. To compute the bi-static RCS using PO, the simulation requirements were very modest, only 20 minutes elapsed time using 8.3 G RAM. As can be seen in the figure, the RCS computed by PO along the specular is almost exactly the same as the much more computationally intensive IE solution. Engineers should choose the IE method



▲ *Fig. 7 Bi-static RCS of a full-sized fighter aircraft at 5 GHz computed using IE and PO. Incident wave impinging on target from $\phi = \theta = 45°$. (a) Model with induced current (b) Bi-static RCS computation along $\phi = 45°$.*

for ultimate verification accuracy. For early computations, optimization and many mono-static cases, the PO technique offers great advantage to solve on a single machine with fast simulation turnaround.

Examining the RCS performance of an aircraft in a particular band in the frequency domain provides the information needed to understand radar performance. Additional information can be had if simulations are performed in both the frequency- and time-domains. As mentioned earlier, time-domain simulations and associated electric field plots provide information as a function of both time and space. This information is particularly useful to understand a radar target's time "signature." It is also very important for design and diagnostics to understand the scattering centers of the target and which elements of the aircraft produce the most significant scattering. ***Figure 8*** shows the electric field over a sequence of three instances in time for scattering of a vertically polarized plane wave striking an aircraft. The plane wave impinges upon the aircraft at a 45 degree angle. The first image shows the plane wave interacting with the radome and an associated specular bounce. In the next

▲ *Fig. 8 Time sequence using transient FEM illustrating scattering locations. (a) Initial plane wave. (b) Plane wave interaction with engine inlet. (c) Scattering from engine inlet propagating back toward source. Note also in (c) the scattering off leading edge of wing.*

image, that incident wave begins to interact with the jet engine inlet below the craft; waves can be seen initiating back toward the source. The third image clearly shows the waves continue their propagation back toward the source. Also seen in the third image is scattering from the wing leading edge. The transient analysis can be used to determine precisely which portions of the aircraft are producing significant scattering and especially the undesirable back scattering for low observable performance.

CONCLUSION

With new technologies, such as IE, hybrid FEBI, IE-Regions and HPC, engineers can solve electrically large full-wave EM models which could not be handled before. Hybrid solutions bring forth the power of specific numerical methods and allow simulation of modes containing regions of complex materials and geometries with outer regions that are electrically large. PO methods provide fast approximate solutions for large metallic models often found in antenna placement and RCS applications. Transient solutions allow engineers to examine the behavior of radiation and scattering in time and space. The physical laws that govern the behavior of radar systems are unwavering. Likewise, engineers will relentlessly drive toward solving ever-larger and more complex electromagnetic radiation and scattering problems. There are equally driven researchers, engineers, and computer scientists committed to expanding the numerical methods and techniques that efficiently solve the challenges of modern radar systems. ■

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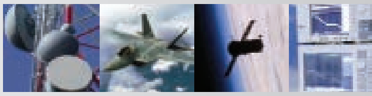

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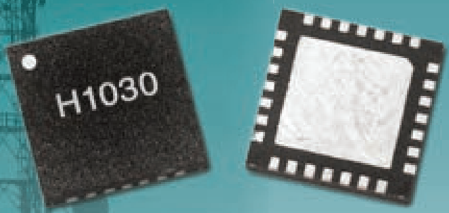

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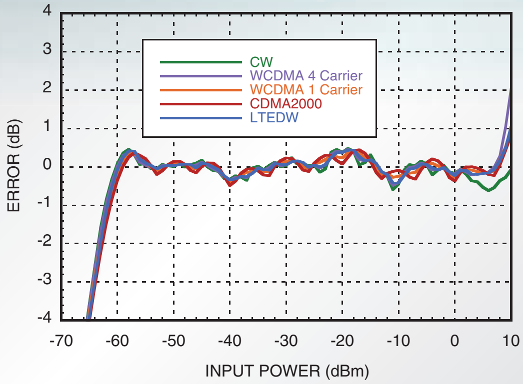

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	DC - 3.9	RMS, Single-Ended	71 ±1	35	-68	+5V @ 70 mA	LP4	**HMC1021LP4E**
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A Dual-Band 3 dB Coupled Line Tandem Hybrid Coupler

A stripline based dual-band 3 dB tandem hybrid coupler employing a minimal number of coupled transmission line elements has been developed. The topology, utilizing two single-section component hybrids in a cascade (tandem), allows for two perfect 3 dB (plus insertion loss) power split points (crossover points) below and above the center frequency of the couplers. The frequencies of the perfect split may differ by a factor of three or greater depending on the center frequency coupling value of either component coupler. A 90° output phase shift consistency, natural for coupled line-based hybrids (backward couplers) and maintained between two output ports of each component hybrid over extremely broad frequency range, guarantees a minimized (0.2 to 0.3 dB) axial ratio for moderate width lower and upper frequency regions around the crossover points. A traditional approach, based on cascading of two (or even three) multi-sectional symmetric couplers in tandem,[1-3] delivering equal split-over extremely broad frequency band, including two bands (lower and upper) of interest and between, will make the design much more complex and result in extra space required, increased insertion loss and possible significant phase deviation from 90°, especially at the upper part of the operational band. The typical tandem design, based on two identical symmetric multi-section component couplers, has been described.[2,3] Each component coupler delivers 8.34 dB and 90° phase shift over a specified bandwidth, in order to deliver 3 dB/90° shift when cascaded. Another solution is an asymmetric tandem of two or even three symmetric couplers.[2,3] A 3:1 bandwidth, with 0.02 dB ripple, can be achieved by cascading a five asymmetric and single-section component couplers, as illustrated by H. Howe[3] in his table 5-6. In both cases, the 3 dB/90° split is delivered over a broader bandwidth with a number of sections of each component coupler and number of couplers in tandem determined by low and high edge frequencies (edge frequency ratio) and amplitude ripples. The principal difference between the described dual-band hybrid coupler and a traditional one is based on the fact that two single section cascaded component couplers produce two points of "perfect" 3 dB/90° split at given lower and upper frequencies of interest only. The theoretical justification, software simulation and experimental prototype development proved the integrity of the proposed design approach and, particularly, the flexibility in adjustment of the two crossover points of equal power split between two output ports to the specified frequency location. The dual-band hybrid coupler was developed specifically for the circularly polarized signal formation, made possible at the single polarizing antenna, delivering two bands (transmit and receive) circularly polarized signal simultaneously.

THEORY

Shown in ***Figure 1*** is a functional block diagram of a typical single-section tandem coupler.[3] The voltage coupling

Alex D. Lapidus
L-3 Communications, Narda Microwave West, Folsom, CA

coefficient at the first component coupler outputs can be found as follows:[4]

$$K_{12} = \left| V_2 / V_1 \right| = C_0 \text{Sin}\,\theta \Big/ \sqrt{1 - C_0^2 \cos^2\theta} \qquad (1)$$

$$K_{13} = \left| V_3 / V_1 \right| = \sqrt{1 - C_0^2} \Big/ \sqrt{1 - C_0^2 \cos^2\theta} \qquad (2)$$

where C_0 is the center frequency coupling value of the single coupler and $\theta = \pi/2 + \pi/2\ \Delta f/f_0$ is the electrical length of the coupler as a function of the deviation from the center frequency. It should be mentioned that the voltage V_3 at the DC output (the output is DC coupled to the input) is naturally 90° behind V_2 at the coupled output. Further vector summation of the two signals at the tandem outputs delivers the projected coupling, including a perfect 3 dB split at the crossover frequencies. First, consider the case of two identical couplers cascaded in tandem.

TWO IDENTICAL COMPONENT HYBRIDS

In order to deliver 3 dB of the overall tandem power split, each component hybrid coupling value at the crossover frequencies should maintain:

$K_{12} = -8.34$ dB (0.383 voltage coupling) at the coupled output[3]

$K_{13} = -0.688$ dB (0.924 voltage coupling) at the DC output

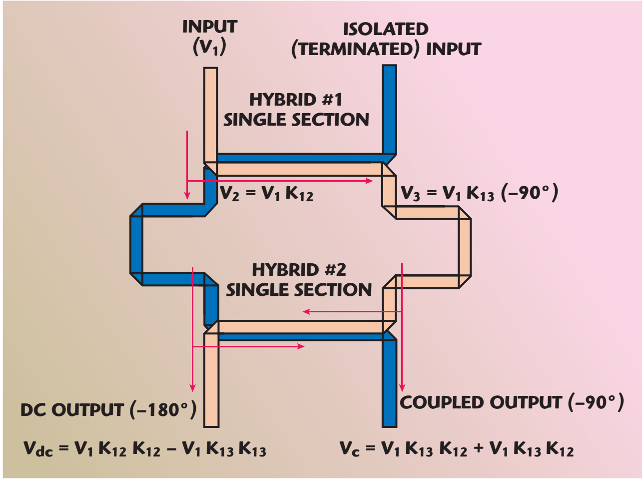
The ratio between the two coupling coefficients is found to be as follows, $\eta = K_{13}/K_{12} = 2.4125$. Then, equating this number to the voltage ratio $|V_3|/|V_2|$, using Equations 1 and 2, the center frequency component hybrid voltage coupling value as a function of the deviation of the cross-over points from the center frequency of the single coupler is obtained:

$$C_0 = 1 \Big/ \sqrt{\eta^2 \cos^2\left(\frac{\Pi}{2}\frac{\Delta f}{f_0}\right) + 1} \qquad (3)$$

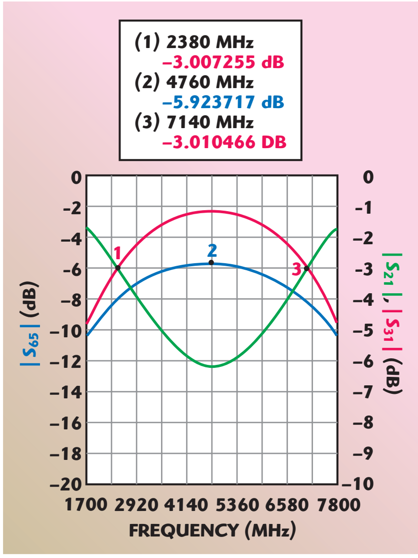
As an illustration, ***Figure 2*** shows the simulated response of the component coupler delivering –5.924 dB (0.506 voltage) coupling at the center frequency (f_0 = 4760 MHz) and 3 dB at $\Delta f/f_0 = \pm 0.5$ (7140 and 2380 MHz) when both identical couplers are cascaded. As seen from Equation 3, the center frequency coupling value of the component hybrid set the symmetric location of the crossover frequency points $\Delta f/f_0$ with respect to the center frequency. Shown in ***Figure 3*** is a coupling curve, presenting a component center frequency coupling value as a function of the relative position of the crossover frequency points.

TWO COMPONENT HYBRIDS OF ARBITRARY COUPLING

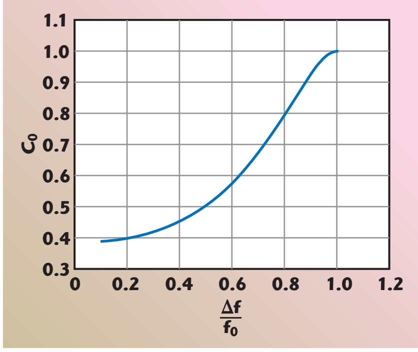
The equal split at the two crossover points equidistant from center



▲ *Fig. 1 Dual-band coupler-hybrid functional diagram.*



▲ *Fig. 2 Component coupler port response (blue) and hybrid tandem response.*



▲ *Fig. 3 Component hybrid center frequency coupling curve.*

frequency is possible with two-component hybrids of an arbitrary coupling provided that the coupling values meet a certain condition. The main factor of the equal split is that the vector summation of two signals coming to each output (DC and coupled) of the tandem should deliver 0.707 of the input voltage. Considering a tandem signal propagation as shown in Figure 1, the voltages at the DC and coupled outputs now can be written as follows:

$$V_{dc} = V_1K_{12}^1K_{12}^2 - V_1K_{13}^1K_{13}^2 \quad (4)$$

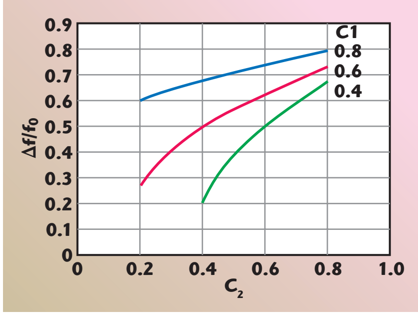
$$V_c = V_1K_{13}^1K_{12}^2 + V_1K_{12}^1K_{13}^2$$

where K_{12}^1 and K_{12}^2, K_{13}^1 and K_{13}^2 are the voltage couplings of an arbitrary frequency at the coupled and DC outputs of the first and second component hybrids, correspondingly. Substituting Equations 1 and 2 in Equation 4 and equating V_{dc} and V_c, after certain algebra, the simplified equation relating the center frequency coupling values of each hybrid with the deviation of crossover point is obtained:

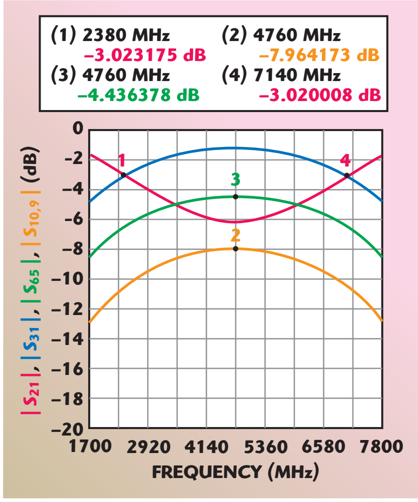
$$\left(C_1\sqrt{1-C_2^2}+C_2\sqrt{1-C_1^2}\right)\cdot \cos\left(\frac{\frac{\Pi}{2}\Delta f}{f_0}\right) = \sqrt{1-C_1^2}\sqrt{1-C_2^2}-C_1C_2\cos^2\left(\frac{\frac{\Pi}{2}\Delta f}{f_0}\right) \quad (5)$$

where C1 and C2 are the center frequency voltage coupling of the component hybrids. Introducing a new variable

$$Y = \cos\left(\frac{\frac{\pi}{2}\Delta f}{f_0}\right)$$



▲ *Fig. 4 3 dB crossover points relative to the center frequency as a function of component hybrid center frequency coupling values.*



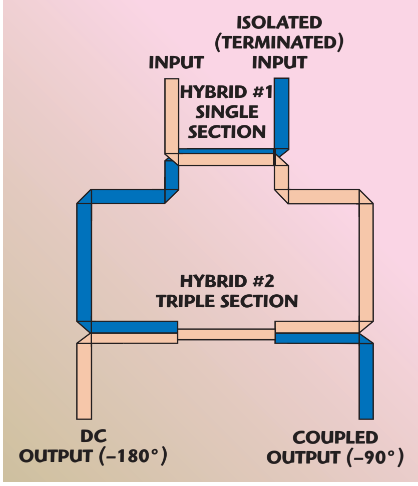
▲ *Fig. 5 Component coupler coupled port responses (green and yellow) and hybrid tandem response.*

and solving a quadratic equation for Y, the $\Delta f/f_0$ as a function of coupling values can be found as shown in ***Figure 4***. Shown in ***Figure 5*** is a simulated coupling response of two-component hybrids having coupling values of −7.96 and −4.44 dB (0.4 and 0.6 voltage coupling) at the center frequency that deliver perfect 3 dB split at $\Delta f/f_0$ = ± 0.5 (7140 and 2380 MHz) when both hybrids are cascaded.

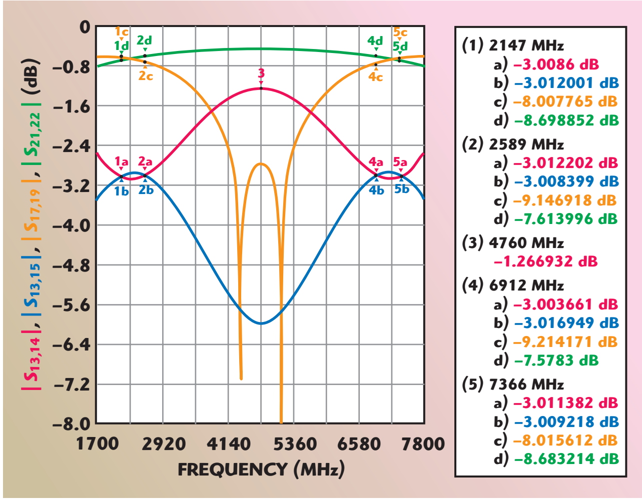
TANDEM COUPLER WITH WIDENED LOWER AND UPPER OPERATIONAL BANDS

The tandem coupler discussed above is based on two cascaded single-section hybrids. Such an approach produces two crossover points of "perfect" power split and moderate-width lower and upper bands of minimized (0.2 to 0.3 dB) axial ratio (MAR), see experimental results discussion. Significant broadening of both operational bands is possible by utilizing a triple-section hybrid in cascade

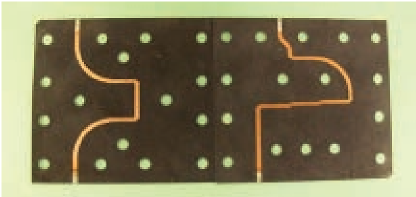
with a single-section one, as shown in ***Figure 6*** for the functional block diagram. In this case, the lower and upper operating minimized axial ratio (MAR) bands are established by two crossover points on each side and, depending on the frequency separation, may be many times wider than in the case of the single-section based tandem coupler. Due to the complexity and inexpediency of finding a mathematical solution to this problem, the coupling values of each section of symmetrical triple-section component hybrid are obtained by optimization performed with a linear circuit simulator. The optimization goals should be set for the MAR regions equidistant from the center frequency as well as for return loss. ***Figure 7*** illustrates a typical lossless element-based simulated response of such a single-triple section dual-band tandem coupler as well as responses of component hybrids. It is clearly seen that both component hybrids, single- and triple-section, produce coupling values approaching 8.34 dB around two MAR regions. At the same time, the triple-section hybrid individual coupling response, as a result of optimization, differs significantly from the typical "flat"[3] response and maintains coupling value slopes reversed to that of the single section in the MAR regions, which assures two crossover points of perfect 3 dB split per side as shown in Figure 7.



▲ *Fig. 6 Single-triple section hybrids tandem.*



▲ *Fig. 7 Single-triple section hybrid tandem response. Tandem output coupling (blue and red), triple section hybrid coupling (yellow), single section hybrid coupling (green).*



▲ *Fig. 8 Single-single section and single-triple section tandem-coupler center boards.*

EXPERIMENTAL RESULTS

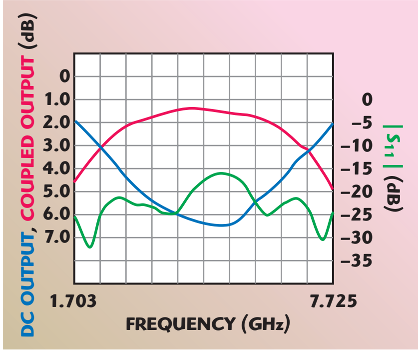
Two dual band tandem-couplers were built and tested, single-single (identical coupling) and single-triple section type. Three RO5880 dielectric boards compressed inside the housing formed a three-layer structure with coupled and interface striplines located on both sides of the center board, forming so-called "through the board coupling." Such a design approach delivers excellent electrical performance, particularly for the return loss, necessary coupling and assures high power operation capabilities. ***Figure 8*** shows a top view of both single- and triple-section based tandem coupler center boards.

