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July 2005

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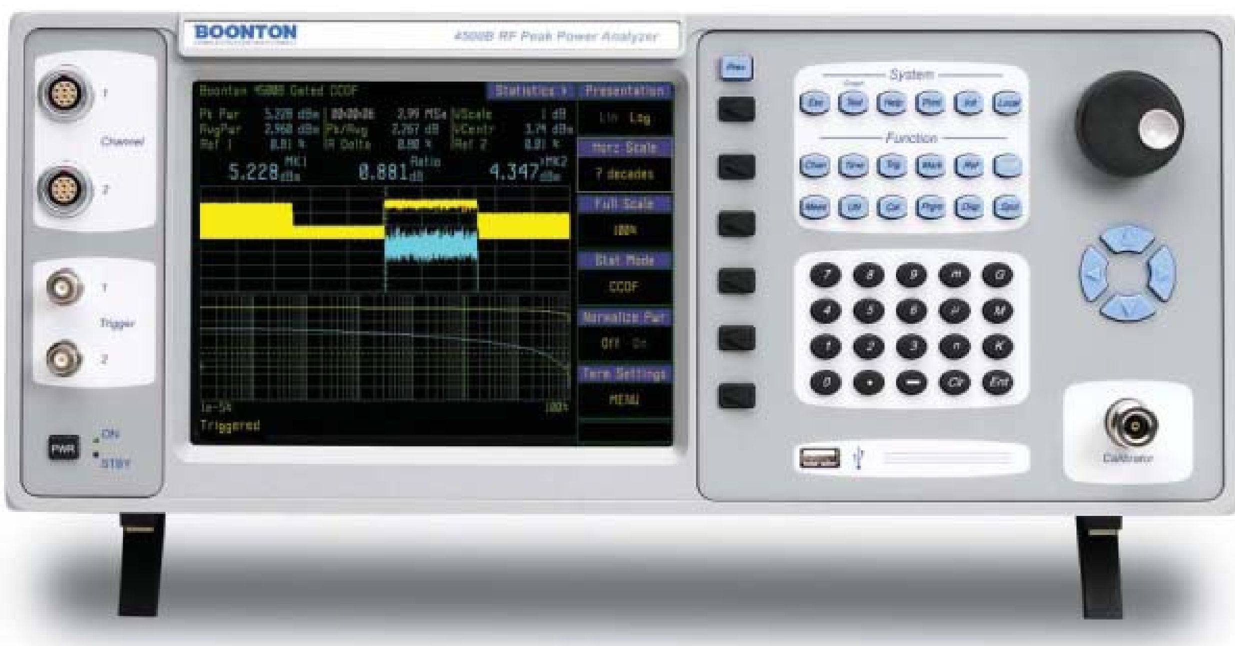

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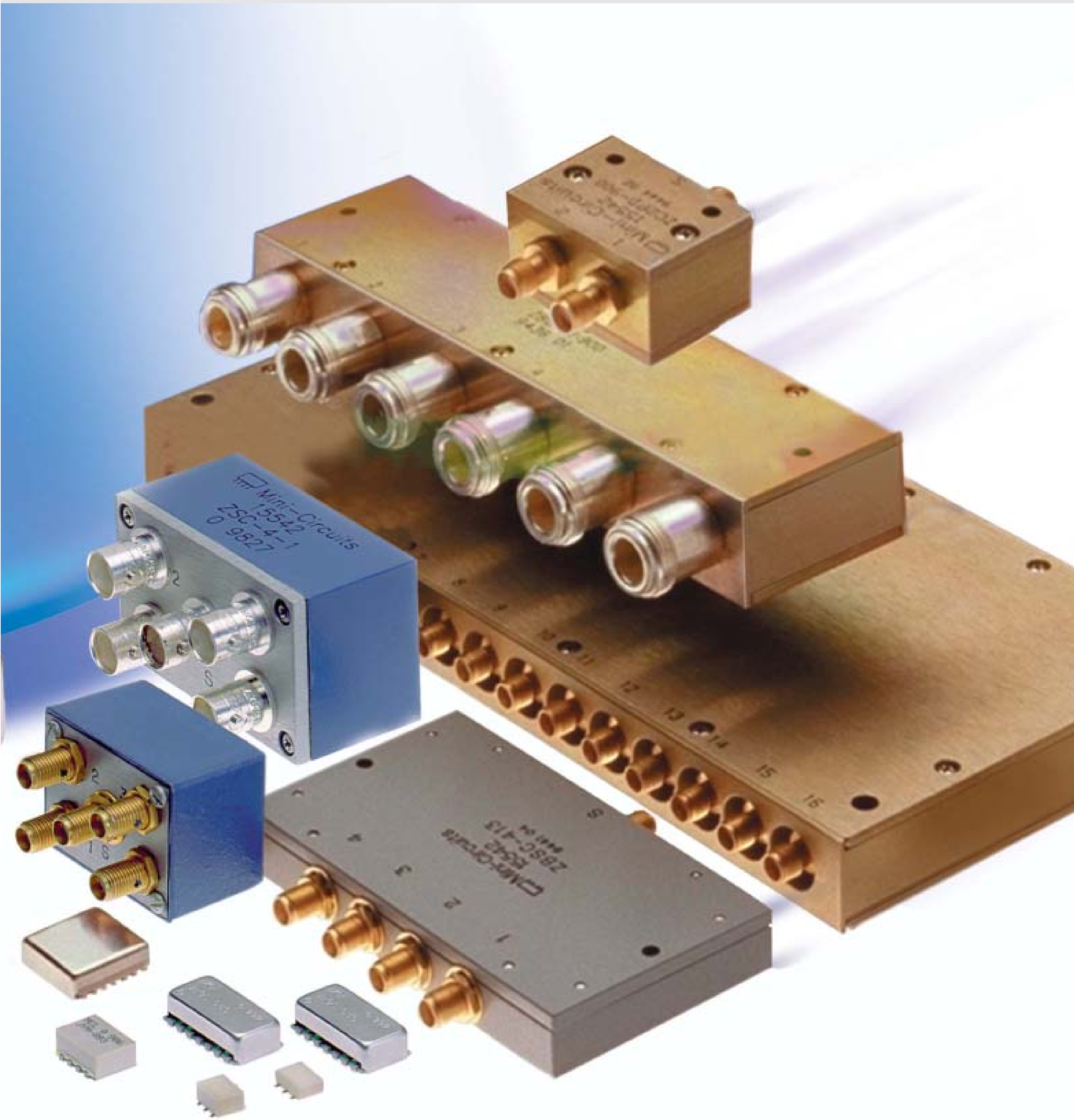
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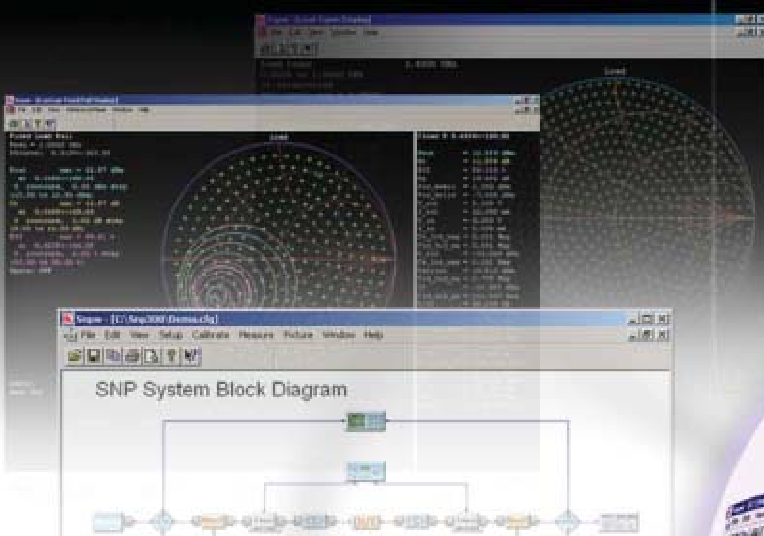

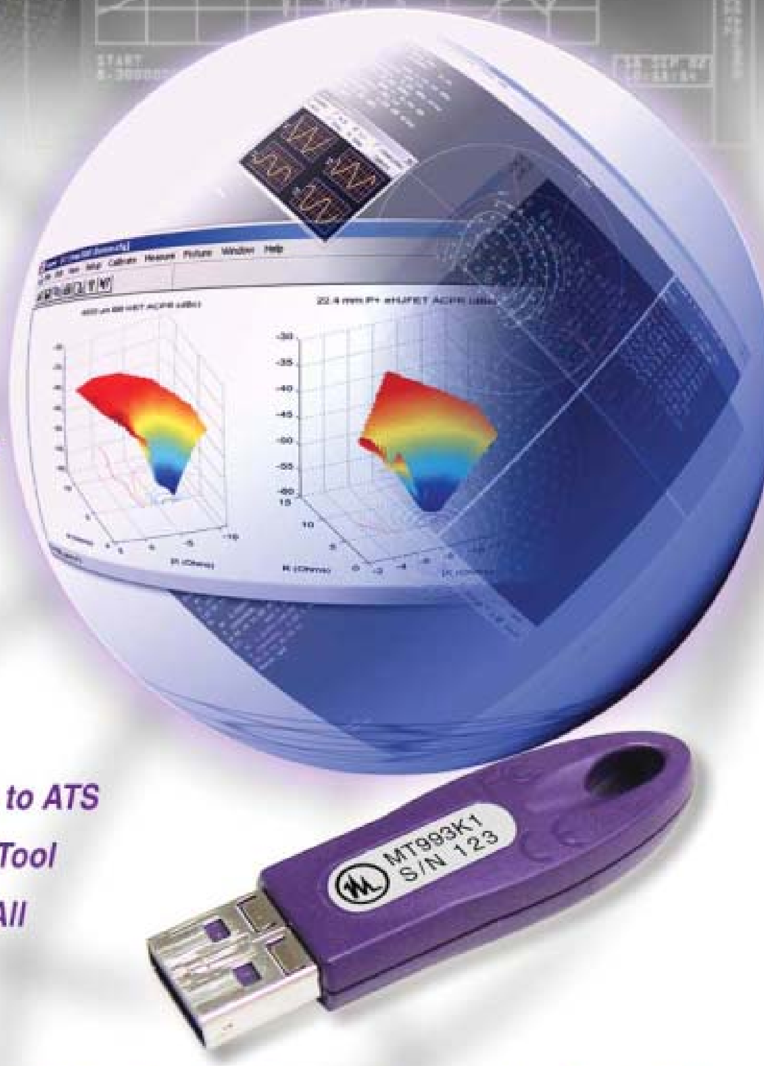

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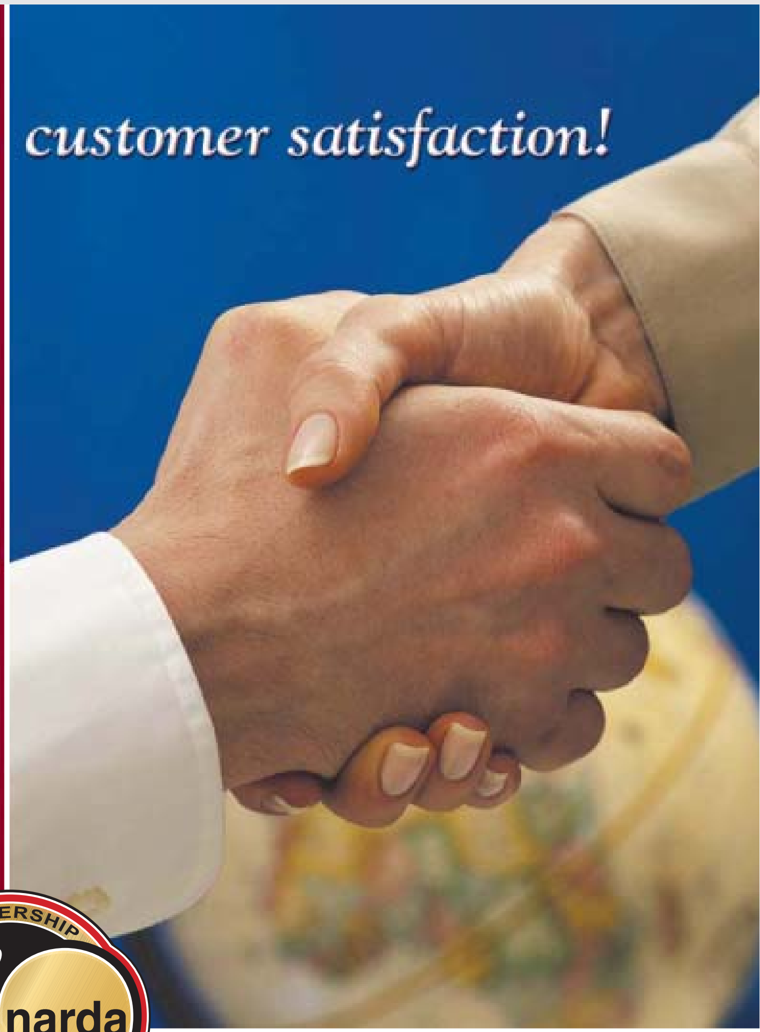