It should be mentioned that a thorough 2.5D EM simulation preceded the experimental prototype development. ***Figures 9*** and ***10*** show the coupling responses for single-single and single-triple section tandem-

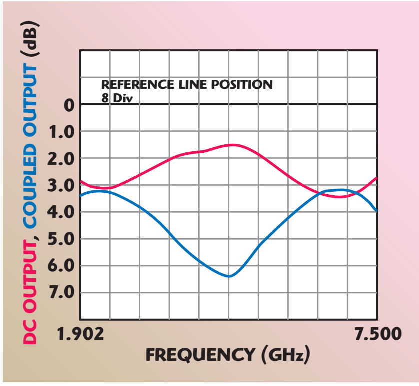
coupler prototypes with lower and upper operation bands centered around 2.38 and 7.14 GHz (3 times frequency), respectively. In the first case, the MAR region of better than 0.3 dB was observed over approximately 100 MHz widebands around the crossover points, with phase shift of 89.7° to 91.7°, measured between ports over the entire frequency span. In the second case (single-triple section), the axial ratio below 0.45 and 0.37 dB were maintained over 1 GHz and 600 MHz widebands for the upper and lower operating bands, correspondingly. The actual insertion loss, different for single- and triple-section component couplers and varying with the frequency, contributed to the asymmetry of the actual prototype responses in the lower and upper MAR regions.

CONCLUSION

In this article, dual-band hybrid-couplers were described and developed for the circularly polarized signal formation. The couplers are formed by cascading two rather simple component hybrids, which deliver nearly perfect power split and necessary phase shift (about 90°) between two output ports at the bands of MAR located at the frequencies different by factor 3 or greater. The simplicity of the design and flexibility of MAR location adjustment, as well as rather low axial ratio achieved for both frequency bands of interest, makes this approach much more appropriate than traditional (ultra broadband) multistage coupler, especially when the low axial ratio and insertion loss are required only for two frequency separated bands. ■



▲ *Fig. 9 Coupling and return loss of single-single section tandem coupler.*



▲ *Fig. 10 Coupling response of single-triple section tandem-coupler.*

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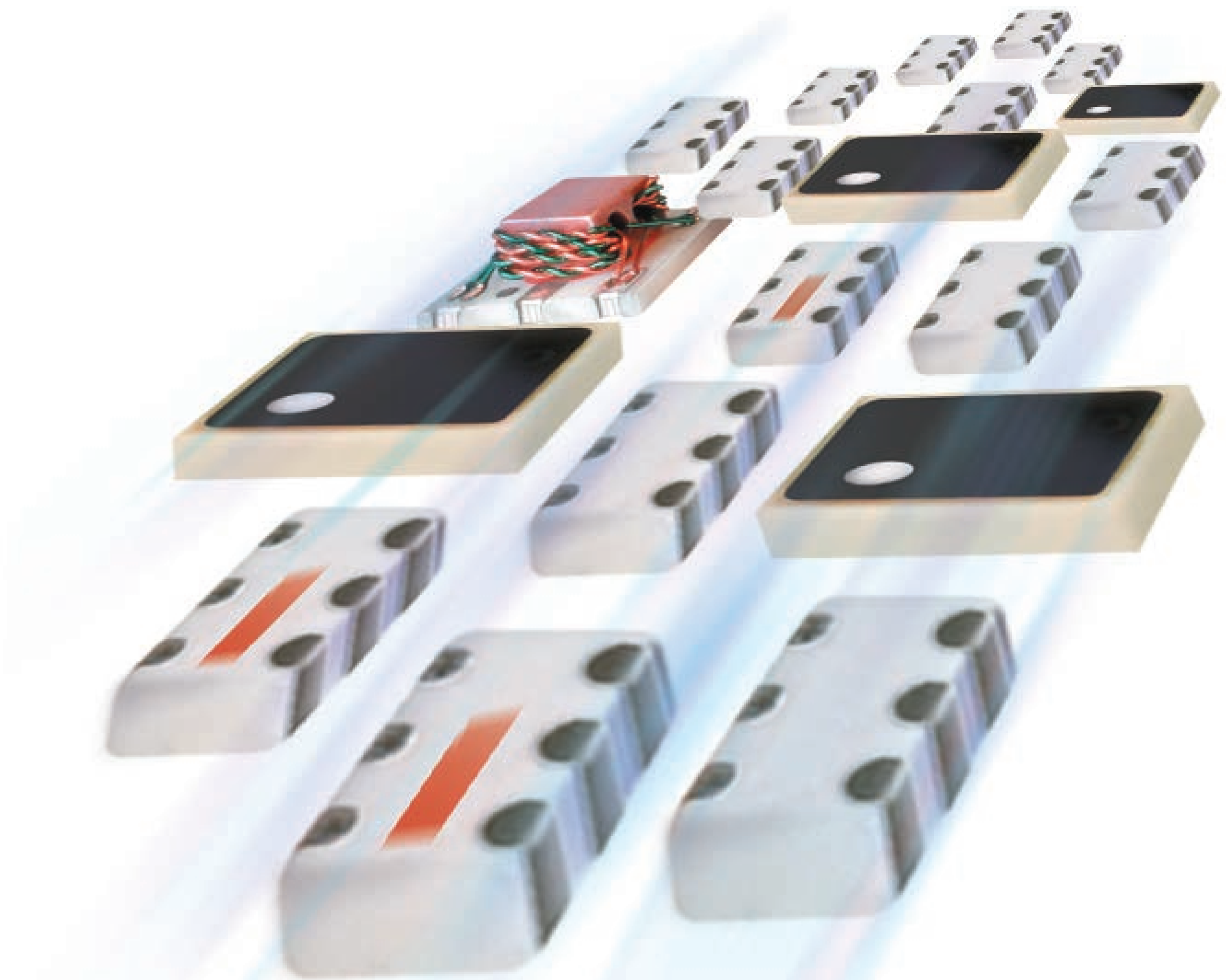

Ultra-Compact On-Chip RF Divider Circuit Employs a PAGS Structure

In this work, a highly miniaturized on-chip Wilkinson power divider was realized on a silicon radio frequency integrated circuit (RFIC) using a coplanar waveguide employing a periodically arrayed ground strip (PAGS) structure. For size reduction and low loss of the Wilkinson power divider, the RF characteristics of coplanar waveguides employing various types of PAGS structures were investigated and an optimal structure of PAGS was extracted. The Wilkinson power divider employing the optimal PAGS structure exhibited good RF performance from 25 to 50 GHz, and its size was 0.044 mm^2, which was 4.8 percent of a conventional one.

Wilkinson power dividers[1] have been widely used for signal division/coupling in power amplifiers (PA),[2] balanced amplifiers and balanced mixers.[3] The development of highly miniaturized, on-chip, power dividers is indispensable for application to silicon radio frequency integrated circuits (RFIC). With the evolution of silicon CMOS device process technology, highly integrated silicon ICs, including RF and baseband blocks, have been developed.[4] However, in spite of the growth of the silicon integration technology, conventional Wilkinson power dividers, employing quarter wavelength lines, have been fabricated outside of RFIC, due to their large size, which has been an obstacle to a realization of a fully integrated silicon front-end.

In this work, to miniaturize the power divider, short wavelength coplanar waveguides, employing a periodic structure, have been used. The periodic structure was optimally designed so that the coplanar waveguide shows much shorter wavelength than a conventional transmission line. Using the optimally designed periodic structure, a highly miniaturized on-chip Wilkinson power divider was realized on silicon RFICs. To miniaturize the power divider, a coplanar waveguide, employing periodically arrayed ground structures, was optimally designed. The size of the on-chip Wilkinson power divider was 4.8 percent of a conventional one.

STRUCTURE OF COPLANAR WAVEGUIDES EMPLOYING PAGS

Transmission lines employing periodic structures have been fabricated on compound semiconducting substrates[5,6] and silicon substrates.[7,8] Transmission lines employing a periodic structure on silicon substrate have shown a low loss characteristic as well as a slow-wave characteristic.[7] For this reason, the transmission lines employing periodic structures were

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used for this application to miniaturize on-chip passive components on a silicon substrate.[8] In this work, transmission lines employing PAGS structures[8] have been used for application to a miniaturized on-chip Wilkinson power divider on a silicon substrate.

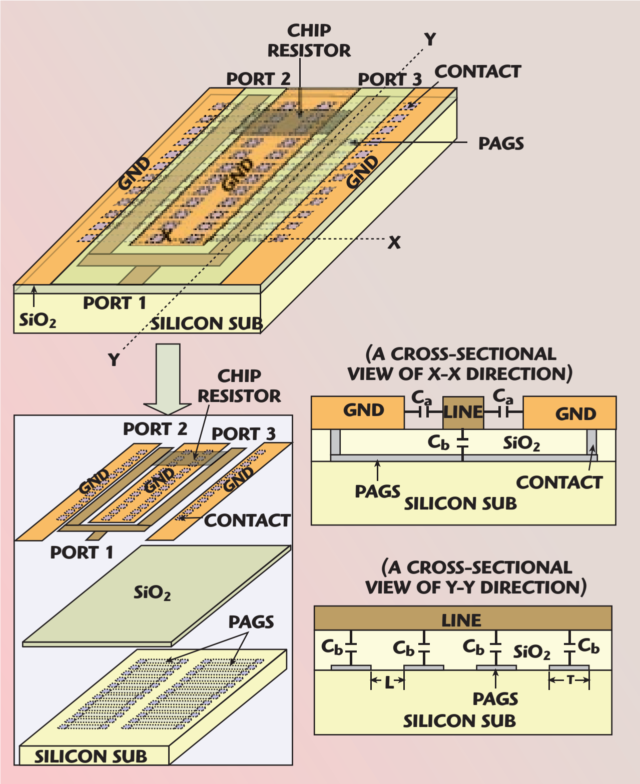
Figure 1 shows the on-chip Wilkinson power divider employing PAGS on a silicon substrate. As shown, the Wilkinson power divider consists of two section transmission lines with a length of λ/4. Each transmission line was realized using a coplanar waveguide employing PAGS. Although a conventional Wilkinson power divider occupies a very large area on a RF circuit,[1] the size of the Wilkinson power divider employing PAGS was highly reduced due to a short wavelength characteristic of the coplanar waveguide employing PAGS. The reason for size reduction of the Wilkinson power divider employing PAGS can be explained as follows: As shown in Figure 1, PAGS exists at the interface between the SiO_2 film and the silicon substrate, and is electrically connected to the top-side ground planes (GND planes) through the contacts (vias). Therefore, PAGS is grounded to the GND planes. As is well known, a conventional coplanar waveguide without PAGS has only a periodic capacitance C_a per unit length, while the coplanar waveguide employing PAGS has an additional capacitance C_b as well as C_a. As shown, C_b is the capacitance between the line and PAGS. In other words, the total capacitance (per unit length) of the coplanar waveguide employing PAGS corresponds to $C_a + C_b$, but the total capacitance of a conventional coplanar waveguide without PAGS corresponds to C_a. Therefore, the coplanar waveguide employing PAGS exhibits a wavelength (λg) much shorter than a conventional coplanar waveguide, because λg is inversely proportional to the periodic capacitance. In other words, $\lambda g = 1/[f(LC)^{0.5}]$.

The wavelength of coplanar waveguide employing PAGS was compared with a conventional coplanar waveguide. ***Figure 2*** shows photographs of a coplanar waveguide employing PAGS and a conventional one. ***Figure 3*** shows the measured wavelength of the coplanar waveguide employing PAGS and a conventional one. The coplanar waveguides were fabricated on a silicon substrate with a height of 600 µm. L and W are 20 µm. As shown, the wavelength of the coplanar waveguide was reduced to 60 to 65 percent of the conventional one by using PAGS. For example, the wavelength of the coplanar waveguide employing PAGS (with a T of 20 µm) is 3.7 mm at 20 GHz, while the wavelength of the conventional coplanar waveguide without is 5.9 mm at the same frequency. The above results indicate that highly miniaturized passive circuits can be realized by using the coplanar waveguide employing PAGS.

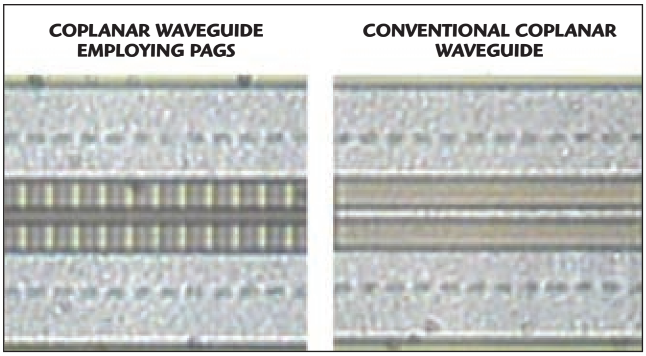
Table 1 shows the characteristic impedance of the coplanar waveguide employing PAGS. It can be seen that an increase of the strip width T results in an enhancement of the periodic capacitance C_b, owing to an increase in capacitive area. Therefore, as shown in the table, the characteristic impedance Z_0 of the coplanar waveguide employing PAGS can be easily controlled by changing the strip width T, because Z_0 depends on the periodic capacitance of the transmission line. These results indicate that highly miniaturized passive components with various impedances can be realized using the coplanar waveguide employing PAGS.

TABLE I
CHARACTERISTIC IMPEDANCE OF THE COPLANAR WAVEGUIDE EMPLOYING PAGS

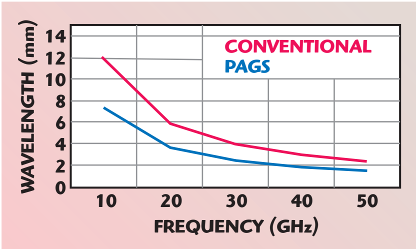
T (µm)	Characteristic Impedance (Ω)
0	67
10	40
20	36
30	34
40	27
50	21



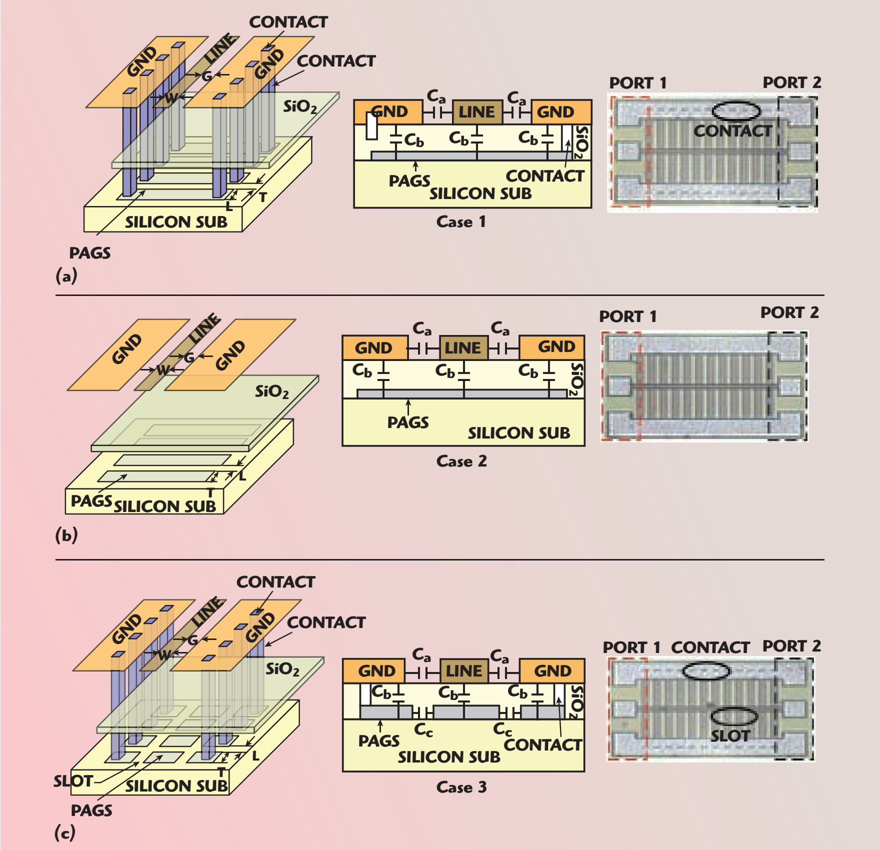
▲ *Fig. 1 On-chip Wilkinson power divider employing PAGS on a silicon substrate.*



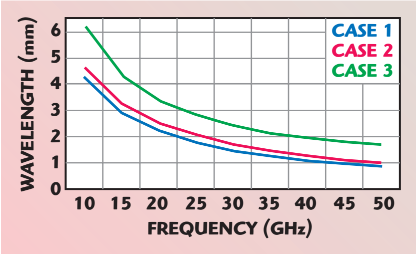
▲ *Fig. 2 Photographs of a coplanar waveguide employing PAGS and a conventional one.*



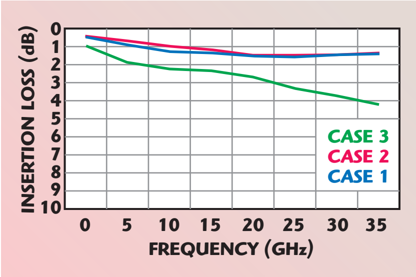
▲ *Fig. 3 Measured wavelength of the coplanar waveguide employing PAGS and a conventional one.*



▲ *Fig. 4 Coplanar waveguides employing PAGS structures.*



▲ *Fig. 5 Wavelength vs. frequency of the coplanar waveguides employing three types of PAGS structures.*

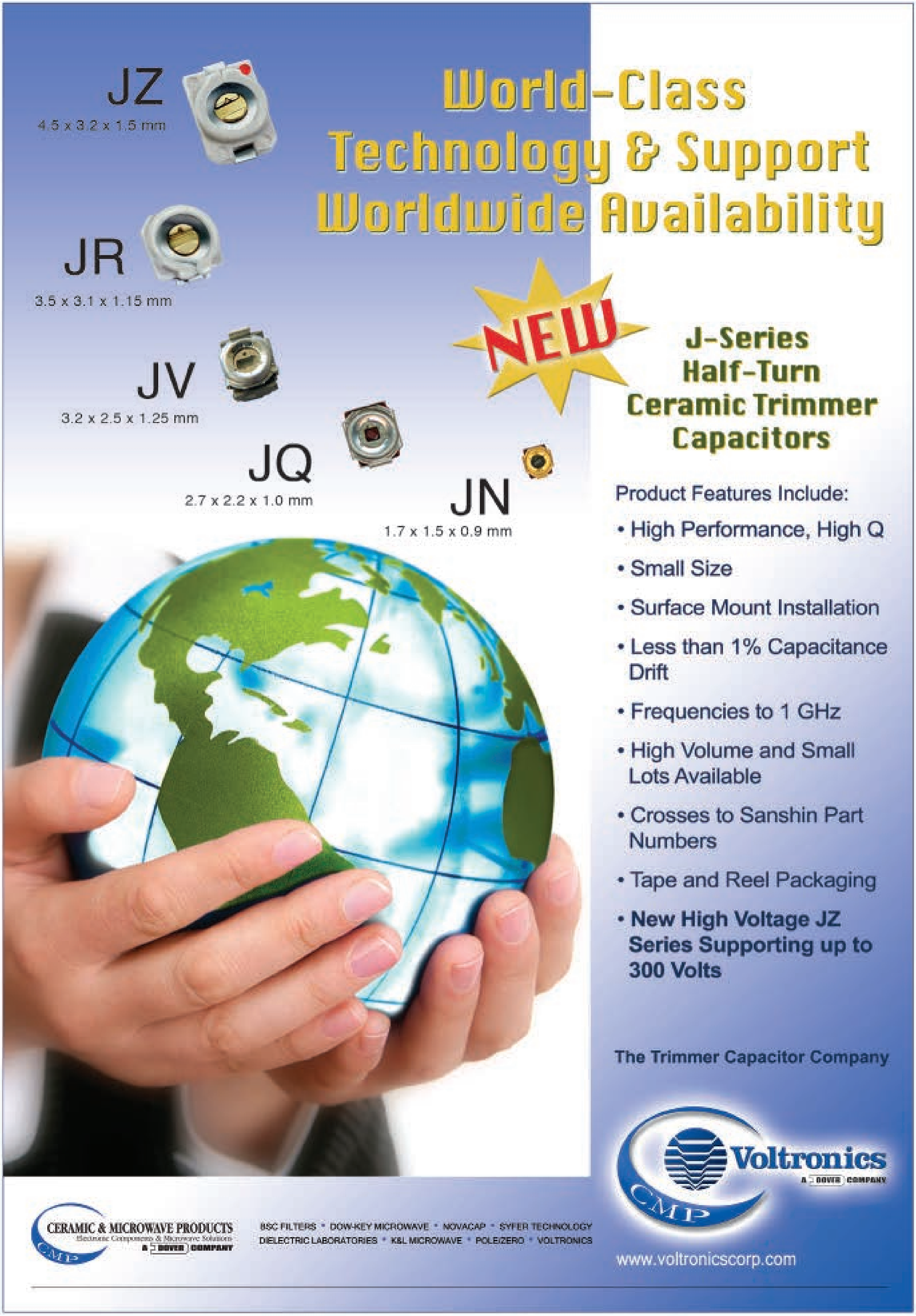


▲ *Fig. 6 Insertion loss of the coplanar waveguides employing three types of PAGS structures.*

RF CHARACTERISTICS OF A COPLANAR WAVEGUIDE WITH VARIOUS PAGS STRUCTURES

In order to select an optimal structure of the PAGS, coplanar waveguides employing various types of PAGS structures were prepared. ***Figure 4*** shows coplanar waveguides employing various types of PAGS structures. Compared with Case 1, contacts between PAGS and ground were removed in Case 2, and slots were added in Case 3. ***Figures 5*** and ***6*** show the wavelength and insertion loss of the coplanar waveguides employing the three types of PAGS structures. Case 1 shows the shortest wavelength of all types. Case 3 shows a wavelength longer than the other types.