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FEATURES

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PART NUMBER		LENGTH INCHES	+/- LENGTH	WEIGHT OUNCES	MAXIMUM VSWR :1 AT FREQUENCY (IN GHz.) UP TO 1	1 TO 2	2 TO 4	4 TO 6	6 TO 12	12 TO 18	MAXIMUM INSERTION LOSS IN dB AT FREQ. (IN GHz.) UP TO 1	1 TO 2	2 TO 4	4 TO 6	6 TO 12	12 TO 18	NOM DELAY nS	LENGTH CM
1-3636-600- 5202	D	2.0	0.05	0.2	1.06	1.10	1.14	1.17	1.20	1.30	0.10	0.13	0.18	0.22	0.31	0.40	0.24	5.1
1-3636-600- 5203	D	3.0	0.05	0.2	1.06	1.10	1.14	1.17	1.20	1.30	0.12	0.16	0.22	0.27	0.38	0.50	0.36	7.6
1-3636-600- 5204	D	4.0	0.05	0.2	1.06	1.10	1.14	1.17	1.20	1.30	0.14	0.18	0.26	0.32	0.46	0.60	0.48	10.2
1-3636-600- 5205	D	5.0	0.10	0.3	1.06	1.10	1.14	1.17	1.20	1.30	0.16	0.21	0.30	0.37	0.53	0.69	0.60	12.7
1-3636-600- 5206	D	6.0	0.10	0.3	1.06	1.10	1.14	1.17	1.20	1.30	0.17	0.24	0.34	0.42	0.61	0.79	0.72	15.2
1-3636-600- 5207		7.0	0.10	0.3	1.06	1.10	1.14	1.17	1.20	1.30	0.19	0.27	0.38	0.47	0.69	0.89	0.84	17.8
1-3636-600- 5208	D	8.0	0.10	0.3	1.06	1.10	1.14	1.17	1.20	1.30	0.21	0.29	0.42	0.52	0.76	0.99	0.96	20.3
1-3636-600- 5209		9.0	0.10	0.3	1.06	1.10	1.14	1.17	1.20	1.30	0.23	0.32	0.46	0.57	0.84	1.08	1.08	22.9
1-3636-600- 5210		10.0	0.10	0.3	1.06	1.10	1.14	1.17	1.20	1.30	0.25	0.35	0.50	0.62	0.92	1.18	1.20	25.4
1-3636-600- 5211		11.0	0.15	0.4	1.06	1.10	1.14	1.17	1.20	1.30	0.27	0.38	0.55	0.67	0.99	1.28	1.32	27.9
1-3636-600- 5212	D	12.0	0.15	0.4	1.06	1.10	1.14	1.17	1.20	1.30	0.29	0.40	0.59	0.72	1.07	1.38	1.44	30.5
1-3636-600- 5213		13.0	0.15	0.4	1.06	1.10	1.14	1.17	1.20	1.30	0.31	0.43	0.63	0.77	1.14	1.47	1.56	33.0
1-3636-600- 5214		14.0	0.15	0.4	1.06	1.10	1.14	1.17	1.20	1.30	0.33	0.46	0.67	0.83	1.22	1.57	1.68	35.6
1-3636-600- 5215		15.0	0.15	0.4	1.06	1.10	1.14	1.17	1.20	1.30	0.35	0.49	0.71	0.88	1.30	1.67	1.80	38.1
1-3636-600- 5216		16.0	0.15	0.4	1.06	1.10	1.14	1.17	1.20	1.30	0.36	0.51	0.75	0.93	1.37	1.77	1.92	40.6
1-3636-600- 5217		17.0	0.15	0.5	1.06	1.10	1.14	1.17	1.20	1.30	0.38	0.54	0.79	0.98	1.45	1.86	2.04	43.2
1-3636-600- 5218	D	18.0	0.15	0.5	1.06	1.10	1.14	1.17	1.20	1.30	0.40	0.57	0.83	1.03	1.52	1.96	2.16	45.7
1-3636-600- 5219		19.0	0.15	0.5	1.06	1.10	1.14	1.17	1.20	1.30	0.42	0.60	0.87	1.08	1.60	2.06	2.28	48.3
1-3636-600- 5220		20.0	0.15	0.5	1.06	1.10	1.14	1.17	1.20	1.30	0.44	0.62	0.91	1.13	1.68	2.15	2.40	50.8
1-3636-600- 5221		21.0	0.15	0.5	1.06	1.10	1.14	1.17	1.20	1.30	0.46	0.65	0.95	1.18	1.75	2.25	2.52	53.3
1-3636-600- 5222		22.0	0.15	0.5	1.06	1.10	1.14	1.17	1.20	1.30	0.48	0.68	0.99	1.23	1.83	2.35	2.64	55.9
1-3636-600- 5223		23.0	0.15	0.6	1.06	1.10	1.14	1.17	1.20	1.30	0.50	0.71	1.03	1.28	1.91	2.45	2.76	58.4
1-3636-600- 5224	D	24.0	0.15	0.6	1.06	1.10	1.14	1.17	1.20	1.30	0.52	0.74	1.07	1.33	1.98	2.54	2.88	61.0
1-3636-600- 5225		25.0	0.15	0.6	1.06	1.10	1.14	1.17	1.20	1.30	0.54	0.76	1.11	1.39	2.06	2.64	3.00	63.5
1-3636-600- 5226		26.0	0.15	0.6	1.06	1.10	1.14	1.17	1.20	1.30	0.56	0.79	1.15	1.44	2.13	2.74	3.12	66.0
1-3636-600- 5227		27.0	0.15	0.6	1.06	1.10	1.14	1.17	1.20	1.30	0.57	0.82	1.19	1.49	2.21	2.84	3.24	68.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.85	1.23	1.54	2.29	2.93	3.36	71.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.87	1.27	1.59	2.36	3.03	3.48	73.7

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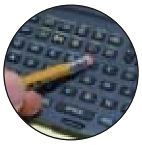

Coming Events

Military Antenna Systems
September 19–21, 2005
Crystal City, VA

This event will address military antenna systems and the necessary requirements to meet the needs of the warfighter. Antennas used for military applications must be rugged, reliable and compact. Meeting these requirements often necessitates a costly support system and added interference problems. The Department of Defense is constantly working to develop and test new antenna systems to meet military demands, and this event will explore the latest in antenna systems for the military. For more information contact Tony Yauch at (800) 882-8684 or e-mail: info@idga.org.

Antenna Systems 2005
September 22–23, 2005
Santa Clara, CA

Antenna Systems 2005 is a two-day international conference focused on the latest and most important advancements in antenna systems technology. The technical conference will serve OEM developers of products that utilize antennas and antenna systems, system operators, antenna integrators and manufacturers, and component and material suppliers interested in learning the latest capabilities and best practices in this rapidly changing field. Antenna Systems 2005 is an opportunity to network with peers, professionals and potential business partners involved in technology solutions serving a variety of applications. See the latest products, services and systems available, and discover what's coming next. Learn the latest business and application developments in antenna markets worldwide. For more information, visit www.antennasonline.com/ast_conf2005_index.htm or contact Jeremy Martin at (720) 528-3770 or e-mail: jeremym@infowebcom.com.

CTIA WIRELESS I.T. and Entertainment 2005
September 27–29, 2005
San Francisco, CA

CTIA WIRELESS I.T. and Entertainment 2005 focuses on integrating wireless technologies into the enterprise and vertical business markets such as healthcare, government and transportation. Additionally, the show reflects the explosive growth in wireless entertainment, encompassing everything from music downloads to digital cameras to interactive games. The capabilities of today's wireless devices continue to expand and improve across business sectors and personal entertainment. For more information, visit www.wirelessit.com.

European Microwave Week 2005
October 3–7, 2005
Paris, France

European Microwave Week 2005 (EuMW) features four major conferences, a three-day commercial exhibition that attracts international players, alongside technical workshops and short courses. **GAAS 2005** – The 13th Gallium Arsenide and other Compound Semiconductors Application Symposium (October 3–4); **ECWT 2005** – The European Conference on Wireless Technology (October 3–4); **EuMC 2005** – The 35th European Microwave Conference (October 4–6); **EuRAD 2005** – The 2nd European Radar Conference (October 6–7); and the **European Microwave Exhibition** (October 4–6). The exhibition is an international showcase for leading manufacturers in the RF, microwave, gallium arsenide, wireless and radar industries. For more information on the event, visit www.eumw2005.com.

International Topical Meeting on Microwave Photonics (MWP)
October 12–14, 2005
Seoul, Korea

MWP 2005 is an international conference on microwave photonic devices, systems and ap-

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S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
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S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	-0.5, +0.8
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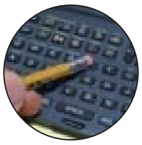

plications. The meeting provides a forum for the presentation of new advances in this multidisciplinary research area, ranging from novel devices to system field trials. It is held annually and rotates between North America, the Asia-Pacific region and Europe. For more information, visit www.mwp2005.org.

Compound Semiconductor IC Symposium
October 30–November 2, 2005
Palm Springs, CA

The Compound Semiconductor IC Symposium (formerly IEEE GaAs IC Symposium) is dedicated to providing an ideal forum for the presentation of gigahertz frequency state-of-the-art electronic circuits, devices and technologies. These areas include commercial wireless, power amplifiers, receivers, high speed digital communications, interface electronics, mm-wave defense and automotive systems. The symposium will again offer the primer course "Basics of GaAs, InP and SiGe RFICs," which is an introductory-level class intended for those wishing to obtain a broad overview of RFIC technology. For more information, visit www.csics.org.

AMTA 2005 Meeting and Symposium
October 30–November 4, 2005
Newport, RI

The Antenna Measurement Techniques Association (AMTA) is the international organization dedicated to the development, application and dissemination of advanced antenna, radar signature and related measurement technologies. The annual meeting and symposium consists of a short course, four days of technical sessions, social programs and an exhibit hall. For more information, contact Julie LaComb, chairman, e-mail: julie@amta2005.com or go to www.amta2005.com.

IEEE Radio and Wireless Symposium
January 17–19, 2006
San Diego, CA

The IEEE Radio and Wireless Symposium (RWS 2006) continues the evolution of the successful Radio and Wireless Conference (RAWCON), most recently held in Atlanta, GA, September 2004. This conference maintains a focus on interdisciplinary aspects of wireless and RF systems and technology with an emphasis on how the elements fit together to shape the latest developments in communications technology and enable the convergence of applications. In addition to oral presentations and posters, RWS includes workshops, panels and a major exhibition. The inaugural RWS 2006 is held as part of a week-long major technical event – *MTT Wireless*. Also participating in *MTT Wireless* are the *Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems* (SiRF) and the *IEEE Topical Workshop on Power Amplifiers for Wireless Communications* (PA Workshop). Companies interested in the exhibition or in sponsorships should contact Kristen Dednah at (781) 769-9750 or e-mail: kdednah@mwjournal.com. For additional information, visit www.radiowireless.org.