As shown, Case 3 shows an insertion loss higher than other types, because the slots on periodic ground strips cause parasitic coupling capacitances, resulting in high loss. According to these results, Case 1 shows the best performances compared with other types. It can be explained as follows. For Case 2, the PAGS was not completely grounded due to the isolation between the PAGS and the GND metal. Also, for Case 3, the middle section of PAGS was isolated from the ground due to the slots, which resulted in an incomplete ground


JZ
4.5 x 3.2 x 1.5 mm
JR
3.5 x 3.1 x 1.15 mm
JV
3.2 x 2.5 x 1.25 mm
JQ
2.7 x 2.2 x 1.0 mm
JN
1.7 x 1.5 x 0.9 mm
World-Class
Technology & Support
Worldwide Availability
NEW
J-Series
Half-Turn
Ceramic Trimmer
Capacitors
Product Features Include:
• High Performance, High Q
• Small Size
• Surface Mount Installation
• Less than 1% Capacitance Drift
• Frequencies to 1 GHz
• High Volume and Small Lots Available
• Crosses to Sanshin Part Numbers
• Tape and Reel Packaging
• New High Voltage JZ Series Supporting up to 300 Volts
The Trimmer Capacitor Company
Voltronics
A DOVER COMPANY
CMP
CERAMIC & MICROWAVE PRODUCTS
Electronic Components & Microwave Solutions
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BSC FILTERS • DOW-KEY MICROWAVE • NOVACAP • SYFER TECHNOLOGY
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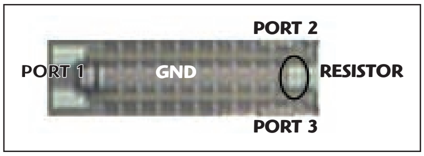
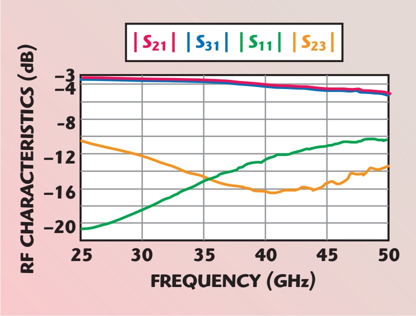
condition. In addition, the slots on the PAGS caused parasitic coupling capacitance, which deteriorated the RF performance. For Case 1, the PAGS was connected to the ground metal through the contacts and there is no slot on the PAGS, which resulted in the best ground condition. In this work, using Case 1, a highly miniaturized Wilkinson power divider was fabricated on a silicon RFIC.

HIGHLY MINIATURIZED ON-CHIP WILKINSON POWER DIVIDER EMPLOYING PAGS

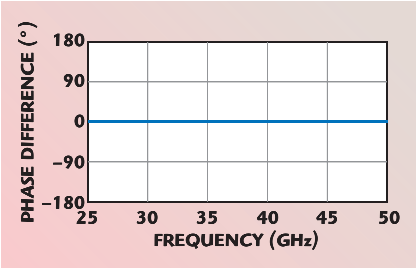
Figure 7 shows a photograph of the on-chip Wilkinson power divider employing PAGS on a silicon RFIC. Because the port impedance was set to 27 Ω for low impedance matching applications, the characteristic impedance of transmission lines comprising the power divider are 38 Ω, and the resistor at the output ports is 54 Ω. In order to realize the coplanar waveguide with a 38 Ω impedance, the value of T was set to 20 μm, according to Table 1. In the case of a center frequency of 40 GHz, the size of the power divider employing PAGS was 0.44×0.1 mm^2, which is 4.8 percent of the size of the one fabricated by a conventional coplanar waveguide method 1. In other words, in the case where the Wilkinson power divider is fabricated with a conventional coplanar waveguide (having a G of 30 μm) on a silicon substrate with a height of 600 μm, the length of a λ/4 line is 0.751 mm at a center frequency of 40 GHz, and the line width W is 580 μm for a characteristic impedance of 27 Ω. Therefore, the size of Wilkinson divider employing conventional coplanar waveguide is 0.916 mm^2. The size comparison of the Wilkinson divider is summarized in ***Table 2***. ***Figure 8*** shows the power division and isolation characteristics of the Wilkinson divider employing PAGS. Good power division characteristics can be observed from 25 to 50 GHz. Specifically, S_{21} and S_{31} exhibit a magnitude of 4.5 dB at 40 GHz. In the frequency range of 25 to 50 GHz, S_{21} and S_{31} show a magnitude of 4.5 ± 1 dB. The power division of the Wilkinson divider fabricated on a Teflon substrate[4] is approximately –4 ± 1 dB and the Wilkinson divider employing PAGS shows a loss higher by 0.5 dB than a conventional one, which originates from the high conductivity of the silicon substrate.[4] The isolation (S_{23}) shows a value of –16.2 dB at 40 GHz, and an isolation characteristic higher than –10.5 dB in the range of 20 to 50 GHz can be observed. ***Figure 9*** shows the phase division characteristic of the Wilkinson divider employing PAGS. The phase difference between the signals at the output ports (port 2 and 3) was measured when the input signal is excited at port 1. Equal phase division characteristics, 0 ± 0.3° in the range of 20 to 50 GHz can be observed.



▲ *Fig. 7 Photograph of the on-chip Wilkinson power divider using PAGS.*



▲ *Fig. 8 Power division and isolation characteristics of the Wilkinson power divider using PAGS on a silicon RFIC.*



▲ *Fig. 9 Phase division characteristic of the Wilkinson power divider using PAGS.*

CONCLUSION

In this work, a highly miniaturized on-chip Wilkinson power divider was fabricated, using a coplanar waveguide employing a PAGS on a silicon RFIC. For size reduction and low loss of the Wilkinson power divider, the RF characteristics of coplanar waveguides employing various types of PAGS structures were investigated, and an optimal structure of the PAGS

TABLE II

SIZE OF ON-CHIP WILKINSON POWER DIVIDERS USING CONVENTIONAL COPLANAR WAVEGUIDE AND PAGS

Item	Line Width W (μm)	Length of λg/4 line (mm)	Size of Power Divider (mm^2)
Power divider employing conventional CPW	580	0.751	0.916
Power divider employing PAGS	20	0.44	0.044

was extracted. The Wilkinson power divider employing the optimal PAGS structure exhibited good RF performances from 25 to 50 GHz, and its size was 0.044 mm^2, which was 4.8 percent of a conventional one. ■

ACKNOWLEDGMENT

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Double Notched Bandpass Filter Achieves UWB Performance

This article presents a novel microstrip structure for double controllable notched bands implementation in an ultrawideband (UWB) bandpass filter (BPF). The double notched bands are created by introducing the proposed structure with a modified multi-mode resonator (MMR). The filter, with a passband from 2.95 to 10.84 GHz, has notched bands at 5.87 GHz (WLAN) and 7.61 GHz (military communication satellite) frequencies, insertion loss of less than 0.2 dB, return loss of better than 16.7 dB, group delay variation of less than 0.2 ns in the three passbands, rejection loss of 37.2 and 30 dB, fractional bandwidth of 114 percent and a wide stopband.

Ultrawideband wireless communication technology has attracted wide attention since the Federal Communications Commission (FCC) released the unlicensed use of the frequency range from 3.1 to 10.6 GHz for commercial communication applications in 2002. Recently, the development of new UWB filters has increased via different methods and structures.[1-7] Due to the existing undesired narrowband radio signals, such as wireless local area network (WLAN) and military satellite communication systems that may interfere with the UWB range defined by the FCC, it is desirable to introduce single or multiple notched bands to avoid interferences from the existing wireless communication into UWB BPFs. Some techniques have been studied.[8-13]

In this article, a UWB BPF with controllable double notched bands is designed, fabricated and tested. This technique is based on parallel-coupled lines. The parallel-coupled lines are designed to generate double notched bands inside a wide passband. The proposed structure is to be applied to an improved microstrip-line single-stage MMR. Previously, an MMR with three stubs was described[7] and in this article, the MMR was improved, using four stubs and two parallel coupled lines to relocate the first three resonant modes within the UWB band, while pushing up the next mode to make up a wider upper stopband. The modified multiple mode resonator and the double coupled feed lines can work together to create the desired UWB BPF with double notched bands. By properly adjusting the gap between the parallel coupled lines, the desired double notched bands can be obtained. The proposed filter is realized on a low cost microstrip substrate with a relative dielectric constant of 6.15 and a thickness of 31 mil.

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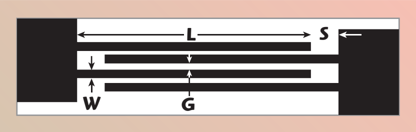
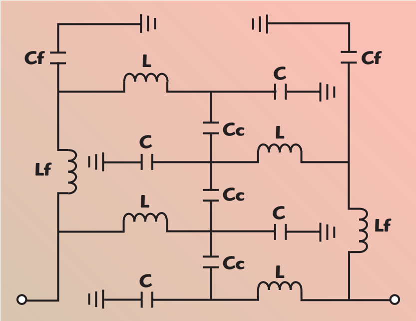
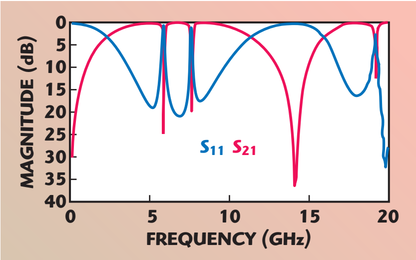


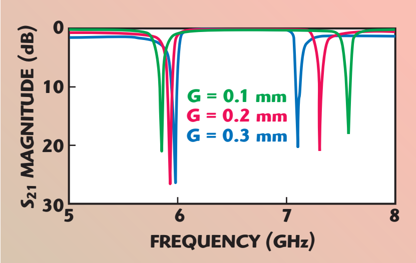
▲ *Fig. 1 Configuration of the proposed microstrip coupled lines.*



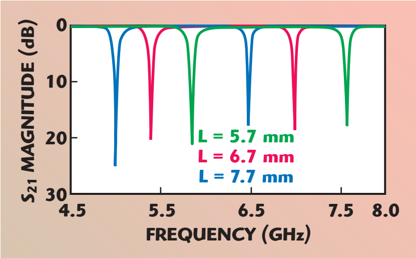
▲ *Fig. 2 LC equivalent circuit of the proposed resonator.*



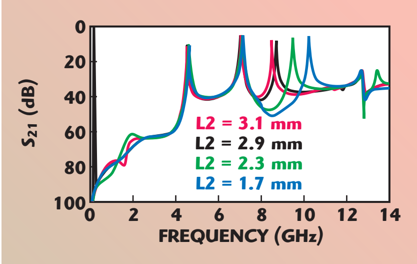
▲ *Fig. 3 EM-simulated response of the resonator.*



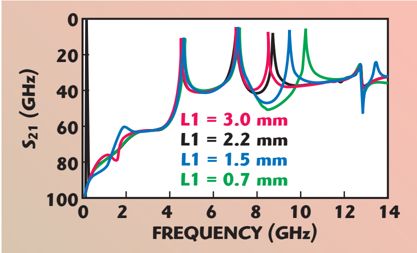
▲ *Fig. 4 Simulated response as a function of G.*



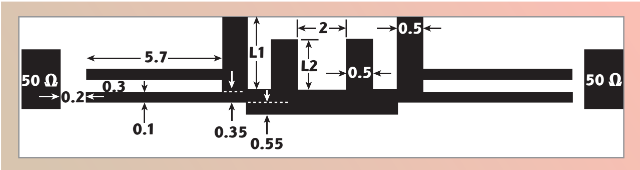
▲ *Fig. 5 Simulated response as a function of L.*



▲ *Fig. 7 S_{21} magnitude of the stub-loaded MMR structure vs. L2.*



▲ *Fig. 8 S_{21} magnitude of the stub-loaded structure vs. L1.*



▲ *Fig. 6 Layout of the modified stub-loaded MMR, which are weakly capacitive-coupled.*

NOTCHED BAND CHARACTERIZATION

Figure 1 illustrates the layout of the proposed microstrip double notched band structure. Sun and Zhu[4] have proposed a structure consisting of three coupled lines with symmetric loaded stubs, to achieve a UWB BPF with a tight coupling degree and enhance the out-of-band performance of an earlier work.[1] Shaman and Hong[10] improved the approach of Sun and Zhu[4] by developing a new technique for notch implementation in UWB BPFs. This technique is to be used on parallel coupled lines with asymmetric loading stubs.

Here, the purpose is to generate the double narrow notched bands, using the structure depicted, with L = 5.7 mm, G = 0.1 mm, S = 0.2 mm and W = 0.1 mm. The length of the lines is chosen to be a quarter-wavelength long, at approximately 7 GHz, to obtain a wide passband. To have a better understanding of the proposed resonator, its LC equivalent circuit is derived as shown in ***Figure 2***. In this circuit, Cf and Lf represent the capacitance and inductance of the feeding lines, respectively, while C and L are used to model the same parameters for the interdigital fingers and finally Cc represents the coupling between these fingers.

Figure 3 displays the EM-simulated insertion and return loss of the proposed structure on a substrate with a dielectric constant of 6.15 and a thickness of 31 mil. To evaluate the resonator structure, the effects of dimension variations on the resonator response are studied. The two dimensions that have the most significant influence and can be used to control the position of the notched bands are G and L. The EM-simulated results of the proposed resonator as a function of G and L variations are shown in ***Figures 4*** and ***5***, respectively. As seen in the figures, by increasing the value of G, both notched frequencies change, so that the f1 frequency increases and the f2 frequency decreases. By increasing the value of L, both of the notched bands move to lower frequencies.

UWB BPF WITH DOUBLE NOTCH

Figure 6 illustrates the layout of the modified MMR. Li and Zhu's MMR[7] has three stubs and here, it has been improved by using four open stubs with two parallel coupled lines. In this way, with adjusting the length of the stubs L1 and L2, the first three resonant modes have been relocated within the UWB passband, while pushing up the next mode to obtain a wider upper stopband. In addition, in this structure, the modified MMR has two parallel coupled lines. As shown in ***Figure 7***, as L2 is lengthened, the first and the second resonant frequencies keep almost unchanged, while the third frequency is moved down and the two other open stubs, with lengths L1, can change the location of the resonant frequencies, so that as L1 lengthened, the first resonant frequency is kept almost unchanged, while the second and the third frequencies are moved down, as shown in ***Figure 8***.

By attaching the modified MMR to the proposed microstrip coupled lines, a UWB BPF with double notched bands can be obtained, and by changing the gaps between the parallel coupled lines, the desired notched frequencies can be achieved. Also, with

changing the shape of the second stubs as shown in ***Figure 9***, the stopband can be improved as shown in ***Figure 10***. By changing the upper coupled line to a trapezoid shape, the notched frequencies moved up slightly (approximately 0.1 GHz). So the final modified structure for an UWB BPF with two notched frequencies at f1 = 5.87 GHz (WLAN) and f2 = 7.61 GHz (military communication satellites) is obtained. ***Figure 11*** is a photograph of the fabricated compact filter.

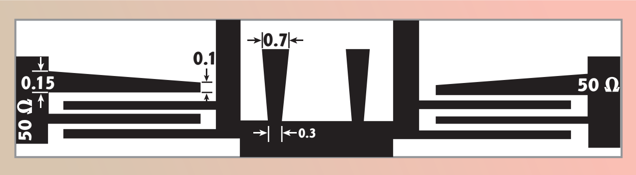


Fig. 9 Microstrip layout of the final UWB BPF with double notch changing the shape of the second stubs.

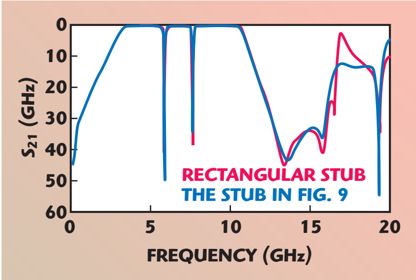


Fig. 10 EM-simulated insertion loss of the UWB BPF with double notch changing the shape of the second stub.

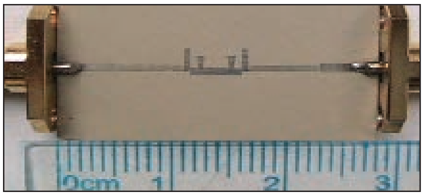


Fig. 11 Photograph of the fabricated compact filter.

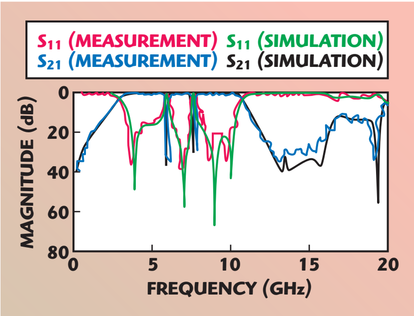
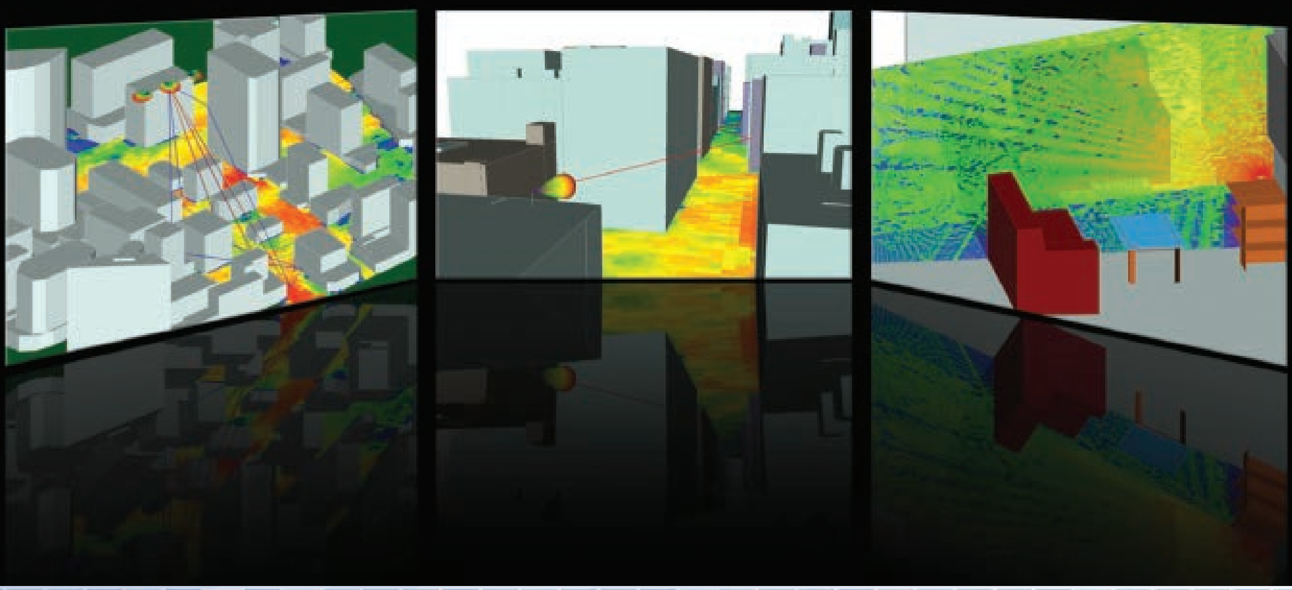


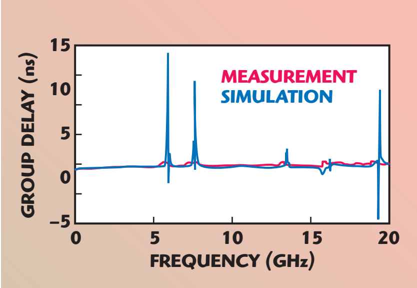
Fig. 12 EM-simulated and measured S_{21} and S_{11} magnitudes of the final UWB BPF with double notch.

SIMULATED AND MEASURED RESULTS

The filter is designed and fabricated on a substrate with a relative dielectric constant of 6.15 and a thickness of 31 mil. Its filtering performance is simulated using the Agilent Momentum software. A 5 mm long microstrip feed line is added to both input and output. It occupies a small size of 17.04 × 3.25 mm.

The final filter is capable of reducing the insertion loss in the three passbands to less than 0.2 dB, the return loss over the three passbands is greater than 16.7 dB, the group delay variation in the three passbands is less than 0.2 ns, the rejection loss is more than 37.2 dB at the midband frequency of the first notched band and better than 30 dB at the midband frequency of the second notched band. The fractional bandwith is 114 percent. Also, a wider stopband less than –12.2 dB up





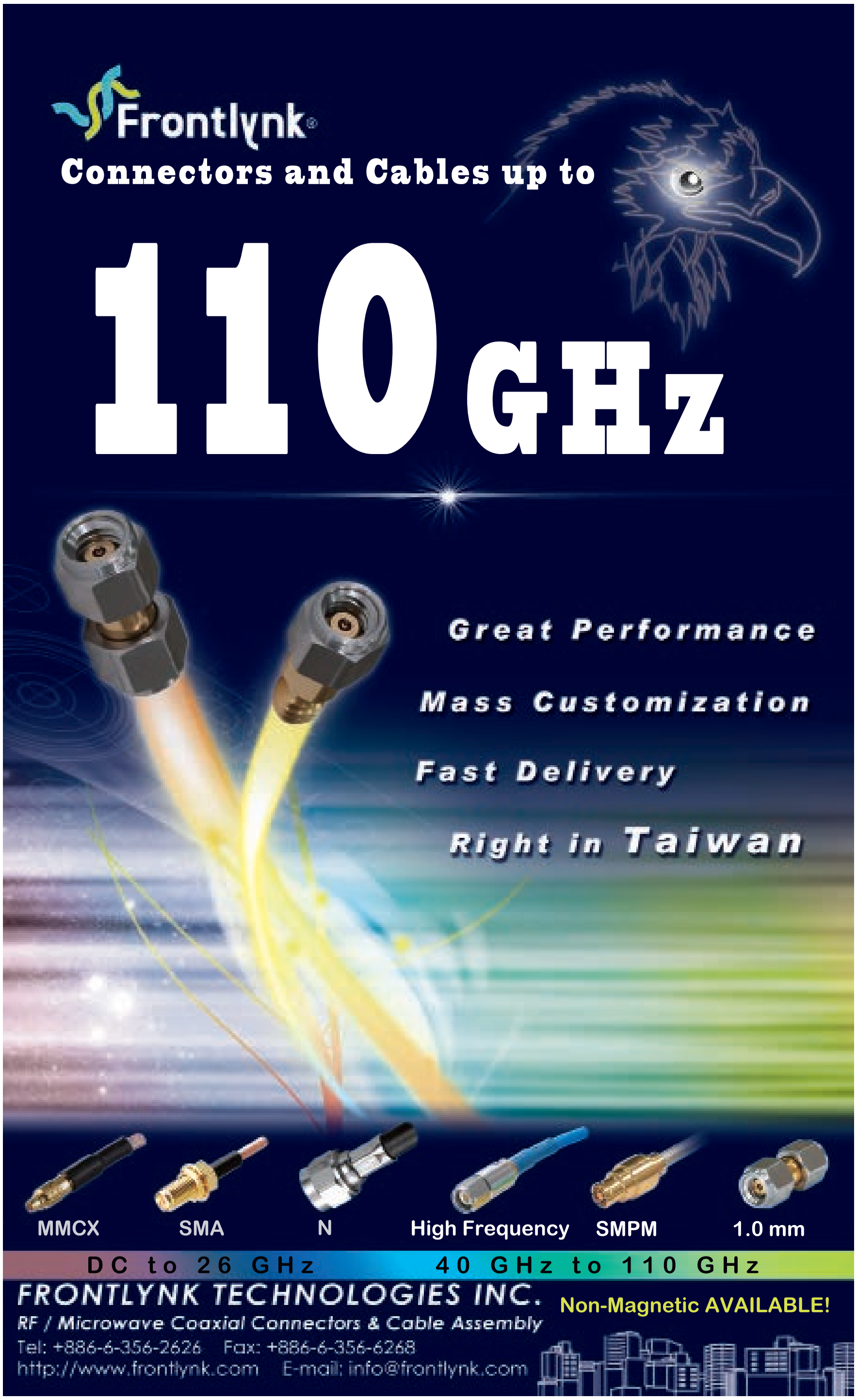
▲ *Fig. 13 EM-simulated and measured group delay of the final UWB BPF with double notch.*

to 19.5 GHz has been obtained. ***Figures 12*** and ***13*** show the simulated and measured frequency response of the S-parameters magnitude and the group delay, where an excellent agreement is obtained.

CONCLUSION

This article has presented a coupling structure for implementing double notched bands in UWB BPFs. It is based on four parallel-coupled lines, which can provide a tight coupling within the FCC-regulated UWB passband, and introduces two notches inside the passband at the desired frequencies. It has been applied to a single stage modified MMR to produce two narrow notched bands inside its passband. The notched frequencies are controllable. The stopband of the final structure has been improved.

The UWB BPF with double notched bands at (5.87 GHz) WLAN frequency and (7.61 GHz) military communication satellite frequency, with small in-band insertion loss, large in-band return loss, high rejection loss and small group delay variation has been obtained. Excellent agreement between the simulated and measured results is obtained.■



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The Importance of Peak Power Measurements for Radar Systems

Radar systems are used for military and civilian aviation, weather system tracking and automobile traffic control to name a few. All of these systems have several things in common, including transmitting and receiving reflected RF energy from a distant object to calculate speed, distance and sometimes elevation. These systems are very important for our safety and require accurate power measurement. This article will focus on aviation or ranging type radar that uses bursts, or chirps of pulse modulated waveforms for fine object detail, and has sensitive receivers for low noise measurements.

The commonly understood idea of radar is referred to as primary and is similar to how a bat uses echo location to find a flying insect. A radar transmitter sends out a pulse of radio energy, and a small proportion is reflected back from the surface of the target aircraft to the radar receiver. The stationary primary radar antenna provides the speed and distance of an approaching aircraft, while a rotating antenna dish provides elevation. This passive interrogation does not provide any other identification information. A system developed to gather more information about the target by the military is called the Identification Friend or Foe (IFF) system and is used to distinguish between friendly and enemy aircraft. The Federal Aviation Administration (FAA) or civilian version is the Air Traffic Control Radar (ATCR) Beacon System or the Secondary Surveillance Radar (SSR) System. Both the military and civilian systems rely on a transponder. The transponder is a radio transceiver on board the aircraft that operates in the same frequency band as the primary radar signal and returns a coded message after interrogation from a ground station transmitter. Both the primary and secondary radar signals require accurate power measurement, but using different criteria. One high power and the other is precise power envelope timing.

A primary radar system has a powerful amplifier to transmit pulsed signals long distances coupled with a sensitive receiver to measure the low power return signal. These two parts of the system are not always compatible. The low noise amplifier (LNA) of the receiver can be easily damaged by a few milliwatts of reflected power from nearby objects in the path of the antenna during operation. Output antenna or other load impedance design problems can appear in the initial design stages. Tube type, high power amplifiers commonly used for radar transmitters like the magnetron or TWTA are difficult to control (solid-state power amplifiers are also used in many cases). To operate efficiently, they are designed to work very close to the saturation point and can exhibit nonlinear

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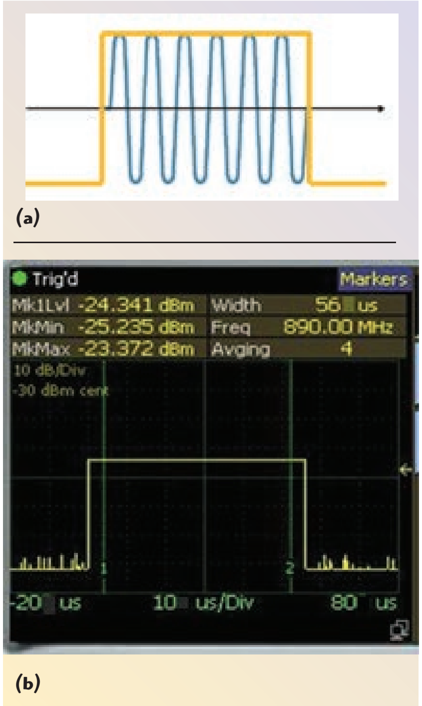
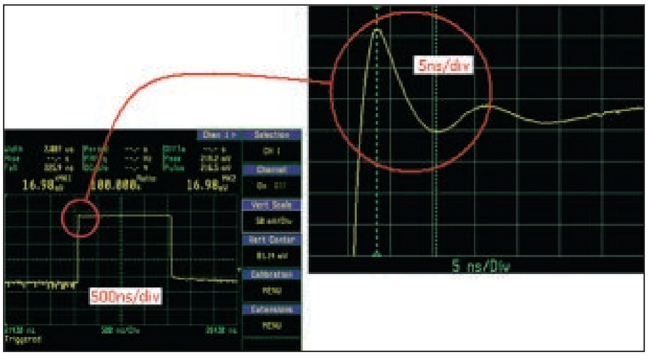
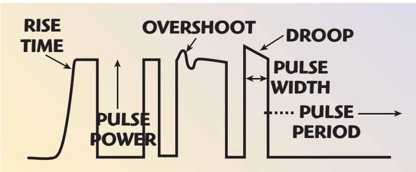


▲ *Fig. 1 Drawing of a pulse modulated CW signal in the time domain (a) and power envelope display on a peak power meter (b).*



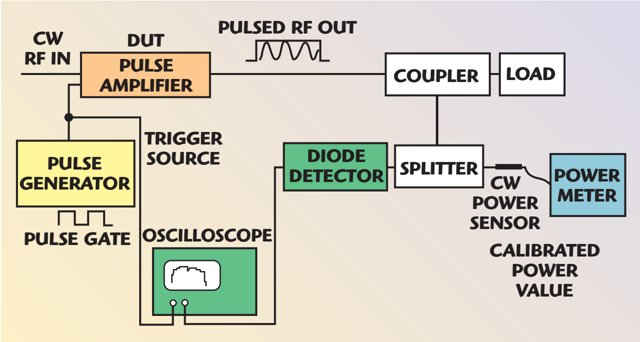
▲ *Fig. 4 Pulse details on a peak power meter.*



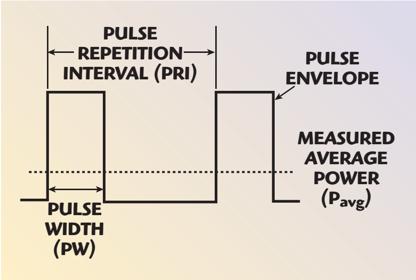
▲ *Fig. 5 Distorted pulse shapes.*

behavior. This causes the transmitted pulse burst to become distorted and not have a purely rectangular power envelope. These are just a few reasons why accurate power measurement of the radar system is so important.

To understand what power parameters are important to measure for radar, it is necessary to understand what is being measured. ***Figure 1a*** is a drawing of a pulse modulated CW signal in the time domain. The blue sinusoid is the voltage waveform or carrier and the yellow rectangle is the demodulated power envelope. ***Figure 1b*** is the power envelope on the display of a modern peak power meter.



▲ *Fig. 2 Block diagram of a diode (crystal) detector system.*



▲ *Fig. 3 Pulse power definitions to calculate average power.*

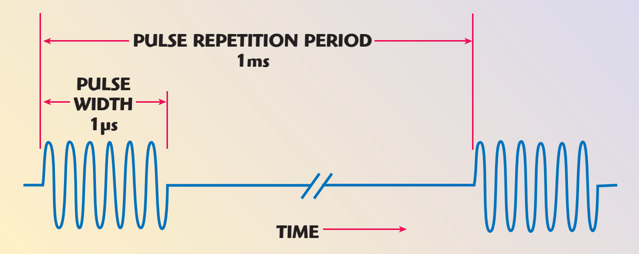
Historically, the power of these radar transmitters was calculated using a system that included a crystal detector, oscilloscope and an average-responding thermal power meter. ***Figure 2*** is a block diagram of a diode (crystal) detector system. The CW input signal is connected to the pulse amplifier (DUT) input and pulse gated via the connected generator for a pulsed radar output signal. The signal is passed through a directional coupler to either a dummy load or actual antenna and the diode detector system. The test signal is then split between an average-responding thermal power meter, and a diode (envelope) detector connected to the oscilloscope. The CW power meter will provide an absolute average power measurement, while the scope provides a limited dynamic range pulse envelope shape. The duty cycle is calculated by dividing the power envelope pulse width by the pulse repetition interval. The pulse power is then calculated by dividing the average power value by the duty cycle measurement as shown in the ***Figure 3***.

This calculation assumes constant power during the pulse-on interval, a perfectly rectangular pulse envelope and a constant duty cycle. The most important point is the pulse power calculation does not measure the actual peak power value and large power envelope excursions are ignored. ***Figure 4*** is from a Boonton 4540 series peak power meter and illustrates the value of a wide dynamic range peak power measurement. The large video BW and wide dynamic range peak power system can be used to locate pulse anomalies that contain energy not measured with an average-responding thermal power sensor.

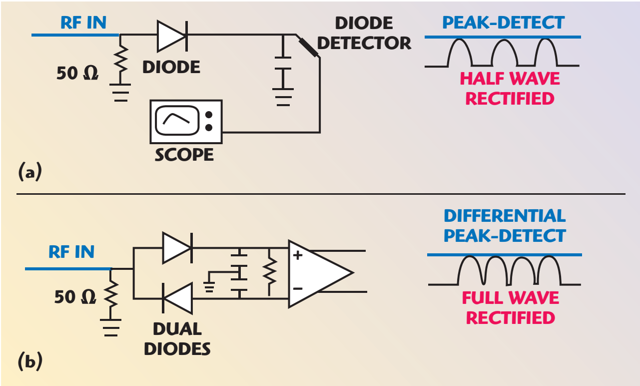
The pulse power calculation does not measure pulse waveform anomalies like overshoot and ringing, or slow edge transitions. These distortions can contain sufficient energy to damage sensitive LNA receivers and should not be ignored. ***Figure 5*** shows several examples of distorted pulse shapes.

Primary or search radar is designed to locate objects at a large distance with fine detail. The fine detail requires a short burst or pulse, while the long distance to target requires a long silent period to account for reflected pulse return time. Due to these constraints, the transmitted signal for most search radars has a very low duty cycle. These low duty cycle waveforms occupy a large dynamic range because of high peak to average power ratios. ***Figure 6*** shows a 0.1 percent duty cycle, or P = 10 Log (0.001) = 30 dBc. This would require a measurement device with at least 10 dB more dynamic range to measure anomalies, or about 40 dB.

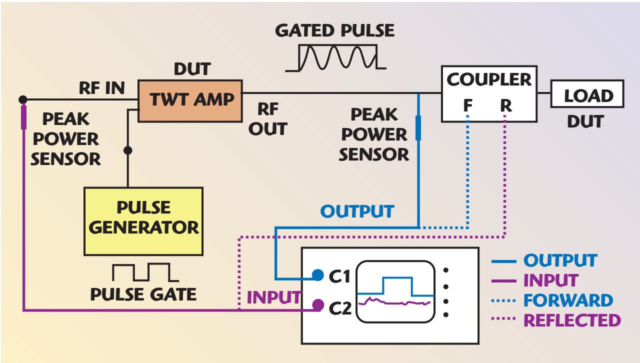
A single-ended detector circuit has uncertainty factors that include a limited dynamic range and a fairly high noise floor. An uncalibrated diode detector has a 20 to 25 dB dynamic range and the output into the oscilloscope varies from directly proportional to power, to nonlinear, to directly proportional to voltage depending



▲ *Fig. 6 Example of 0.1 percent duty cycle.*



▲ *Fig. 7 Comparison of a single ended diode detector circuit (a) and a dual diode differential detection circuit (b).*



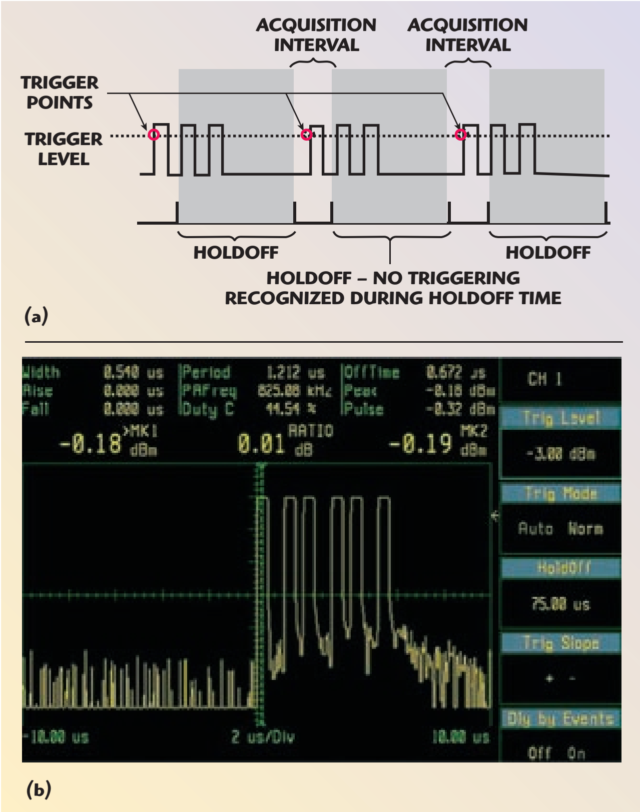
▲ *Fig. 8 Compact differential configuration for a peak power meter.*

upon the absolute power level. This behavior requires a lengthy calibration process that does not account for any temperature variation or a change in carrier frequency limiting its use for measuring the required detail, or high peak to average ratio of a radar signal.