IEEE MTT-S International Microwave Symposium and Exhibition
June 11–16, 2006
San Francisco, CA

The IMS Symposium will serve as the centerpiece of Microwave Week 2006. Topics will include: research, development and application of RF and microwave theory and techniques. In addition to IMS2006, a microwave exhibition, a historical exhibit, the RFIC symposium and the ARFTG conference will be held during Microwave Week 2006. The technical sessions will run Tuesday through Thursday of Microwave Week. Workshops will be held Sunday, Monday and Friday, and the ARFTG Microwave Measurements Conference will be held on Friday. For exhibition information, contact Kristen Dednah, Horizon House Publications, 685 Canton St., Norwood, MA 02062 (781) 769-9750 or email: kdednah@mwjournal.com.

Workshops & Courses

Concurrent RF System/Circuit Design

■ **Topics:** This technology seminar on concurrent RF system/circuit design will demonstrate a methodology that enables a participant to significantly accelerate system and circuit analysis. Topics ranging from WLAN receiver sensitivity analysis to power amplifier design reuse will be discussed. Highlights of the seminar will include model creation, RF link cascade analysis and digital predistortion. For more information, visit www.appwave.com/download/seminar.aspx.
■ **Site:** Portland, OR
■ **Date:** July 28, 2005
■ **Contact:** Applied Wave Research Inc., 1960 E. Grand Avenue, Suite 430, El Segundo, CA 90245 (310) 726-3000.

FPGAs for DSP and Communications

■ **Topics:** In this intensive course, the use of FPGAs is looked at specifically for DSP algorithms, applications and architectures. Particular emphasis is on communications given the widespread use of FPGAs in this market and the sheer variety of problems to be solved. For more information, visit www.uclaextension.edu.
■ **Site:** Los Angeles, CA
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■ **Topics:** This course will give participants the fundamental knowledge necessary to make the most efficient design-rule set for a high speed design, organize the design process to most efficiently execute the design, select the appropriate materials for the PCB itself, and select the tool set that will make the design process most efficient. For more information, visit www.unex.berkeley.edu.
■ **Site:** Redwood City, CA
■ **Dates:** August 22–24, 2005
■ **Contact:** UC Berkeley Extension, 1995 University Avenue, Berkeley, CA 94720 (510) 642-4151 or e-mail: course@unex.berkeley.edu.

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■ **Topics:** This four-day Summer School, hosted by Sabanci University, Istanbul, offers intermediate sessions dealing with the fundamentals, theory and practical aspects of wireless systems, RF and microwave technology and power amplifiers. Tutorials on RF integrated circuit design techniques with application examples and software tools are also included.
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■ **Dates:** Aug. 30–Sept. 2, 2005
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■ **Dates:** September 27–30, 2005
■ **Contact:** Georgia Institute of Technology, Professional Education, PO Box 93686, Atlanta, GA 30377 (404) 385-3500.

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■ **Site:** Archived on-line course.
■ **Dates:** Archived on-line for anytime viewing.
■ **Contact:** FEEDS Office at the University of South Florida (813) 974-3783.

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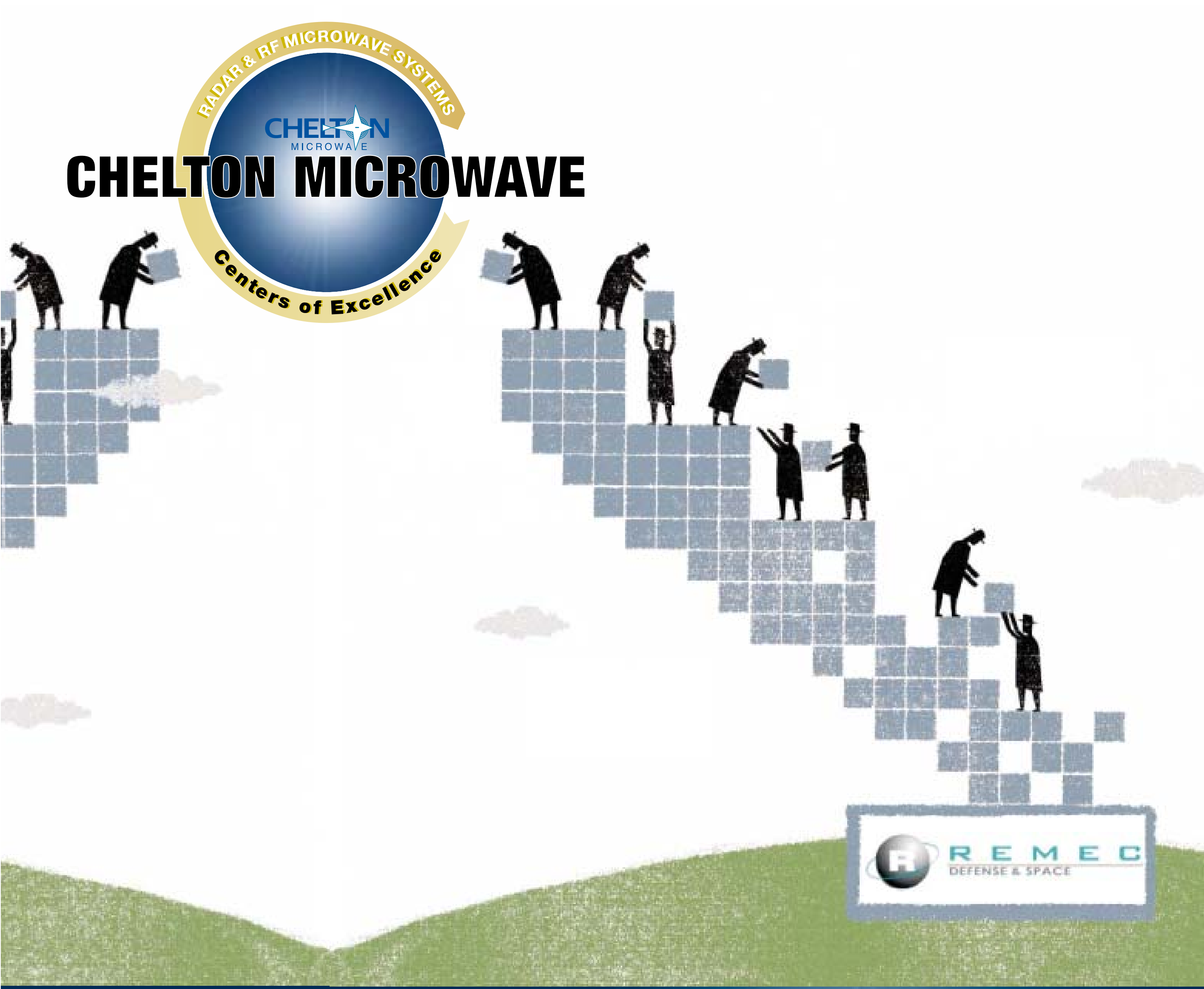
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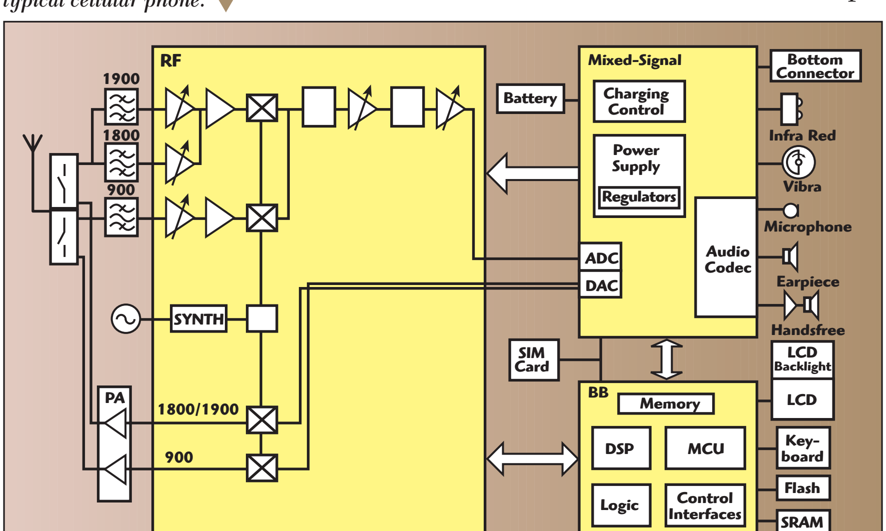
MULTIRADIO YIELDS CHALLENGES FOR MOBILE PHONES

Wireless technologies have developed in a way that can best be described as 'unbelievable.' Global mobile subscriptions rose to 1.7 billion in 2004 and the number continues to grow at a healthy pace. Furthermore, the production volumes of cellular phones are remarkable when compared to other consumer products — by 2002 the number of cellular phones sold worldwide was more than double that of the combined number of vehicles and PCs.