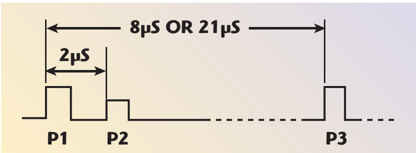
Figure 7 compares a single ended diode detector circuit to a dual diode differential detection circuit. The dual diode circuit is used in modern peak power sensors. The half wave rectified input from the single ended detector does not accurately represent the asymmetrical waveforms and is affected by harmonic content. Matching to the RF source becomes difficult due to the parallel effect of the output load impedance. This load is necessary to achieve fast pulse response, and can either be the oscilloscope's internal 50 Ω termination or an external resistor. A portion of this impedance appears in parallel with the detector's input termination, which affects the input VSWR. The effect is very small at low input levels, but becomes pronounced at high RF power inputs.

The dual diode differential circuit in Figure 7 has several important advantages. The differential pair of balanced diodes measures the fully rectified waveform. This improves linearity, measurement response time and cancels most waveform asymmetry for accurate signal envelope detection. The differential configuration reduces common mode noise, lowering the sensor noise floor while increasing dynamic range. This compact differential configuration in a peak power sensor can be used on a two-channel peak power meter to simultaneously measure forward and reflected power, which is illustrated in ***Figure 8***.

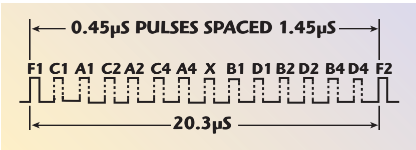
Up to this point, we have not discussed the importance of fast and reliable triggering. To provide precise timing between signals or precise anomaly location, the peak power meter uses an oscilloscope-like hardware trigger. This comparator circuit allows the capture of low nano sec rise time signals and 100 or 200 ps feature placement. ***Figure 9*** is a multiple pulse waveform captured using a positive rising edge trigger with hold-off. The pulse envelope edge stability requires a fast trigger comparator circuit because interpolating between sample data points does not provide the necessary stability for fine feature loca-



▲ *Fig. 9 Multiple pulse waveform (a) captured using a positive rising edge trigger with hold-off (b).*



▲ *Fig. 10 Mode A and C interrogation format.*



▲ *Fig. 11 Mode A and C reply format.*

tion. The precise timing relationship between the pulses is captured using fast trigger circuits and is displayed on the peak power meter screen.

Precise timing is important for primary and secondary radar. Many primary radar receivers have a fast responding protection circuit to dump energy via a spark gap system that protects the sensitive front-end LNA from reflected power damage. This system requires accurate measurement of fast rise time signals and precise timing of the protection circuit response during design.

There are several modes of IFF or SSR type secondary radar interrogation schemes and each is identified by the difference in spacing between two transmitter pulses, known as P1 and P3. Each mode produces a different response from the aircraft. A third pulse, P2, in the figure is inserted for side band interference suppression. The Mode A and C interrogation shown in ***Figure 10*** contains the pulse timing diagram and is the same mode in response format.

A Mode-A interrogation elicits a 12-pulse reply, indicating an identity number associated with that aircraft. The 12 data pulses are bracketed by two framing pulses, F1 and F2, shown in ***Figure 11***.

Mode A and C are used to illustrate why precise trigger capability is needed for measuring secondary radar signals and is not the only modulation scheme available for returning additional information about an aircraft. Depending on your requirements, either IFF pulse location to interpret digital information or capturing a fast rising primary envelope edge, a fast responding trigger comparator is a very important feature.

Measuring radar signals requires a large dynamic range device to view specific pulse anomalies and advanced triggering capabilities to locate specific events in long pulse trains. A calibrated differential peak power sensor offers superior dynamic range capability in comparison to a single-ended diode detector when measuring pulse envelope anomalies with low duty cycle characteristics. Using a peak power meter that has two oscilloscope-like trigger channels for viewing secondary radar timing relationships in addition to the peak sensor input channels to view the peak power envelope provides unmatched capabilities when measuring radar signals. ■

GaN Switches Enable Hot Switching at Higher Power

RF power control elements, such as RF switches, are an integral element of any RF system and traditionally have been built using Si PIN diodes for higher power applications and GaAs FETs for lower power and higher speed applications. The use of GaN HEMT-based technology in this application area promises to be a game changer, as GaN HEMT-based switches can simultaneously offer higher power handling and ruggedness capability as well as low control current requirements. They also deliver excellent insertion loss and isolation over an ultrawideband, all within a very small form factor.

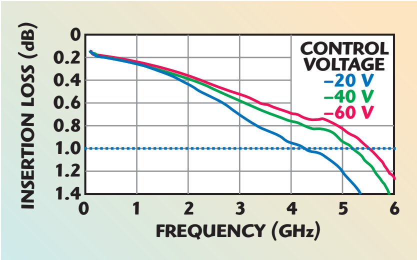
These capabilities are demonstrated by the family of RF switch products developed by RFMD. The GaN HEMT-based switches are attractive for multiple applications — MilCom, electronic warfare, radar, test and measurement, commercial infrastructure communications, and medical — as they offer unique advantages over competing technologies. Some examples are silicon-on-sapphire, GaAs FET, PIN diodes and even electromechanical switches, depending on the specific application and market drivers. The RFSW2100 GaN HEMT MMIC switch from RFMD is a reflective, hot switchable SPDT switch that offers broadband power handling capability from DC to 6 GHz, with low insertion loss (< 0.4 dB at 2 GHz), excellent isolation (~ 39 dB at 2 GHz), fast switching times (~ 40 ns), as well as low drive current capability (< 0.5 mA). These devices are available both in die form and in a 3×3 mm, 12-pin QFN package, which is well suited for ease of integration into a variety of applications. The device is designed to present 50 Ω input/output impedance over a broad DC to 6 GHz band and can switch 45 W of uncompressed RF power (defined by 0.1 dB com-

RFMD
Greensboro, NC

TABLE I

PERFORMANCE SPECIFICATION - RFSW2100

Frequency		DC to 6	GHz
Rated Input Power ($P_{0.1}$dB)		45	W, CW
Insertion Loss		< 1	dB, f < 5.5 GHz
Isolation, Off-state		> 30	dB, f < 4 GHz
		> 20	dB, f < 6 GHz
Switching Speed	On	40	ns
	Off	22	ns
Control Voltage (45 W at 3:1 VSWR)		0/-60	V
Control Current		< 0.5	mA
Input/Output Return Loss		> 10	dB
IIP_3		72	dBm
Package Type		3×3 mm, 12 lead air-cavity QFN	



▲ *Fig. 1 Frequency dependence of insertion loss.*

pression of insertion loss). In addition to these capabilities, the RFSW2100 offers a very respectable IIP3 of 72 dBm, which offers additional possibilities to designers in need of a rugged, high power, low loss switch for more linear applications, as summarized in ***Table 1***.

The RFSW2100 is designed within the same 0.5 µm GaN technology platform as RFMD's qualified and production released GaN1C process-technology platform and thus benefits from the industry-leading process technology manufacturing control afforded to power amplifier products based on the GaN1C technology platform. Among the key attributes of this process are very high breakdown voltage-per-unit distance and high current density (~ 1 A per unit mm of gate periphery) that offer the combination of low R_{ON} and the ability to withstand high reverse voltages. This high breakdown voltage capability enabled operation at control voltages of negative 60 V, enabling excellent ruggedness (exceeding 3:1 at 45 W) as shown in ***Figure 1*** and survivability without compromising insertion loss, as the performance improves at larger negative control voltages. The low leakage current (< 1 mA) in the OFF condition leads to low OFF current drive requirements as well as good power dissipation in the OFF state. This power handling and VSWR capability represents a 5× improvement in power handling over a comparable 0.5 µm GaAs FET-based switch. In addition, as the RFSW2100 is a voltage-controlled device, turning the switch ON is achieved by simply biasing to 0 V, with control current in the ON state being almost negligible (< 0.5 mA) up to input powers of 45 W. This offers the RFSW2100 a tremendous advantage over Si PIN diode switches in terms of greatly reduced control circuitry, BOM, board space, weight and cost.

The key small signal figure of merit (FOM) for a switch technology is the product of the resistance in the ON state (R_{ON}) and the capacitance in the OFF state (C_{OFF}), expressed as a frequency $[1/(2\pi R_{ON} \cdot C_{OFF})]$ or a time constant $(R_{ON} \cdot C_{OFF})$. RFMD's RFSW2100 switch technology offers a figure of merit of 343 GHz, obtained by minimizing C_{OFF} and R_{ON}. The low C_{OFF} results from small fringing capacitances obtained from RFMD's GaN-on-SiC process as well as the semi-insulating SiC substrate material. The benefits of the thermally conductive semi-insulating SiC substrate are two-fold, minimized leakage current during large voltage swings across the device and maximum heat transfer from the active channel of the device to the heat sink. This excellent heat sinking within the die itself results in very stable high power operation over a wide temperature range as well as linear operation over a greater input power range. Due to the fact that the frequency dependence of the insertion loss is dominated by the C_{OFF}, instead of R_{ON}, the RFSW2100 provides an industry-leading insertion loss (< 0.4 dB at 2 GHz) over an extremely wideband while offering exceptional $P_{0.1}$dB power handling (> 45 W) and ruggedness (better than 3:1), rendering it attractive for applications, such as military communication and electronic warfare as well as infrastructure and communication applications.

The RFSW2100 SPDT switch is available both in bare die (RFSW2100D) and in a 3 × 3 mm, 12 lead air cavity QFN package, specifically designed for handling higher power in a compact form factor. This package offers similar advantages with regard to handling the power dissipation in GaN-based devices, similar to metal flange, ceramic air cavity packages that house high power RFMD GaN power amplifier products. Due to the excellent current capability and breakdown voltage afforded by RFMD's GaN1 process, in die form, this RFSW2100D switch offers an additional power handling capability up to 75 W, depending on the capability of the heat sink environment and mounting, as well as an improvement in insertion loss in the higher frequency range (maintaining < 1 dB of insertion loss up to 6 GHz). In addition to the RFSW2100 SPDT switch, RFMD is developing a family of high power, extremely broadband switches that extend from DC to 18 GHz, enabled by the excellent breakdown voltage and small signal FOM resulting from RFMD's GaN-on-SiC technology. RFMD's GaN1-based switch technology also enables development of higher power and multi-throw count switches, which are expected to undergo product qualification in 2012.

RFMD,
Greensboro, NC
(336) 664-1233,
www.rfmd.com.

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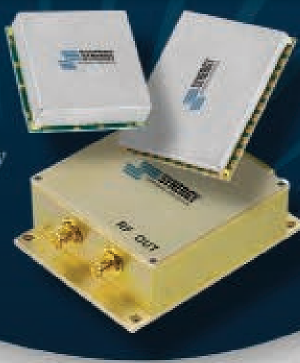
INTELLIGENT INTERACTIVE SYNTHESIZERS

i2S®

Model #	Frequency (MHz)	Step Size (kHz)	Typical Phase Noise (dBc/Hz)	
			@10 kHz	@100 kHz
COMPACT SIZE				
FSW511-50	50 - 115	500	-112	-127
FSW1125-10	110 - 250	100	-104	-132
FSW1545-50	150 - 450	500	-102	-120
FSW1857-100	180 - 570	1000	-98	-120
FSW2476-10	240 - 760	100	-98	-124
KFSW40110-50	400 - 1100	500	-95	-122
FSW50120-50	500 - 1200	500	-94	-118
FSW60170-50	600 - 1700	500	-90	-117
FSW80150-10	800 - 1500	100	-92	-118
FSW80210-50	800 - 2100	500	-90	-113
FSW85150-50	850 - 1500	500	-93	-120
FSH9496-20	940 - 970	200	-109	-134
KFSW100230-50	1000 - 2300	500	-92	-115
FSH127171-50	1270 - 1710	500	-96	-126
FSW150320-10	1500 - 3200	100	-79	-108
FSW170280-50	1700 - 2800	500	-86	-112
FSW190410-50	1900 - 4100	500	-82	-109
FSW200400-100	2000 - 4000	1000	-85	-110
FSW216265-50	2160 - 2650	500	-92	-122
FSH250300-100	2500 - 3000	1000	-94	-122
FSW300600-100	3000 - 6000	1000	-78	-100
FSH310410-1M	3100 - 4100	10000	-92	-98
SINGLE SUPPLY				
LFSW514-50	50 - 140	500	-115	-127
LFSW1545-50	150 - 450	500	-98	-120
LFSW2476-10	240 - 760	100	-100	-124
LFSW35105-20	350 - 1050	200	-98	-120
LFSH4055-10	408 - 552	100	-99	-108
LFSW50120-50	500 - 1200	500	-97	-118
LFSW60170-10	600 - 1700	100	-92	-117
LFSW80210-50	800 - 2100	500	-92	-113
LFSW110250-50	1100 - 2500	500	-92	-115
LFSW120205-100	1200 - 2050	1000	-96	-106
LFSW150320-25	1500 - 3200	250	-86	-112
LFSW168236-100	1680 - 2360	1000	-102	-117
LFSW170225-1M	1700 - 2250	10000	-102	-123
LFSW190410-12	1900 - 4100	125	-80	-105
LFSW190410-100	1900 - 4100	1000	-85	-110
LFSH196225-50	1960 - 2250	500	-96	-127
LFSW200400-100	2000 - 4000	1000	-82	-107
LFSW290342-100	2900 - 3420	1000	-87	-107
LFSW300600-20	3000 - 6000	200	-73	-98
LFSW397697-100	3970 - 6970	1000	-80	-100
LFSW400460-1M	4000 - 4600	10000	-95	-100

RoHS COMPLIANT

Patented Technology



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201 McLean Boulevard, Paterson, NJ 07504

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Robust Antenna Solutions For Maritime Surveillance Radar

Ergun Bora,
CEO of the Radar and EW Group, Aselsan
Visit www.mwjournal.com to read this in-depth interview.

The tactical and technical capabilities of a radar system are determined mainly by the technical features of the associated antenna subsystem. Aselsan has developed a family of naval surveillance radars with individually developed, cutting-edge antennas tailored to provide excellent system performance, which has been verified in various field trials. The maritime surveillance radar family consists of ALPER, the Naval Low Probability of Intercept (LPI) radar for vessels; DALYAN, the subsurface counterpart of ALPER for submarines; and SERDAR, the coastal surveillance radar for critical coastal areas, shown in ***Figure 1***.

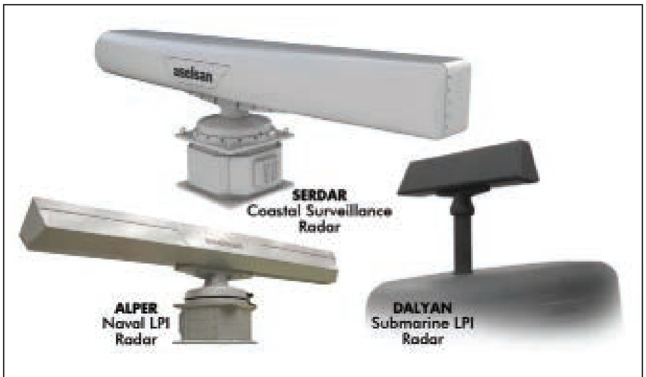


Fig. 1 Aselsan maritime surveillance radar family.

The first to be launched was ALPER and systems have since been delivered to the Turkish Navy. The radar has excellent Electronic Counter-Countermeasures (ECCM) and LPI characteristics with an extensive detection range and a low level of emittance. SERDAR, which started factory acceptance testing in late

Aselsan
Ankara, Turkey

2011, exhibits similar characteristics but with a larger antenna, and it also eliminates blind zones in the coastal region being covered, regardless of terrain. ***Table 1*** shows the main features/specifications of the ALPER and SERDAR radars. DALYAN, which will go into production in 2012, is essentially ALPER's submarine counterpart with similar radar system features.

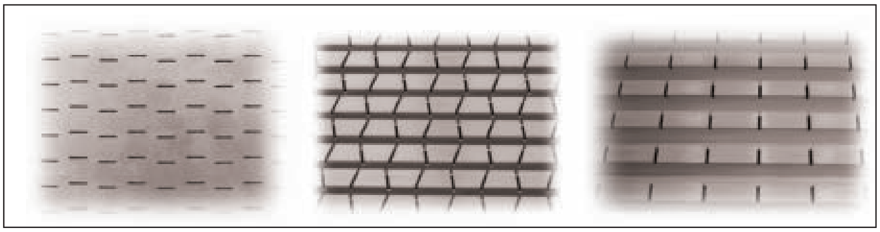
SLOTTED WAVEGUIDE ARRAYS

For all three maritime surveillance radar systems, slotted waveguide array (SWGA) antenna technology plays a key role in system performance. To meet combined LPI radar system and ECCM requirements, elaborate antenna designs are employed. Aselsan has developed two families of SWGA antennas for radar applications. One family consists of traveling-wave type planar phased arrays having fractional bandwidths up to 10 percent with electronically steerable beams and/or shaped beams, dual/linear polarization, high gain, ultra low side lobe levels and low cross polarization levels. These are mainly suitable for surveillance radar systems. The other family covers resonant planar phased arrays with exceptionally wide bandwidths, fixed monopulse beams, dual/linear/circular polarization, high gain, very low side lobe levels and low cross polarization levels. These are particularly suitable for reconnaissance and tracking radars.