Fig. 1 Block diagram of a typical cellular phone.



The interest in the evolution of cellular phones nowadays is focused mainly on the applications. The cellular phone, the main device that people always carry with them, is considered the key platform for mobile convergence applications, including web browsing, imaging, high bit-rate video streaming and video calls. With convergence, cellular phones will evolve from the traditional cost-optimized handhelds to multifunctional interoperable terminals in a variety of form-factors. The applications, together with the cellular phone form-factor, design and user interface, provide the main means of differentiation among manufacturers.

The transceiver side, on the other hand, has long been driven by the increased need for integration, cost-reduction and, to some extent, power reduction. Currently, transceiver development has reached a certain maturity, as shown by the block diagram of today's typical, basic category triple-band GSM phone in ***Figure 1***. The engine consists of three main chips: one for RF, one for baseband, and one for mixed-signal and

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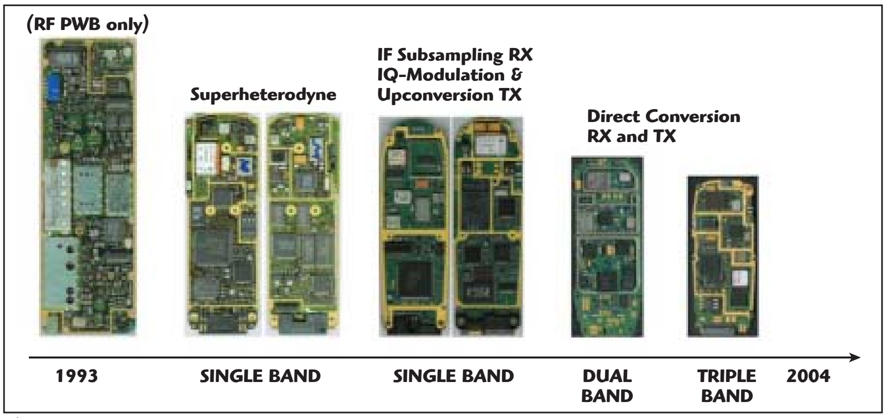


▲ *Fig. 2 Engine development for cellular phones.*

energy management. The chips are either proprietary designs or based on available chip sets. The product includes a total of 345 parts. While integration, cost and power reduction are still key challenges for cellular phone development, it is the number of additional radios that explode the complexity of the transceiver.

The objective of this article is to discuss the key challenges of transceiver implementation for future mobile terminals. The architecture development and opportunities for further integration are described and the key challenges of the multiradio concept driven by various radio standards are presented. Finally, strategies for managing the growing complexity are discussed.

PAST ARCHITECTURE DEVELOPMENT

New implementation architectures enable the adoption of new technologies. The new technologies, in turn, bring improvements in product requirements, such as performance, miniaturization, power consumption, reliability and cost. In wireless access implementation, several successful development steps over the last 15 years of cellular phone development have laid the foundation for future technology advances. These steps have provided clear improvements in miniaturization and functionality, as shown in the wiring board-level engine development illustrated in ***Figure 2***. In the first phase, the RF and baseband circuitry were implemented on separate printed wiring boards (PWB). Careful design of the wiring board and shieldings enabled the embedding of the whole engine on the same wiring board, resulting in a significant size and cost reduction of the cellular phones. The market saw the first real handportable devices.

The next major step was the integration that took place within both the baseband and RF. Digital signal processing (DSP) and microprocessor unit (MPU) functionalities were integrated together with logic circuitry on a baseband application-specific integrated circuit (ASIC). In the RF side, the discrete superheterodyne RF was mapped onto silicon RFICs. Again, significant size and cost benefits were achieved.

In the RF front-end, however, it was the next architecture, the direct conversion, which really benefited from the silicon implementation. Although the direct conversion receiver architecture is old, it was not feasible for mass-production for a long time because of DC offset and signal self-mixing problems. The architecture became practical only in the mid-1990s when RFIC technology had matured to include sufficiently fast and homogeneous transistors, and the quality of the design models and tools had improved significantly.

Direct conversion architecture provided huge benefits in component count reduction; several filters and synthesizers were removed and the total silicon area was reduced. Furthermore, when multi-band and 2G/3G multi-mode transceivers became a requirement, the direct conversion architecture proved to be a flexible platform for the multi-mode operation enabling easy reuse of several functional blocks.

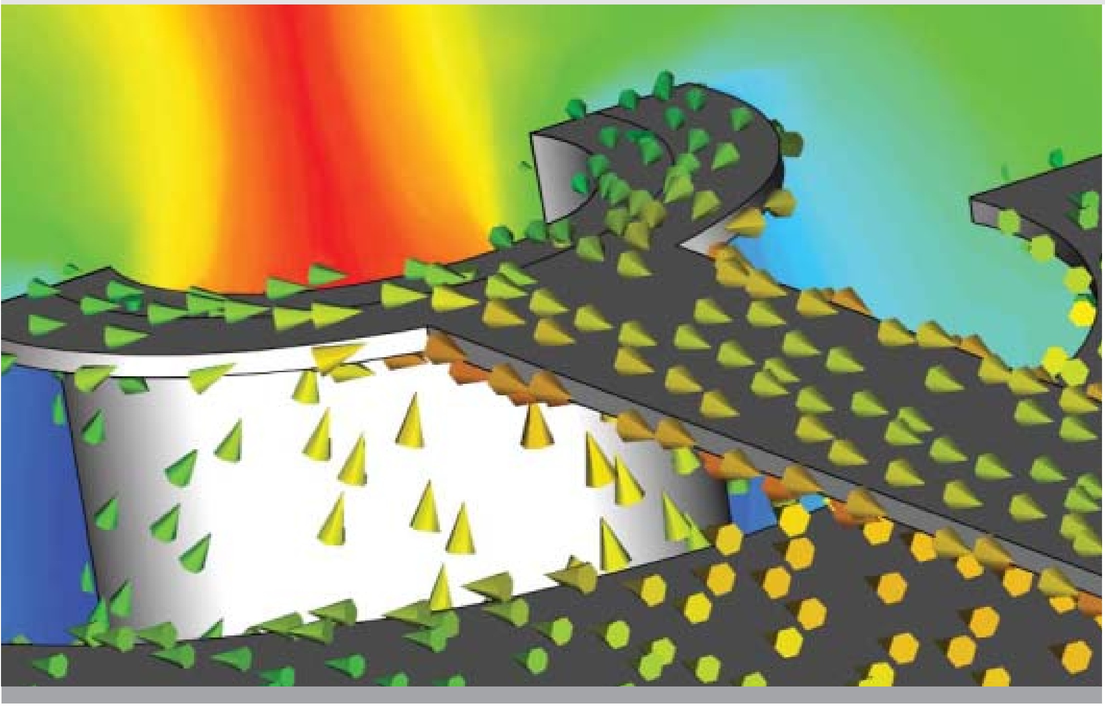
IMPACT OF CMOS EVOLUTION

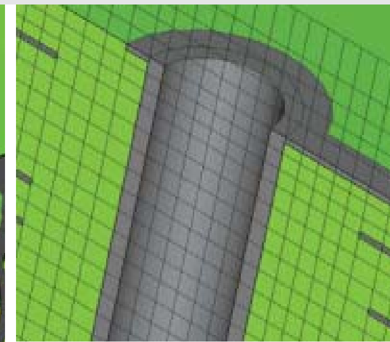
Looking to the future of RF, digital CMOS technology has been the hottest research topic in recent years. The 130 nm bulk CMOS technology has also proven to be applicable for the RF, but it still suffers from several disadvantages. In particular, substrate-coupling effects are stronger and the maturity of transistor models is not at a comparable level as in the widely used RF BiCMOS. With 90 nm and 65 nm technology nodes, physical effects, such as leakage currents and process variations, start to have a significant impact on performance.[1] Furthermore, the cost calculation of RF CMOS reveals that a one-to-one replacement of the RF circuit with a CMOS version provides only marginal, if any, cost benefit. The calculation changes immediately when large digital content, such as digital filtering and control logic, is integrated on the same chip.

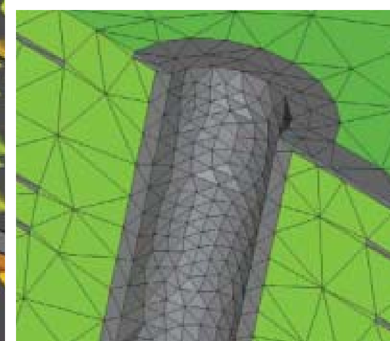
To fully exploit the speed of the latest digital CMOS technology in RF, new circuits and architectures need to be invented. In contrast to just mapping the traditional RF circuits to CMOS, the new architectures could be based on fast sampling and time-discrete signal processing. The interface between the RF and baseband then becomes blurred and the portability of the RF front-end to the future CMOS process nodes improves dramatically. Recently, examples of new, more digital architectures have been reported.[2,3] These new architectures pave the way to true single-chip radios, especially for products for high volume entry markets.

In the baseband, the processing power requirement and the complexity continue to grow with high data rates. Today, the baseband ASICs that include the processor core or cores are not only limited in performance by the computational power, but also by the on-chip communication, line delays and clock distribution. In order to reduce the load from the processing cores, decentralized architectures are being considered. Small controller processors or units running at low frequencies can then be distributed within the engine. With multiple processors, management of the processing power resources becomes one of the key challenges.

An alternative approach to optimize the baseband is to utilize config-







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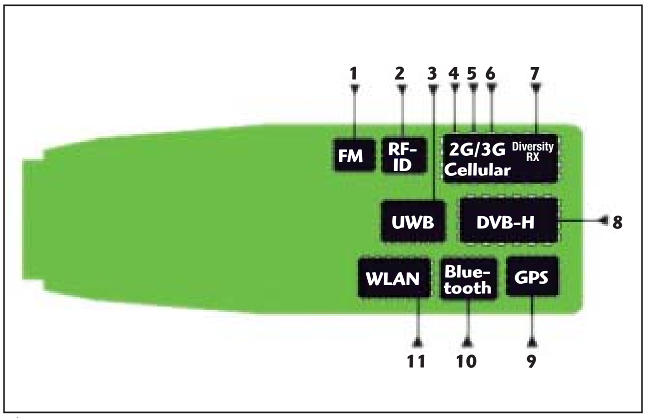

Fig. 3 Multiradio components.

urable logic, configurable processors or processor generators. They provide more freedom in optimizing the trade-off between performance and flexibility. Still, due to the exploding baseband complexity of cellular platforms, the main challenges have to do with design methodology, verification and testability.

MULTIRADIO

The evolution of wireless standards is not showing any signs of convergence towards a small number of global systems. Instead, the current wireless systems continue to evolve and new systems are being proposed and put into use for consumer applications. The cellular wireless systems will adopt higher data rates — high speed downlink packet access (HSDPA), the evolution of the WCDMA system, will offer, in the first phases, average data speeds of 1 to 2 Mbit/s, which in subsequent phases will increase to over 10 Mbit/s.

In addition to cellular systems, other wireless systems start to find their way into mobile terminals, including proximity radios (Bluetooth and RFID, for example), wireless local area network radios (IEEE802.11a/b/g), and receivers for positioning (GPS) and broadcasting (DVB-H). Wireless broadband offering fast wireless Internet access with good coverage and mobility is likely to become yet another category of radios. Although some radios are serving a clearly identified application, such as GPS for positioning, many applications will be available through different radio bearers. Thus, the services are required to be radio-agnostic in the multiradio environment. This is best achieved by utilizing the Internet protocol convergence as the unified connection layer.

The high number of radios introduces huge challenges for the terminal implementation, as shown in ***Figure 3***. The transceiver part of the mobile terminal is developing towards versatile multiradios with a large number of parallel functional blocks that can interfere with each other. The interference tolerance from several concurrently operated radios becomes a requirement that exceeds the specifications in the radio standards. The optimized integration level, on the other hand, depends on the variety of product variants based on the same platform. Architecture modularity then becomes a key target for rapid product development. Furthermore, reconfigurability and reuse of circuit blocks can be a means for complexity and silicon area reduction in multiradio implementation.

Multiradios introduce miniaturization challenges to the antennas and front-end filters. More than ten different antennas is unacceptable from a volume utilization perspective. Instead, the antennas need to be designed as compact multi-system antenna modules and filter miniaturization is crucial. Bulk-acoustic-wave technology (BAW) is one key enabler for filter miniaturization whereas micro-electro-mechanical systems (MEMS) technology still requires proof for RF applications.

STRATEGIES FOR COMPLEXITY MANAGEMENT

The evolution of communication and application functions has substantially increased the system level complexity — the number of functional blocks increases, resulting in a growing number of interfaces, power consumption increases, and the amount of data increases, resulting in growth in traffic and memory space. Methods and technologies to tackle the increasing complexity of the system include standardized solutions and interfaces, adaptive and flexible platforms, and more accurate modeling.

The key interfaces of cellular engines, as shown in Figure 1, for example, have traditionally been based on dedicated solutions. As the variety of components that can be used to build the products in the future, especially in the more high end categories, will significantly grow, it will not be possible to go on with only dedicated implementations. Interfaces need to be standardized to easily attach new components to the system. The Mobile Industry Processor Interface (MIPI) alliance is an example initiative for standardized interfaces for mobile application processors.[4]

To achieve the best performance in handheld devices, any overhead in the system must be eliminated; therefore, adaptive solutions are required, such as dynamic voltage and frequency scaling, and the usage of reconfigurable circuits in baseband platforms. All possible means for preventing unnecessary switching in digital circuits and overheads in latencies need to be applied. Flexibility will be the key enabler to implement a wide selection of product categories in the future. As a part of this strategy, enormous ASICs may not be the most probable choice, because they can be too expensive and more difficult to test. In addition to flexibility, power consumption, total cost and time-to-market continue to be important drivers.

TYING EVERYTHING TOGETHER WITH DESIGN TOOLS

As complex systems comprise an enormous amount of parameters and dependences to be optimized, advanced electronic design automation (EDA) tools are needed to support product development. Tools are enablers for faster time-to-market and boosters of evolution. Achievements in embedding, miniaturization, power savings or design verification depend strongly on the tools. The top-down design flows currently available still have weak spots that require extensive effort and orientation from the designers.