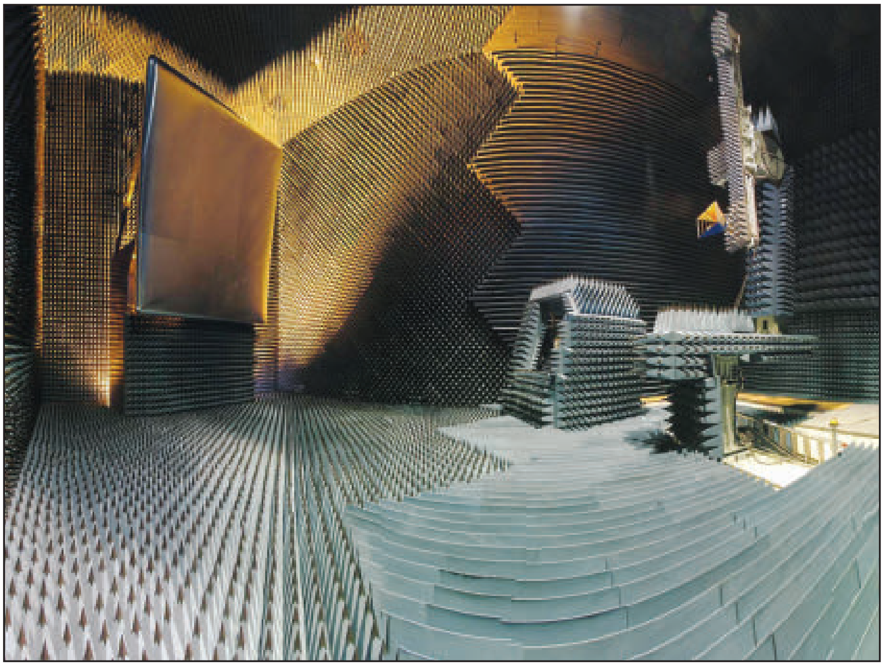
TABLE I

THE MAIN FEATURES/SPECIFICATIONS OF THE ALPER AND SERDAR RADARS

Feature	ALPER	SERDAR
Application	Naval LPI Radar	Coastal Surveillance Radar
Frequency	X-Band	X-Band
Range Modes	12/24/36 NM	12/24/48 NM
Instantaneous Bandwidth	Selectable 60/30/20 MHz	Selectable 60/30/15 MHz
Maximum Range	36 NM	48 NM
Antenna Length	2 m	4 m
Antenna Rotation Rate	> 20 rpm	6, 12, 18 rpm
MTBF	> 10,000 hours	> 10,000 hours
Power Consumption	< 800 W	< 2500 W
Power Supply	115 VAC	220 VAC
Operating Temperature	-20° to +50°C	-30° to +50°C



▲ *Fig. 2 SWGA profiles.*



▲ *Fig. 3 Aselsan's compact test range facility.*

MANUFACTURING AND TESTING

Aselsan SWGA antennas employ inclined edge wall, broad wall and non-inclined edge wall designs with custom waveguide cross sections depending on the radar antenna pattern. ***Figure 2*** shows SWGA profiles. High precision CNC milling, electro discharge machining (EDM), metal plating, aluminum vacuum brazing, torch brazing and metal bonding are the key in-house manufacturing processes that are specifically tailored for SWGA antenna manufacturing. Electromagnetic characteristics of the SWGA antennas are carefully measured using several in-house test chambers, such as anechoic planar near field testing, anechoic far field testing or anechoic compact testing (see ***Figure 3***), depending on the size and type of the antenna. Environmental characteristics of the SWGA antennas are verified in environmental test facilities capable of performing system tests in accordance with MIL-STD-810F/G.

ALPER

The ALPER Naval LPI radar is designed and developed for navigation, surveillance, detection and tracking of surface and low altitude air targets in the littoral sea environment. It can be utilized with navigation radar, sharing its navigation control console, and can be linked to a combat management system (CMS). The main technical

features of ALPER are a digital receiver, clutter suppression and detection algorithms, digital signal processing, a solid-state transmitter with adjustable output power and an SWGA array with high angular resolution and low sidelobe levels.

ALPER employs a 2 m long SWGA antenna operating at X-Band. The antenna has a horizontally polarized fan beam to meet angular resolution requirements and low side lobe and cross polarization levels in 3D space, within the whole operating frequency band to meet ECCM requirements. Antenna polarization can be factory set to circular polarization. The radar also has a low radar cross section (RCS) radome structure, making it suitable for integration on stealth military vessels.

DALYAN

DALYAN's Line Replaceable Units are basically the same as those of ALPER, except for the antenna. DALYAN's antenna is capable of withstanding 60 Bars of hydrostatic pressure, an essential feature for submarine radar, and it also has low RCS characteristics. A frequency selective surface radome with low insertion loss can also be employed to further reduce the RCS, without altering the antenna characteristics.

The antenna is 1 m long, employing a horizontally polarized cosec^2 shaped beam tilted to the horizon with respect to the broadside of the array aperture in the elevation plane, directing maximum energy to the horizon. In order to improve the direction finding capability in the azimuth plane, a monopulse beamforming structure is employed.

SERDAR

SERDAR, the coastal surveillance radar that shares similar technical features with ALPER, is optimized for detection in the littoral environment. It can be directly linked to command and control (C2) systems. SERDAR's capabilities mean that the antenna detection zone can start directly at the coast, free of any blind zones, regardless of the site geography. Whether the coast is mountainous or flat, the beam coverage can be optimized due to its adjustable beamformer.

SERDAR's antenna is a 4 m long SWGA operating at X-Band. The antenna employs a horizontally polarized inverse cosec^2 fan beam to meet angular resolution requirements and low sidelobe and cross polarization levels in 3D space across the whole operating frequency band. With the aid of an elevation beamformer, adjustable shaped beam synthesis can be achieved and antenna polarization can be factory set to circular polarization as well.

Aselsan's maritime surveillance radar family, with incorporated customization features, provides exceptional solutions for coastal, marine and submarine surveillance.

Aselsan,
Ankara, Turkey
+90 312 592 10 00,
marketing@aselsan.com.tr,
www.aselsan.com.tr.

8 to 23 GHz, 500° Time Delay/Phase Shifter

Hittite Microwave Corp. has developed a new broadband time delay/phase shifter that is ideal for clock chain and skew adjustment in 10G-RZ, 40G/100G RZ-DQPSK fiber optic applications. The HMC877LC3 is one of the first time delay/phase shifter products to provide 0 to 500° (1.4 Unit Interval) continuously adjustable delay over a wide 8 to 23 GHz frequency range. The device provides a differential output voltage with constant amplitude for single-ended or differential input voltages above the input sensitivity level. A control pin may be used to adjust the output voltage swing between 500 and 900 mVp-p.

The device provides a time delay/phase shift, which is linearly monotonic with respect to the differential delay control voltage, over a ±0.6 V tuning range. It also features internal temperature compensation and bias circuitry to minimize delay variations with temperature, ensuring an extremely stable programmable time delay over both frequency and temperature. A high delay control modulation bandwidth (3 dB rolloff point) of 2.5 GHz combined with a single +3.3 V operation also make the HMC877LC3 an excellent choice for military, space, test and measurement and broadband applications. Designed for maximum flexibility, all RF input and outputs are internally terminated with 50 Ω to Vcc and can be AC or DC coupled. Output pins can be connected directly to a 50 Ω to Vcc terminated system, while DC blocking capacitors must be used if the terminated system input is 50 Ω to a DC voltage other than Vcc.

Hittite's broadband time delay product line also includes the HMC856LC5 and HMC910LC4B. The HMC856LC5 is a broadband time delay with a five-bit digital control that supports 28 Gbps data and provides nearly 100 ps of delay range with 3 ps resolution. This monotonic delay is DC coupled and compensated for stable operation over both power supply and temperature variation. The HMC910LC4B is a broadband time delay with 0 to 70 ps continuously adjustable delay range. The delay control is linearly monotonic with respect to the control voltage and the control input has a modulation bandwidth of 600 MHz. The HMC877LC3 supports phase alignment for clocks, while the HMC856LC5 and HMC910LC4B support serial data lane alignment in applications such as 100G DWDM transponders.

VENDORVIEW

Hittite Microwave Corp., Chelmsford, MA, www.hittite.com, sales@hittite.com.

16 GHz Digital Frequency Discriminator with Phase Detection

Mercury Computer Systems has introduced the first 16 GHz Digital Frequency Discriminator (DFD) with Phase Modulation on Pulse (PMOP) detection. The FM021814 blends the ability to generate phase and frequency information data streams, providing highly reliable and accurate information instantaneously. Mercury's digital frequency discriminators provide a compelling competitive advantage in terms of performance, size and cost for critical defense applications.

The FM021800 series of Digital Instantaneous Frequency Measurement (DIFM) products monitor the entire 2 to 18 GHz band, instantaneously. These receivers are capable of sampling rates up to 80 MHz and measuring pulses as short as 50 ns and up to CW signals. Phase data can be sampled "on command" at 80 MHz with eight-bit resolution or delivered as continuously streaming information at 40 MHz. Streaming data allows users to detect PMOP with extremely low latency, while buffered data allows the user to analyze the information with greater resolution and accuracy.

Mechanically, these DIFMs are designed to comply with demanding airborne specifications and operate over a temperature range of –40° to +85°C. The FM021814 standard output is a 14-bit digital word that represents the RF input frequency with a nominal frequency resolution of 1 MHz and an RMS accuracy of < 3 MHz. User-defined parameters include sensitivity/dynamic range, triggering/sampling, output data format, data flags and mounting locations. The output format can be modified to emulate existing systems. Applications include airborne/ground systems, radar warning receivers, spectral intelligence and system testing/verification. The unit is packaged in a small, 65 cubic inch form factor, weighing 2.75 pounds.

Mercury Computer Systems Inc., Chelmsford, MA (866) 627-6951, www.mc.com.

Tech Brief

6 GHz Instantaneous BW RF Record and Playback System

X-COM Systems has developed the Wideband Acquisition Record and Playback (WARP) system that allows the entire frequency spectrum between 4 MHz and 6 GHz to be instantaneously captured and recorded for long periods without loss of a single event. When combined with X-COM's Spectro-X signal analysis software, it allows the performance of electronic warfare, radar, and wireless communications and satellite communications systems to be comprehensively evaluated.

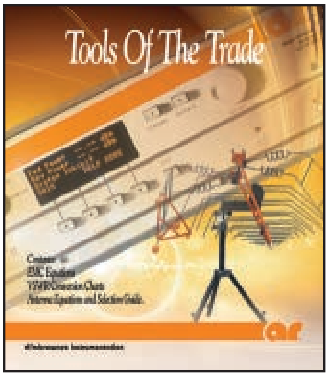
The WARP system can capture directly from an antenna all activity from the lowest frequencies through C-Band, which includes navigation, AM, FM, shortwave and TV broadcasters, amateur radio, industrial, scientific and medical (ISM) systems, cordless phones, aviation, government and military systems, all commercial wireless networks, WiFi, Bluetooth, GPS, as well as some radar and satellite communications systems. It can also accept downconverted signals from higher frequencies, expanding its range through the millimeter wavelengths used by satellite communications and other military systems.

The WARP system converts captured signals to the digital domain using a 12 Gsample/s analog-to-digital converter (ADC), and stores the data on solid-state media with capacity of up to 32 TBytes that allows 44 minutes of continuous signal capture. This data can then be analyzed with X-COM's Spectro-X or other software to find signals of interest even when in the presence of much stronger signals or when interferers appear randomly and infrequently.

The system can reconvert the entire 6 GHz bandwidth or only the portion of interest to analog form so it can be used to stimulate a radar, EW, or communications system to evaluate its performance. X-COM's WaveCAFE software can be used to create custom waveforms that can be incorporated into the data stream. The signal pattern can be rearranged using X-COM's RF Editor software, which has a user interface similar to that of professional audio or video editing software.

X-COM Systems,
Reston, VA (703) 390-1087,
www.xcomsystems.com.

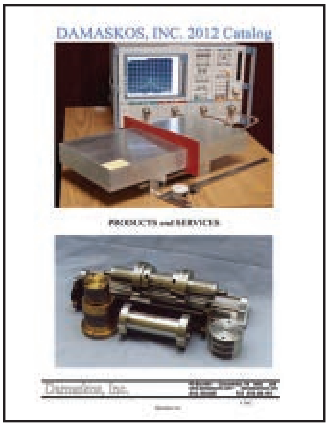
Tools of the Trade Poster



Request your free copy of AR's Tools of the Trade Poster! This reference poster includes EMC equations, VSWR conversion charts, antenna equations and an antenna selection guide. Download electronic or request a hard copy of the poster from www.arworld.us/html/posterrequest.asp.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181 www.arworld.us.

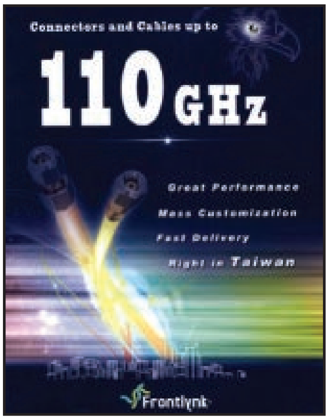
Measurement Devices



The company's new catalog describes its products for measuring the magnetic and dielectric properties of materials from low RF through microwave and millimeter-wave frequencies. Devices are presented for measuring thin low loss materials in a variety of broadband cavities to coax, waveguide and free space setups to measure bulk materials and panels.

Damaskos Inc.,
Concordville, PA (610) 358-0200, www.damaskosinc.com.

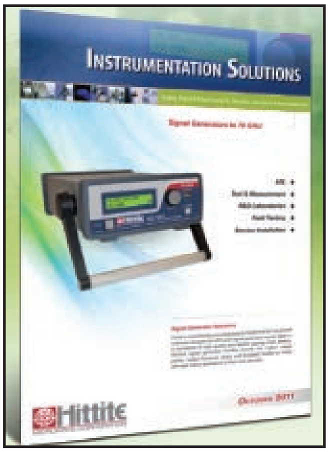
Connectors and Cables



Frontlynk's Connectors and Cables up to 110 GHz is an eight-page catalog that details the 1.0 mm Series, SMPM Series, High Frequency Series, 7/16 Series and the SMP Series. Frontlynk, located in Taiwan, promises great performance, mass customization and fast delivery.

Frontlynk Technologies Inc.,
Tainan, Taiwan +886-6-356-2626, www.frontlynk.com.

Instrumentation Solutions



Hittite Microwave Corp., supplier of complete MMIC-based solutions for communication and military markets, is pleased to announce the release of the new Instrumentation Solutions Brochure summarizing its line of signal generators, which provide frequency coverage up to 70 GHz. This brochure organizes Hittite's portfolio by performance and frequency coverage. Also included are applications, software and accessories and general specifications information. Full specifications are available at www.tm-hittite.com. Contact TE@hittite.com to request a demo today!

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343, www.hittite.com.

Wireless Infrastructure

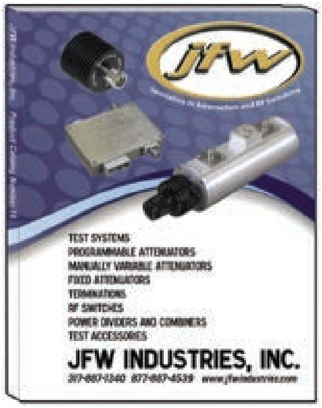
HUBER+SUHNER has released a 2012 edition of the Wireless Infrastructure catalogue, www.wireless-infrastructure.com. It contains a comprehensive Power to the Antenna (PTTA) portfolio and the superior hybrid cabling system called MASTERLINE extreme. The catalogue has two main sections, one for Remote Radio Installation Solutions and a second for Conventional Cell Sites using corrugated copper cables. The catalogue is a guide to select the "right" installation solution and provides detailed technical and ordering information.

HUBER+SUHNER,
Herisau, Switzerland +41 (0) 71 353 41 11,
www.hubersuhner.com.

RF Catalog

The new RF catalog presents the large variety of RF products and includes diverse new development, such as RF probes with integrated attenuator and with integrated filter. In addition to these innovations, the proven standard RF products are also illustrated. Three-dimensional drawings offer important visual information. The practical catalog register guides the customer easily to the required contacting solution and to the numerous accessories. The catalog can be downloaded from www.ingun.com.

Ingun Prüfmittelbau GmbH,
Konstanz, Germany +49 7531 8105-0, www.ingun.com.



Components and Test Systems

JFW's new catalog for RF components and test systems features new models specifically designed for WiFi, LTE and applications up to 18 GHz. The catalog also highlights a unique selection of high power, solid-state switches. The full catalog or sections of it can be downloaded through the company's website or call to request a copy.

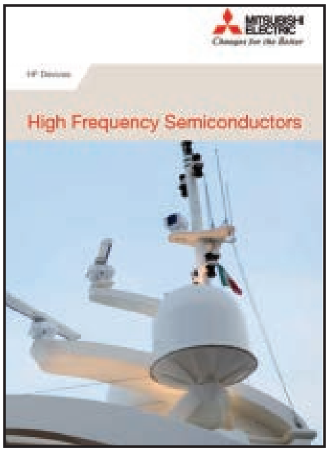
JFW Industries Inc.,
Indianapolis, IN (877) 887-4539, www.jfwindustries.com.

IF/RF Microwave Signal Processing Components Guide

VENDORVIEW

Mini-Circuits' 164-page catalog includes more than 750 new products and the industry's most comprehensive listing of RF/IF and microwave components and subsystems with more than 4100 products and more than 25 product lines, including state-of-the-art amplifiers, mixers, VCOs, synthesizers, filters, test accessories and USB Power Sensors. Mini-Circuits' website provides additional data, application notes, design tools and its powerful YONI search engine, which searches actual test data on thousands of units.

Mini-Circuits,
Brooklyn, NY (718) 934-4500, www.minicircuits.com.



High Frequency Semiconductors

Mitsubishi Electric Europe is introducing its latest catalog "High Frequency Semiconductors" focusing on Gallium Nitride and Gallium Arsenide-based devices. The catalog covers discrete and internally matched GaN HEMTs and GaAs FETs as well as transistors. The low noise GaAs HEMTs are in use as amplifiers for satellite receivers (DBS) and automotive radar. High power GaN and GaAs devices are used as power amplifiers in radio links, radars, satellite communication systems and space.

Mitsubishi Electric Europe B.V.,
Semiconductors – European Business Group,
Ratingen, Germany +49 2102 486 0, www.mitsubishichips.eu.

Overview and Capabilities Brochure

VENDORVIEW

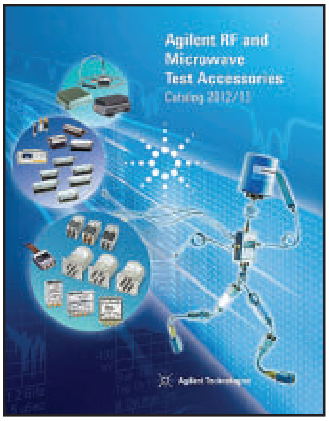
Planar Monolithics Industries (PMI) has released its latest product Overview and Capabilities Brochure. The brochure contains a listing of various RF components and RF module product types up to 40 GHz, including amplifiers, attenuators, phase shifters, detectors, DLVA/SDLVA's, filters, limiters, switches and switch matrices.

Planar Monolithics Industries,
Frederick, MD (301) 662-5019, www.pmi-rf.com.

Wireless Products Catalog

Times Microwave Systems announces the availability of the sixteenth edition of the LMR® Wireless Products Catalog. The expanded 238-page catalog includes the entire range of LMR® cables, the Times-Protect® line of innovative lightning surge protector products for RF equipment and the latest SilverLine® test cable innovations. Also included in this latest edition are the brand new LMR®-SW low loss, low PIM cables, the new –X no-braid-trim LMR® connectors, the Times-Protect® Smart-Panel™ and SilverLine® LP Low PIM test cables.

Times Microwave Systems,
Wallingford, CT (203) 949-8400, www.timesmicrowave.com.



Test Accessories Catalog

VENDORVIEW

The 2012/2013 RF & Microwave Test Accessories Catalog offers 215 pages of in-depth information on the most reliable and repeatable RF and microwave switches, attenuators, amplifiers and other test accessories, including adaptors, detectors, directional couplers, power dividers, splitters and terminations. The catalog features new product highlights and easy-to-read product selection and comparison tables. Order online at www.agilent.com/find/mtacatalog. Registration is required for mailing.

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Santa Clara, CA (800) 829-4444, www.agilent.com.