Today's multilevel requirements include C-code, very high speed IC description language (VHDL) and transistor-level descriptions, not only traditional mixed-signal based environments. A better framework and standardized data transmission formats are needed for information

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AML016L2802	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
AML48L3001	4.0 – 8.0	30	±1.0	1.2	+10	1.8:1	150
AML412L3002	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
AML1226L3301	12.0 – 26.5	33	±2.0	2.8	+8	2.5:1	200
Broadband Medium Power Amplifiers							
AML0016P2001	0.01 – 6.0	21	±1.25	3.2*	+23*	2.0:1	480
AML26P3001-2W	2.0 – 6.0	28	±2.5	6	+33	1.8:1	1500
AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
AML618P3502-2W	6.0 – 18.0	35	±2.5	4	+33	2.0:1	1850
Narrow Band Low Noise Amplifiers							
AML23L2801	2.8 – 3.1	28	±0.75	0.7	+10	1.8:1	150
AML1414L2401	14.0 – 14.5	24	±0.75	1.5	+10	1.5:1	130
AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

Low Phase Noise Amplifiers — Phase noise (dBc/Hz) at offset

Part Number	Frequency (GHz)	Gain (dB)	Output Power (dBm)	100Hz	1KHz	10KHz	100KHz
AML811PN0908	8.5 – 11.0	9	17	-154	-159	-167	-170
AML811PN1808	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
AML811PN1508	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
AML26PN0904	2.0 – 6.0	9	20	-150	-165	-165	-178
AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

High Dynamic Range Amplifiers

Part Number	Frequency (MHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	DC
AR01003251X	2 – 32	21	32	52	+28V @ 470mA
AFL30040125	50 – 500	23	28	53	+28V @ 700mA
BP60070024X	20 – 2000	32	30	43	+15V @ 1100mA

*Above 500MHz.

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Broadband Microwave Power Amplifiers						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0218-30	2 - 18	30	1	29	30	3
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-44	8 - 12	44	22	42	45	22
L1218-43	12 - 18	43	20	41.5	45	22
Millimeter-Wave Power Amplifiers						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2632-37	26 - 32	37	5	36	38	10
L2640-27	26 - 40	27	0.5	26	30	2
L2630-37	26.5 - 30.5	37	5	36	38	10
L2732-35	27 - 32	35	2.8	33	35	6
L3040-30	30 - 40	30	1	29	35	4
L3236-36	32 - 36	36	4	35	40	12
L3640-36	36 - 40	36	4	35	40	10

High-Power Rack Mount Amplifiers

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Pac (kW)	Height (in)
C071077-52	7.1 - 7.7	52.5	170	51.5	1.8	10.25
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-40	26.5 - 30.5	40	10	39	0.25	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25

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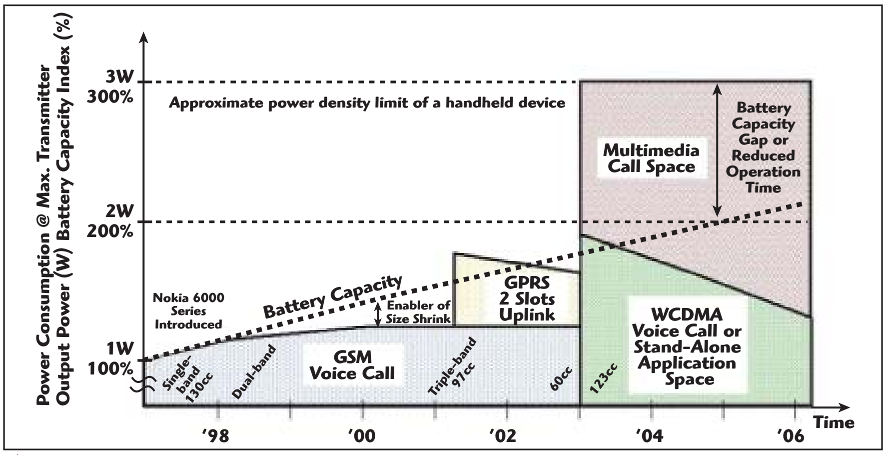


▲ *Fig. 4 Battery capacity and power consumption indexes with the maximum output power level in cellular transmitters.*

transfer from one tool to another and to fully enable utilization of intellectual property blocks in integrated circuit design.

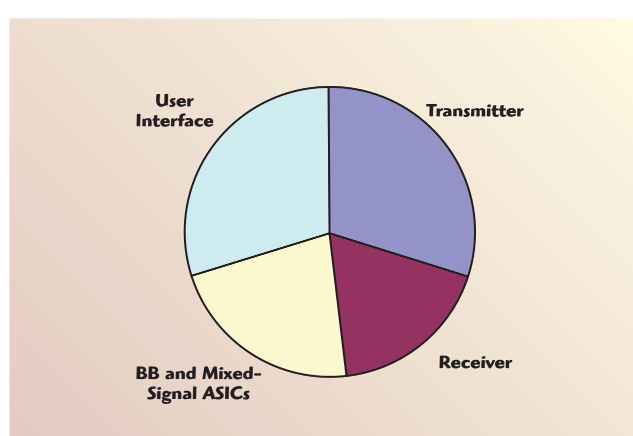
Closer collaboration between technology and EDA tool houses is needed to provide seamless, reliable and tested design environments. Tool integration challenges are visible in particular in substrate noise modeling tools, 3D package modeling combined with RFIC simulations, HW/SW partitioning optimization, and more powerful and flexible antenna simulation algorithms, and in adding RF imperfections into system simulations.

TIGHT POWER BUDGET

Since the middle of the 1990s, many 2G phones have provided users with good operation times. As an example, the first member of the Nokia 6000 cellular phone series introduced in 1997 provided 3.3 hours of talk-time and 180 hours of standby time. Using that as a reference and focusing on talk or application times, the general trends in power consumption and lithium-ion battery capacity can be represented, as shown in ***Figure 4***. Constant annual growth of approximately 10 percent in battery capacity has enabled continuous battery volume shrinkage, while having the absolute milliamperehour level constant over the years. It has also enabled new features like multislot transmission in a GSM uplink without significant compromises in operation time. Figure 4 describes the highest output power levels in the transmitter, which in real life happens only very infrequently. Most of the time, the total power consumption is significantly lower. The good news is that technology evolution has also enabled good talk-time for the first WCDMA phones, even at the maximum transmitter power level. However, careful design is needed for the highest power consumption peaks, when 3G or WLAN communication is run simultaneously with multimedia applications. Therefore, it is important that the power consumption of the wireless access engines be reduced in the future to release power for the applications.

The power partitioning in a 3G phone is represented in ***Figure 5***. Power consumption can be divided into four significant portions: transmitter, including the power amplifier, receiver, digital and mixed-signal ASICs, and user interface HW, including the display, speaker, etc. Compared to the power partitioning in a 3G terminal, the power amplifier more noticeably dominates the power consumption in 2G terminals. Typical power-added efficiencies of the GSM power amplifiers are in the range of 40 to 55 percent.

In WCDMA, a non-constant envelope modulation is used; therefore, the power amplifier has to operate in lin-



▲ *Fig. 5 Power consumption breakdown in video streaming in a 3G phone.*

ear mode, resulting in lower power-added efficiencies — typically in the range of 30 to 40 percent. Since the transmitters are rarely used at the maximum power level in cellular systems, not only should the maximum efficiencies be compared, but the overall power consumption over the probability-density function of the transmitted power of the terminal should be evaluated.

CONCLUSION

Mobile phones are complex embedded systems where all functional blocks are custom-made for mobility. The combination of miniaturization and functionality is unprecedented compared to other consumer products. In terms of production volumes, the mobile phone is in a class of its own. Development has been based on advances, either evolutionary or disruptive, in implementation architectures and technologies. In particular, mobile phones have benefited from the early exploitation of leading-edge semiconductor technologies. With the rapid growth of the number of radios that are taken into use in mobile terminals, the architectures and technologies of wireless access continue to be optimized towards versatile multiradios.