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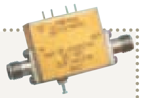


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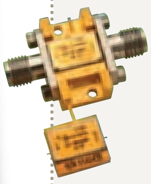
Broad and *Ultra-Broadband*
Amplifiers



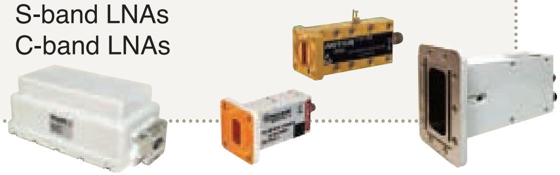
- **0.1 - 40 GHz**
- Standard models covering all standard Communication, SATCOM and Military Bands
- Over **2,500 standard models**

SATCOM and *Radar*
High-Performance Amplifiers

- SATCOM, Radar and Satellite Bands
- **Pulsed Power** Amplifiers
- Compact designs

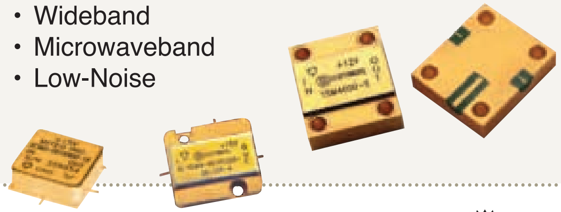

Waveguide
Amplifiers

- **Noise Figures** as low as **28°K**
- Over **500 standard models** available
- Cooled **Ka-Band LNAs** down to **80°K**
- Rugged outdoor and airborne applications
- Waveguides with fiber optic interfaces
- S-band LNAs
- C-band LNAs



Surface Mount
Amplifiers

- **True Surface Mount** Amplifiers with frequencies **up to 40 GHz**
- Ultra High Frequencies
- Wideband
- Microwaveband
- Low-Noise

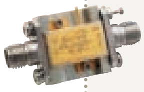


Quality RF/Microwave Prducts For Over 40 Years

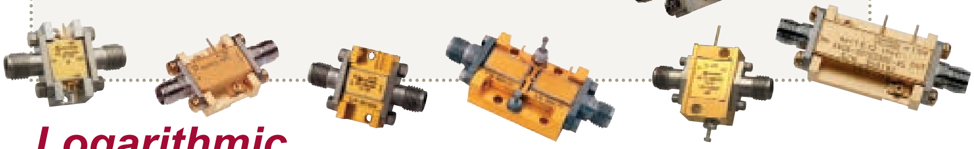
3 YEAR WARRANTY

Low Noise

Amplifiers .001 MHz to 75 GHz

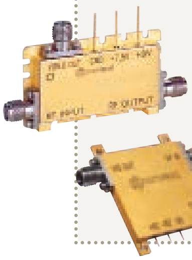


- **Lowest guaranteed noise figures** in the industry, ie: 0.3 dB in L-band and 2 dB in K-band
- Over **2,500 standard models** available
- Surface Mount, Connectorized, In-line

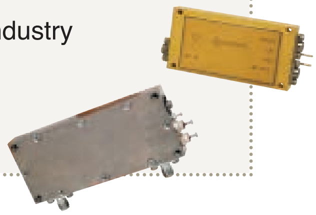


Logarithmic

Amplifiers available to 8 GHz



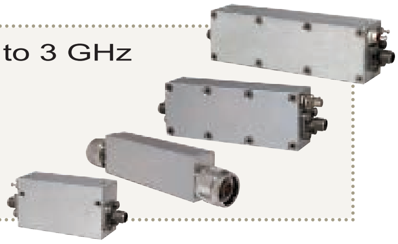
- **Fastest Rise time** in the industry, as low as **1 ns**
- -55 to +95°C temperature stability
- **Lowest Sensitivity levels** in the industry as low as -95 dBm
- Compact **Low Profile Housings**
- Space and Airborne qualified



Bipolar

Amplifiers available 1 KHz to 3 GHz

- Lowest noise figures available:
  1.1 dB @ 10 MHz
  1.4 dB @ 500 MHz
  1.7 dB @ 1 GHz

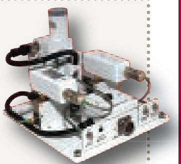


Complete Amplifier Assemblies and Sub-Assemblies

With over 40 years of RF/microwave component expertise. MITEQ designs and manufactures single or multifunction assemblies to customer specifications.

SATCOM

Amplifier **Systems and Equipment**



Amplifier Systems • Redundant LNAs • Fiber Optic LNAs
Amplifier Plate Assemblies

TWT Amplifiers • **Instrumentation Power** Amplifiers
• 5 - 51 GHz Coverage • Indoor and Outdoor Ruggedized Configurations

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For further information, please contact our Sales Department at
(631) 439-9220 or e-mail components@miteq.com

Other Amplifiers Available:

- Built-In Test Detector
- Coaxial In-Line
- Cryogenic
- Desktop
- Detector Log Video
- Drop In
- Dual Output
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- Gain Control
- IF Gain Control
- IF Auto Gain Control
- Limiting
- Low Current Consumption
- Low Frequency
- Low Phase Noise
- Medium Power
- Power Monitoring
- Pulse
- Pulse Modulated
- SATCOM
- Spaceborne
- Surface Mount
- Temperature Compensated
- Waveguide
- Multi-Octave
- 75 Ohm

MITEQ Components

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- Multipliers
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- Frequency Generation Products
- Microwave Control Products
- Passive Power Components
- IF Signal Processing
- Integrated Assemblies

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www.miteq.com

GaN Power Amplifier

Aethercomm Inc. has recently completed a new X-Band Gallium Nitride (GaN) power amplifier design, which operates from 7600 to 7800 MHz. This GaN amplifier design, model number SSPA 7.6-7.8-150, produces 150+ W (P3dB) output power across this frequency band. This X-Band GaN power amplifier is smaller (4.85" × 7.95" × 1.42"), more efficient and offers higher power than conventional GaAs FET power amplifiers.

Aethercomm Inc.,
Carlsbad, CA
(760) 208-6002,
www.aethercomm.com.

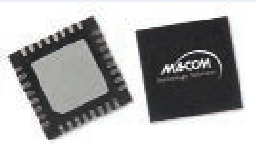
Equalized Cable Runs

The Cobham Cable Products group has integrated an adjustable equalizer with a variable attenuator module into an ETNC jack/ETNC jack bulkhead adapter for incorporation into cable runs. The result is cable runs of different cable sizes and lengths have matched, constant IL over broad frequency ranges. The design has been qualified for military airborne applications aboard jet aircraft. The frequency range is < 0.5 to > 18 GHz, VSWR 2:1 maximum and it can correct differences > 25 dB over specified frequency band.

Cobham Antenna Systems,
Exeter, NH (603) 775-5200,
www.cobham.com.

VCOs for Radio Applications

VENDORVIEW

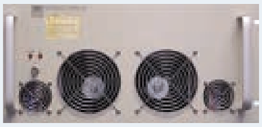


M/A-COM Technology Solutions Inc. has a new set of VCOs for radio applications. The MAOC-009871, MAOC-009872 and MAOC-010334 meet the high performance requirements of high capacity digital radios by optimizing for low phase noise, wide tuning range, and low current consumption. Packaged in a lead-free 5 mm, 32-lead PQFN package, the VCOs feature an integrated buffer amplifier and excellent temperature stability. Operating with case temperature at or below +85°C, the VCOs allows for a MTBF of 2,500,000 hours. With a 5 V bias supply, these VCOs operate between the 8.4 to 11.8 GHz frequency band.

M/A-COM Technology Solutions Inc.,
Lowell, MA (800) 366-2266,
www.macomtech.com.

9 to 10.5 GHz Power Amplifiers

Models C090105-50 and C090105-53 are X-Band high power rack-mount amplifiers operating over the 9 to 10.5 GHz bandwidth. The model C090105-50 amplifier delivers 100 W minimum of output power across the entire



bandwidth with greater than 52 dB of small signal gain. The model C090105-53 amplifier delivers 200 W minimum of output power across the entire bandwidth with greater than 52 dB of small signal gain. These amplifiers can be factory tuned to provide 100 or 200 W for adjacent bands, including 8.5 to 9.6 GHz and 10.7 to 11.7 GHz. Enclosure size: 19" × 24" × 8.75" panel. 1.7 KW (for model C090105-53) typical.

Microsemi,
Santa Clara, CA (408) 727-6666,
www.amlj.com.

Ka-Band LNA

VENDORVIEW

Model AMFW-7F-17702130-120-23P-WP is a low noise, high dynamic range weatherproof Ka-Band front-end, operating 17.7 to 21.3 GHz. The aluminum alloy housing is

sealed against most severe environmental conditions and is also fully EMI shielded. This LNA includes reverse voltage, over current and over temperature protection in addition to full internal regulation. Total weight is approximately 800 grams, and dimensions are 156 × 70 × 51 mm. It has a minimum gain of 60 dB, flat to within ±1 dB, and maximum noise temperature of 120 K° and is capable of a minimum of 23 dBm P1dB across the full band. Noise temperature will typically change with base temperature of the LNA at a rate of 0.28 K/°C.

MITEQ Inc.,
Hauppauge, NY (631) 439-9469,
www.miteq.com.

Solid-state Switch

VENDORVIEW

PMI model P4T-0R1G20G-100-T-SFF is a single pole, four throw, solid-state absorptive switch that operates over the 100 MHz to 20 GHz frequency range. This model provides 110 dB of isolation over the entire frequency range of operation and offers low insertion loss performance with fast switching speeds.

Planar Monolithics Industries Inc.,
Frederick, MD (301) 662-5019,
www.pmi-rf.com.

DCS Duplexer

RADITEK's DCS band surface-mount ceramic diplexer is a high performance DCS duplexer

in a convenient surface-mount package. It is used mainly for splitting transmit and receive signals to and from a common antenna. RDUP-1710-1785-1805-1880M-4415-3W-S-ca-j Series typical performance specifications are 3 dB insertion loss, 48 dB isolation/rejection, 13 dB return loss, -40° to +85°C operating temperature. These units are proven in the field and are fully RoHS compliant.

RADITEK Inc.,
San Jose, CA (408) 266-7404,
www.raditek.com.

Miniature Coaxial Switch

This miniature coaxial switch is a single pole, two position type. The switch provides extremely high reliability, long life and excellent electrical performance characteristics over the frequency range of DC to 65 GHz. The miniature package utilizes high density packaging techniques, hence the overall volume of the switch is less than 3/4 cubic inch.

RLC Electronics Inc.,
Mt. Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

2-Way Combiner, 20 to 1000 MHz

VENDORVIEW

The model D8682 is a high power combiner designed specifically for multi-octave, commercial and military solid-state amplifier applications. This model is only one of several Werlatone combiners available with full 20 to 1000 MHz bandwidth, at power levels ranging from 25 to 500 W CW. D8682 is rated at 500 W CW and will tolerate a full input failure at rated power with forced air cooling and 300 W CW without forced air cooling.

Werlatone Inc.,
Patterson, NY (845) 278-2220,
www.werlatone.com.

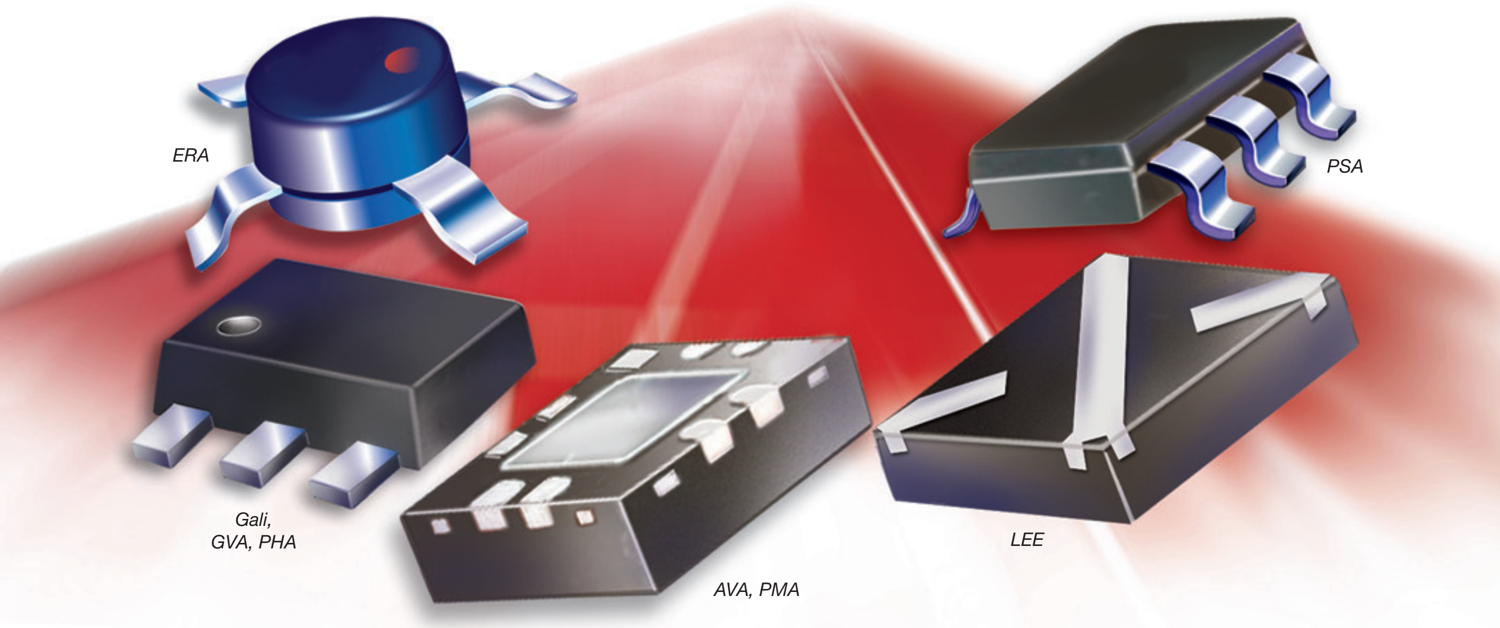
Fixed Frequency Synthesizer

The SFS1900A-LF is a single frequency synthesizer that operates at 1900 MHz. This synthesizer features a typical phase noise of -98 dBc/Hz at 10 KHz offset and typical sideband spurs of -70 dBc. It is designed to deliver a typical output power of 0 dBm with a VCO voltage supply of 5 V DC while drawing 25 mA (typical) and a phase locked loop voltage of 3.3 V DC while drawing 10 mA (typical) over the temperature range of -40° to +85°C. This package measures 0.60" × 0.60" × 0.13." It is available in tape-and-reel packaging for production requirements.

Z-Communications Inc.,
Poway, CA (858) 621-2700,
www.zcomm.com.

MMIC AMPLIFIERS

DC to 20 GHz from 73¢ qty.1000



NF from 0.5 dB, IP3 to +48 dBm, Gain 8 to 31 dB, Pout to +30 dBm

Think of all you stand to gain. With more than ~~124~~ 145 catalog models, Mini-Circuits offers one of the industry's broadest selection of low-cost MMIC amplifiers. Our ultra-broadband InGaP HBT and PHEMT amplifiers offer low noise figure, high IP3, and a wide selection of gain to enable optimization in your commercial, industrial or military application.

Our tight process control guarantees consistent performance across multiple production runs, so you can have confidence in every unit. In fact, cascading our amplifiers often results in less than 1dB total gain variation at any given frequency. These MMIC amplifiers can even meet your most critical size and power consumption requirements with supply voltages as low as 2.8 V, and current consumption down to 20 mA, and packages as small as SOT-363.

Visit our website to select the amplifier that meets your specific needs. Each model includes pricing, full electrical, mechanical, and environmental specifications, and a full set of characterization data including S-Parameters. So why wait, place your order today and have units in your hands as early as tomorrow. *RoHS compliant*

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U.S. Patents 7739260, 7761442

IF/RF MICROWAVE COMPONENTS

New Products

Components

Low Insertion Loss Filter

The PB1446WB low insertion loss filter for C-Band receive satellite terminals comes in a compact and lightweight housing, which is suitable for ground or maritime satellite communications systems. It operates over a passband of 3.6 to 4.2 GHz and has an insertion loss of 0.25 dB typical. The filter also removes interference from radars and other transmitters operating in the area by providing over 60 dB of rejection from DC to 3.185 GHz and from 4.55 to 4.9 GHz. It also has over 90 dB of rejection from 4.9 to 11 GHz. Designed for harsh environments, it is manufactured in a rugged brazed structure with no tuning screws and no silver plating.

A1 Microwave Ltd.,
Pickering, UK +44 (0)1751 476600,
www.a1microwave.com.

Switched Digital Attenuator

VENDORVIEW

Aeroflex/Weinschel's new model 4201-63 MMIC digital attenuator operates over the 0.4 to 6 GHz frequency range and provides an attenuation range from 0 to 63 dB in 1 dB increments. VSWR is 2:1 maximum. Attenuation accuracy is ± 1 dB or 4 percent. Insertion loss is 7 dB maximum, power rating is 20 dBm, switching time is 300 nSec maximum and operating voltage is -5 V at 10 mA. It uses SMA female connectors and the operating range is 0° to 70°C. Dimensions are 2.35" × 1.75" × 0.75."

Aeroflex/Weinschel,
Frederick, MD (301) 846-9222,
www.aeroflex.com/microwave.

D/A Converters

Analog Devices Inc. (ADI) introduced D/A (digital-to-analog) converters that provide high accuracy and ultra-low noise, simplifying the design of precision instrumentation and analytical equipment. The D/A converters incorporate integrated precision reference conditioning circuitry, making them system ready and providing a 60 percent reduction in board space compared to competing standalone data converters. The AD5790 D/A converter offers ±2-LSB accuracy at 20-bit, while the AD5780 features ±1-LSB accuracy at 18-bit over temperature. Guaranteed monotonic, the devices specify –1-LSB max DNL. The AD5790 and AD5780 D/A converters feature 1.1 μV peak-to-peak, low frequency output noise, 9-nV/rt-Hz noise spectral density and less than 0.05 ppm/°C temperature drift. The output can be configured for standard unipolar (+5 V, +10 V) or bipolar (±5 V, ±10 V) output ranges.

Analog Devices Inc.,
Norwood, MA (781) 329-4700,
www.analog.com.

Resistive Power Divider/Combiner

Model 151270002 is a two-way, 50 Ω resistive power divider/combiner that has a DC to 6 GHz operating frequency range, 1.50:1 VSWR and SMA female connectors. This device exhibits 1 dB nominal insertion loss (above theoretical loss), ±0.5 dB amplitude tracking and is rated 2 W average power at the sum port. Applications for this unit include antenna sharing, intermodulation distortion measurements, diversity gain measurements and gain compression/isolation measurements. Model series 151270XXX* is available in 2, 4, 6 and 8 way configurations (*insert desired configuration, two-way = 002).

BroadWave Technologies Inc.,
Greenwood, IN (317) 888-8316,
www.broadwavetechnologies.com.

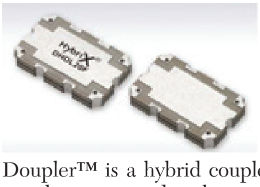
Compact SSPA with BUC

XTS-20KaL-B1 is a 20 W solid-state Ka-Band block up converter (BUC) for commercial and military Ka-Band satellite communications uplinks. It is designed for high data-rate satellite communications uplinks and is available covering 29 to 30 GHz, or 30 to 31 GHz. It features 10 W of linear power in an 18-pound antenna-mount package, measuring 11.6" × 5.5" × 6.5", and is energy efficient, typically consuming only 180 W. This rugged, compact and efficient product is optimized for transportable SATCOM terminals that require high linear power, and is designed to be mechanically interchangeable with existing Xicom solid-state products in X- and Ku-Bands for terminals designed to support multiple bands.

Comtech Xicom Technology Inc.,
Santa Clara, CA (408) 213-3000,
www.xicomtech.com.

Integrated Hybrid Combiner

VENDORVIEW

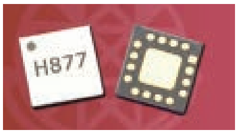


Florida RF Labs has introduced a new and innovative solution for power combining and monitoring. The Doupler™ is a hybrid coupler and directional coupler integrated within a single SMT package. This novel approach brings together the benefits of reduced component count, lower insertion loss, and minimized PCB footprint. Doupler allows for simplified PCB layout that eliminates impedance mismatch and interference, which are inherent with the conventional approach. This technologically advanced product is available in all 3G and 4G frequency bands. When Doupler is complemented by EMC Technology's Smart Detector power sensing terminations, a totally passive power combining and monitoring solution can be realized with the lowest loss and highest circuit reliability.

Florida RF Labs,
Stuart, FL (772) 600-1632,
www.emc-rflabs.com.

Time Delay/Phase Shifter

VENDORVIEW



The HMC877LC3, Time Delay/Phase Shifter is ideal for clock chain and skew adjustment in 10G-RZ, 40G/100G RZ-DQPSK fiber optic applications. The HMC877LC3 is the first Time Delay/Phase Shifter product in the market to provide up to 1.4 UI (500°) continuously adjustable delay over a wide 8 to 23 GHz frequency range, while maintaining a constant differential output voltage. The device accepts either single-ended or differential input signals, while providing a 500 to 900 mVp-p programmable differential output swing. The HMC877LC3 provides a time delay/phase shift, which is linearly monotonic with respect to the differential delay control voltage, over a ±0.6 V tuning range. On-chip compensation circuitry ensures an extremely stable programmable time delay over both frequency and temperature. A high delay control modulation bandwidth (3 dB rolloff point) of 2.5 GHz combined with single +3.3 V operation also make the HMC877LC3 ideal for phase modulation in military and space, test and measurement and broadband applications.

Hittite Microwave Corp.,
Chelmsford, MA
(978) 250-3343,
www.hittite.com.

Power Combiner/Divider

VENDORVIEW

Narda, an L-3 Communications company, introduced the model 30402 two-way RF power combiner that operates from 820 to 915 MHz, making it an excellent choice for use in wireless base stations. The model 30402 has a maximum VSWR of 1.3:1, insertion loss of 0.5 dB (3.5 dB including combining losses), isolation of 20 dB, amplitude balance of 0.2 dB, and phase balance of ±3°. As a combiner, the unit will handle 40 W average and 1.3 kW peak RF input power. As a divider it will handle 80 W average power and 3 kW peak power. It weighs 4.9 ounces and uses Type-N female connectors.

Narda Microwave-East,
Hauppauge, NY
(631) 231-1700,
www.nardamicrowave.com/east.

High Power Switches

VENDORVIEW

Skyworks Solutions Inc. has introduced a family of high power 50 Ω terminated, single-pole, double-throw switches. The small-package SKY13348-374LF and SKY13370-374LF are ideal for high power access points and router applications given their matched ports, which reduce low noise amplifier pulling and deliver better system performance. Additional features

include low insertion loss, high isolation and high linearity for improved data throughput.
Skyworks Solutions Inc.,
Woburn, MA (781) 376-3000,
www.skyworksinc.com.

Amplifiers

RF Amplifier MMICs

Richardson RFPD Inc. announced off-the-shelf availability for a complete set of key building-block RF amplifiers, each of which has been designed specifically for enhanced performance in demanding applications, such as 3G/4G wireless communications systems. The product line is based on advanced semiconductor technologies, including InGaP HBT and Enhanced-Mode GaAs PHEMT (E-PHEMT), providing a superior combination of high dynamic range, low noise figure and low intermodulation distortion relative to P1dB. Applications include macrocell down to picocell and femtocell base station transmitter and receiver designs, tower-mount amplifiers, remote radio heads and RF repeaters.
Freescale Semiconductor distributor
Richardson RFPD,
LaFox, IL
(630) 208-2700,
www.richardsonrfpd.com.

Push-pull Amplifier

VENDORVIEW

The ZHL-132LM-75+ is a high performance, push-pull amplifier featuring low second-and third-order distortion products across its 40 to 1300 MHz bandwidth. Designed for a 6 V/256 mA typical power supply, with F connectors in/out, it is a high value, low cost solution providing a 14 dB gain for CATV, instrumentation, and many other applications at VHF, UHF, and lower L-Band frequencies. The rugged, aluminum alloy case measures 3.75" × 2" × 0.80"
Mini-Circuits,
Brooklyn, NY
(718) 934-4500,
www.minicircuits.com.

Low Noise Amplifiers

As the industry's first GPS LNAs to dynamically suppress strong cellular, Bluetooth and WLAN transmit signals, the NXP BGU700x family offers the best reception for weak GPS signals, delivering an improvement of 10 dB or better IP3 under -40 to -20 dBm jamming conditions, while the noise figure remains below 1 dB. Requiring only two external components, the BGU700x LNAs save up to 50 percent in PCB size and 10 percent in component cost. The NXP BGU700x/BGU8007 series use adaptive biasing to immediately detect any output power from jammers, and compensate by temporarily increasing the current. As a result, optimal GPS signal reception is maintained for as long as possible. Each device in the BGU700x/BGU8007 series requires only one input matching inductor and one supply decoupling capacitor to complete the design. This creates a very compact design and lowers the bill of materials. For example, the BGU7005 is in a 1.45 × 1 mm package with an application area of only 4.53 × 4.53 mm.
NXP Semiconductors N.V.,
Eindhoven, Netherlands + 31 40 27 29960,
www.nxp.com.

Material

Heatsink

Designed for applications requiring high power densities and where forced air cooling is present, Ohmite has released a larger version of its MV/MA heatsink, which provides even more heat dissipation. The longer, more efficient fin extrusions on the new version give nearly twice

the thermal performance as their smaller MV/MA 102 product. The MV/MA 302 heatsink is 2.2" × 1.71" and uses the same installation mechanism, which provides two internal spring clips for mounting up to four TO-247 or TO-264 devices. The spring clips eliminate the need for mounting holes and screws, are resilient and provide the same amount of force after repeated use.
Ohmite Manufacturing Co.,
Arlington Heights, IL
(847) 238-0300,
www.ohmite.com.

Semiconductors/ICs

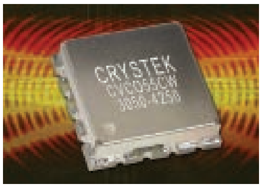
GaN on SiC Devices

Integra Technologies Inc. (ITI), a manufacturer of high power pulsed RF transistors, announced the development of two Gallium Nitride on Silicon Carbide (GaN on SiC) technology devices targeted for the military communication market. Integra's world class RF design team has launched several new products characterized for broadband applications ranging from 30 to 512 MHz to 100 to 1000 MHz. Intended for commercial broadband communication applications, including EW jammers, the unmatched devices provide a range of output power from 25 W to over 200 W in a low parasitic wide lead ceramic package.
Integra Technologies Inc.,
El Segundo, CA
(310) 606-0855,
www.integratech.com.

Sources

3050 to 4250 MHz VCO

Crystek's CVCO55CW-3050-4250 VCO operates from 3050 to 4250 MHz with a control



voltage range of 1.5 to 18.5 V. This VCO features a typical phase noise of -85 dBc/Hz at 10 KHz offset and has excellent linearity. Output power is typically +1.5 dBm. Engineered and manufactured in the USA, the model CVCO55CW-3050-4250 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 5 V, with a maximum current consumption of 16 mA. Pulling and pushing are minimized to 5 MHz and 5 MHz/V, respectively. Second harmonic suppression is -15 dBc typical. The CVCO55CW-3050-4250 is ideal for use in applications, such as digital radio equipment, fixed wireless access, satellite communications systems and base stations.
Crystek Corp.,
Ft. Myers, FL
(800) 237-3061, www.crystek.com.

GPS Disciplined Oscillator

LC_1×1 is an extremely small Global Positioning System Disciplined Oscillator (GPSDO) that has been designed for cost-sensitive LTE applications. LC_1×1 is backwards compatible to the popular Jackson Labs Technologies Inc. FireFly-IIA GPSDO, designed to meet stringent LTE holdover specifications that previously required Rubidium references. At only 1.6" × 1.9" × 0.8," LC_1×1 provides Stratum-1 long-term performance of typically better than 1 part per trillion (1E-12) averaged over 24 hours. LC_1×1 is available in a low profile (0.63" high) single-oven oscillator version, or a higher performance doubleoven oscillator version. LC_1×1 is a 10 MHz frequency and timing reference.
Jackson Labs Technologies Inc.,
Los Gatos, CA (408) 354-7888,
www.jackson-labs.com.

Test Equipment

PIM Analyzer

VENDORVIEW

Anritsu Co. introduces the MW8209A PIM Master, a passive intermodulation (PIM) analyzer that covers the 900 MHz band to address the growing need to measure PIM in E-GSM networks, including UMTS Band VIII and LTE Band 8. Designed for use with Anritsu handheld analyzers, the MW8209A comes with Anritsu's Distance-to-PIM technology, the only tool on the market that can determine if the cause of PIM is at the base station or in the surrounding environment. Field engineers and technicians can use the MW8209A to help ensure optimum performance of UMTS Band VIII and LTE Band 8 networks by locating PIM faults before intermodulation distortion adversely affects signal transmission. The MW8209A has been designed to be integrated with Anritsu's handheld instruments, including the S332E/S362E Site Master™ cable and antenna analyzers, MS2712E/MS2713E and MS272xC Spectrum Master™ handheld spectrum analyzers, MT8212E/MT8213E Cell Master™ handheld analyzers and the MT8221B/MT8222A BTS Master™ handheld analyzers.

Anritsu Co.,
Morgan Hill, CA (800) 267-4878,
www.anritsu.com.

Phase-locked Crystal Oscillator

The PLXO-100 is a phase-locked crystal oscillator operating at 100 MHz in a miniature connectorized package (1.5" × 1.5" × 0.6"). Locked to an external 10 MHz frequency reference, the device exhibits exceptionally low phase noise (-130 dBc/Hz at 1 KHz offset), low spurs (-70 dBc), +0 dBm output power on a supply voltage of +12 V DC. The addition of an internal reference-detect switch enables the user to employ the external frequency reference that, if disabled, will automatically switch to an internal 10 MHz reference, thereby providing uninterrupted use of the PLXO-100. EM Research offers the PLXO Series in a surface-mount (0.9" × 0.9" × 0.15") or connectorized package at custom fixed-frequencies from 5 to > 500 MHz. The PLXO Series features low jitter (< 0.05 pSec. RMS at 100 MHz, typical), optional internal references and select supply voltages (+3.3, +5, +8, +12 or +15 V DC).

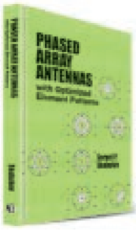
EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com.

Mixed Signal Oscilloscope

This hardware option turns the R&S RTO high performance oscilloscope into a mixed signal oscilloscope (MSO), enabling quick, accurate testing of complex embedded design. In addition to the usual two or four analog channels, the oscilloscope now features 16 digital logic channels with 400 MHz input frequency, while fully utilizing the benefits of the base unit for mixed signal analysis. Equipped with the MSO option, the R&S RTO allows time correlation between the instrument's analog and digital sections. The option comes with hardware-based acquisition, trigger and processing units. Even when the digital channels are on, high acquisition rates of over 200,000 waveforms/second can be achieved.

Rohde & Schwarz,
Munich, Germany
+49 89 4129-13779,
www.rohde-schwarz.com.

MICRO-ADS



Phased Array Antennas with Optimized Element Patterns

Sergei P. Skobelev

Rapid development of phased array antennas started in the 1940s after the first samples of antennas with electrical beam scanning appeared. Many large stationary radars with phased arrays were built in countries that had access to this technology for defense applications. Today, these radars have applications in air traffic control, imaging, automotive safety, shipboard fire-control, counter battery radar, satellite communication systems and Earth communication stations.

This book covers a systematic description of the theory and methods of shaping the sector and contour element patterns in linear and planar phased array antennas. It is based mainly on the work and results of the author and is compared to the results obtained by other experts in the field. The author's research on the subject of this book started in the mid-1970s while he was studying at the Moscow Institute of Physics and Technology. The results presented were obtained from his research over the years in various institutions.

The book starts with the fundamental relations for phased arrays obtained using the general antenna theory applied to periodic structures. Then various types of array configurations are covered, including the details about their design and characterization. The book covers the subject in great detail, but only focuses on this specific subject. So it is mainly designed for researchers and engineers working in the array antenna area. It is also useful for students specializing in antennas and microwave engineering.

To order this book, contact:

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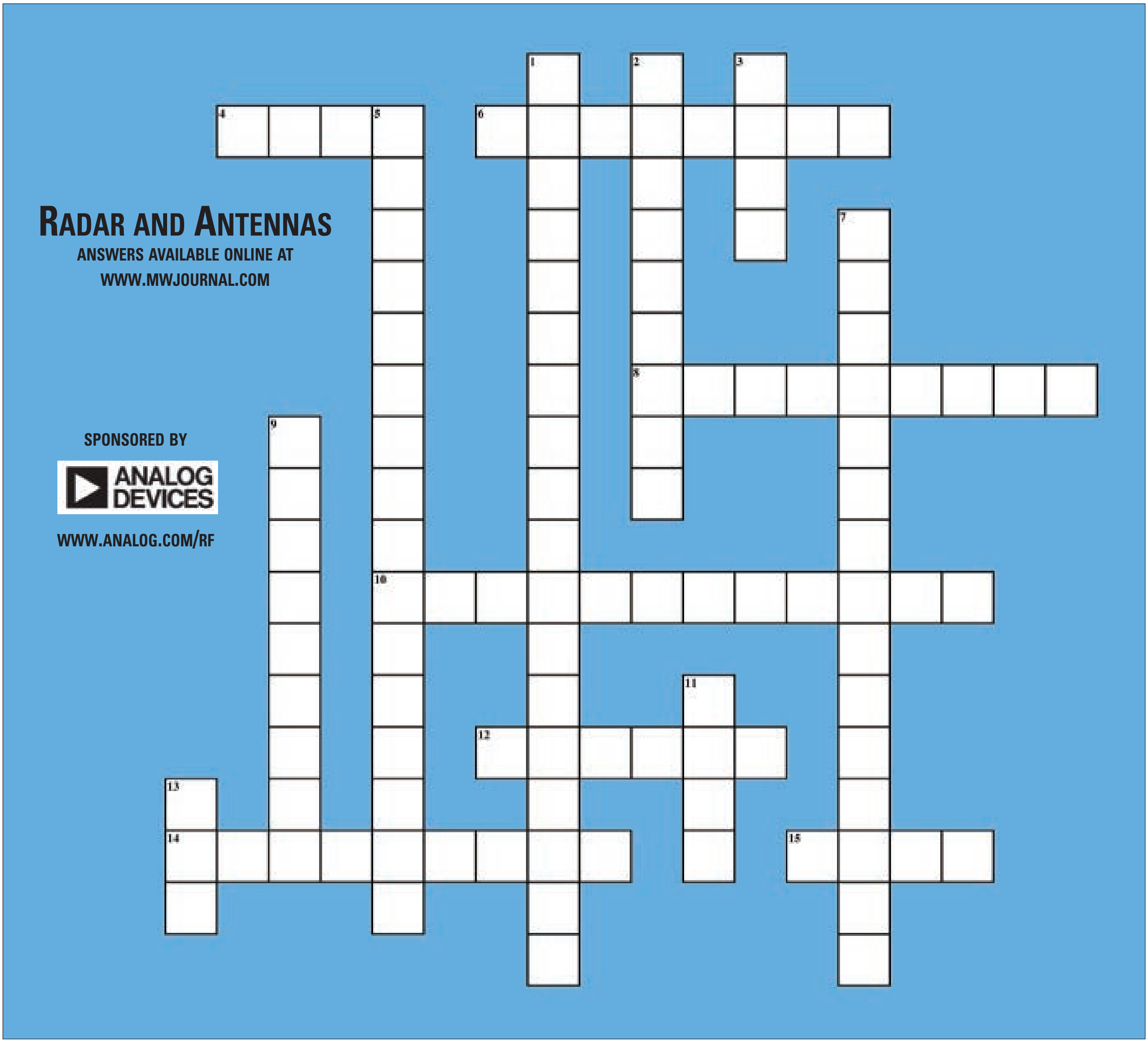
MWJ Puzzler



ACROSS

4 A device with an array of configurable logic blocks with each cell of the block programmable to perform one of many functions

6 The time for a power pulse to reach its target value (2 words)

8 A power divider consists of two parallel uncoupled $\lambda/4$ transmission lines

10 A type of beamforming network that enables the antenna beam is steered depending on the ports fed (2 words)

12 Short for Beyond Next Generation Mobile Broadband

14 Calculated by dividing the power envelope pulse width by the pulse repetition interval (2 words)

15 Short for Commercial Off the Shelf

DOWN

1 A device that is typically constructed from two coupled transmission lines set close enough together such that energy passing through one is coupled to the other (2 words)

2 Calculated by dividing the average power value by the duty cycle measurement (2 words)

3 Short for multiple input multiple output

5 The power difference in dB between the two output ports of a 3 dB hybrid (2 words)

7 Enables the capture of a radar signal for anaylsis or re-transmit back with changes to fool the enemy (3 words)

9 When a power pulse goes higher than intended on the initial pulse

11 A type of active radar that includes hundreds or thousands of T/R modules in an array

13 Short for analog-to-digital converter

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Model	Type	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Isolation (dB)
D6233	2-Way	10-1000	25	3.25 x 2 x 1.1	0.75	1.35:1	20
D8632	2-Way	20-1000	50	2.2 x 2.02 x 1.5	0.7	1.40:1	20
D8300	2-Way	20-1000	100	2.45 x 2 x 0.91	0.5	1.35:1	20
D8544W*	2-Way	20-1000	100	2.85 x 2.5 x 1	0.5	1.35:1	18
D8682	2-Way	20-1000	500	5.2 x 2.65 x 1.8	0.6	1.35:1	15
D8851W*	2-Way	20-1000	500	5.6 x 3.05 x 1.8	0.6	1.35:1	15
D7365	4-Way	20-1000	100	5 x 2 x 1	0.75	1.35:1	20
D7439	4-Way	20-1000	250	5 x 5 x 1.5	0.75	1.35:1	18
D8746	4-Way	20-1000	500	7.2 x 3.5 x 1.4	0.7	1.35:1	15
D9048	4-Way	20-1000	500	5 x 4.7 x 1.4	0.6	1.35:1	17

* "W" references a Watertight Design

Dual Directional Couplers

Model	Coupling (dB)	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Directivity (dB)
C8858	40	10-1000	250	2.09 x 1.16 x 0.57	0.4	1.30:1	20
C8631*	40	20-1000	150	1.5 x 0.95 x 0.5	0.35	1.25:1	20
C8696	40	20-1000	150	1.76 x 1.16 x 0.57	0.35	1.25:1	20
C8686	40	20-1000	500	5.2 x 2.7 x 1.7	0.35	1.25:1	20

* Non-Connectorized / Tabs

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