The multiradios bring huge challenges to transceiver architecture, interference tolerance and miniaturization. The evolution of system complexity is taking a large step forward; consequently, system complexity management becomes the main challenge. To meet the time-to-market requirements while applying new technologies and techniques, advanced system level design tools are needed. In particular, power consumption, top-down design flow, flexibility, HW reconfigurability, programmability, standard interfaces and embedding are the key features that should be mastered in advanced system level design tools. ■

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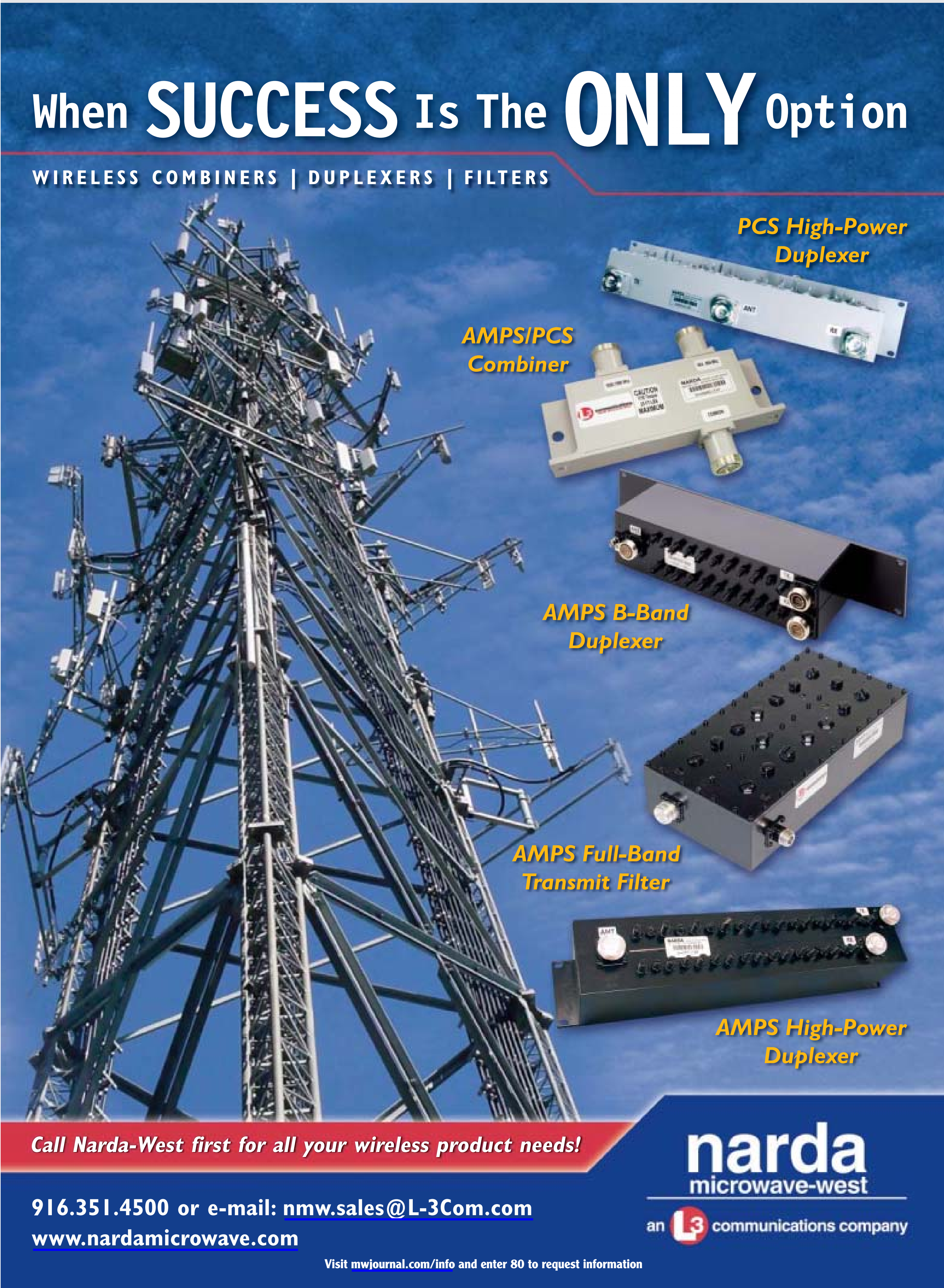
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LOW NOISE OCTAVE BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
CA01-2110	0.5 - 1.0	28	1.0 MAX, 0.7 TYP	+10	+20	2.0:1
CA12-2110	1.0 - 2.0	30	1.0 MAX, 0.7 TYP	+10	+20	2.0:1
CA24-2110	2.0 - 4.0	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA48-2110	4.0 - 8.0	32	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA812-3110	8.0 - 12.0	27	1.8 MAX, 1.6 TYP	+10	+20	2.0:1
CA1218-4110	12.0 - 18.0	25	2.0 MAX, 1.8 TYP	+10	+20	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
CA0102-3110	0.1 - 2.0	28	2.0 Max, 1.5 Typ	+10	+20	2.0:1
CA0106-3110	0.1 - 6.0	28	2.0 Max, 1.5 Typ	+10	+20	2.0:1
CA0108-3110	0.1 - 8.0	26	2.2 Max, 1.8 Typ	+10	+20	2.0:1
CA0108-4112	0.1 - 8.0	32	3.0 MAX, 1.8 Typ	+22	+32	2.0:1
CA26-3110	2.0 - 6.0	26	2.0 MAX, 1.5 TYP	+10	+20	2.0:1
CA26-3113	2.0 - 6.0	28	4.0 MAX, 3.0 TYP	+27	+37	2.0:1
CA26-4114	2.0 - 6.0	22	5.0 MAX, 3.5 TYP	+30	+40	2.0:1
CA618-4112	6.0 - 18.0	25	5.0 MAX, 3.5 TYP	+23	+33	2.0:1
CA618-5113	6.0 - 18.0	24	5.0 MAX, 3.5 TYP	+27	+37	2.0:1
CA618-6114	6.0 - 18.0	35	5.0 MAX, 3.5 TYP	+30	+40	2.0:1
CA618-6115	6.0 - 18.0	35	6.0 MAX, 3.5 TYP	+32	+41	2.0:1
CA218-4110	2.0 - 18.0	30	5.0 MAX, 3.5 TYP	+20	+30	2.0:1
CA218-4112	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+24	+34	2.0:1
CA218-4113	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+27	+37	2.0:1

NARROW BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
LOW NOISE:						
CA01-2110	0.4 - 0.5	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA01-2112	0.8 - 1.0	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA12-3116	1.2 - 1.6	25	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.2 - 2.4	30	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10	+20	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.5 TYP	+10	+20	2.0:1
CA1819-4110	17.7 - 18.3	20	2.0 MAX, 1.8 TYP	+10	+20	2.0:1
MEDIUM POWER:						
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA23-4110	2.7 - 2.9	32	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35	+43	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33	+41	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33	+42	2.0:1
CA1218-5116	12.0 - 18.0	35	6.0 MAX, 5.0 TYP	+30	+40	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21	+31	2.0:1
CA1718-4110	17.7 - 18.1	25	5.0 MAX, 4.5 TYP	+27	+37	2.0:1

COMPETITIVE PRICING OFFERED

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	Unit Price Qty 1-9 $US
CA12-A02	1.0-2.0	26	1.6	+10	$395
CA24-A02	2.0-4.0	26	1.8	+10	$395
CA48-A02	4.0-8.0	24	2.0	+10	$395
CA812-A02	8.0-12.0	22	2.5	+10	$395
CA1218-A02	12.0-18.0	16	3.5	+10	$395

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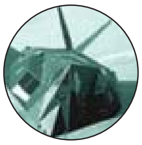

Harris Awarded $35 M Contract Modification to Modernize FAA Communications

Harris Corp. announced that it has been awarded a $35 M contract modification by the Federal Aviation Administration to upgrade the voice communications displays used by the nation's air traffic controllers as part of the existing Voice Switching and Control System (VSCS) contract that the company was awarded in 1991. "We are very proud of our longstanding association with the FAA under the VSCS contract," said Al Dukes, president of the Civil Programs business unit of Harris Corp.'s Government Communications Systems Division (GCSD). "This upgrade reflects our ongoing commitment to ensuring that this critical element of the National Airspace System infrastructure continues to provide the FAA with the most advanced and cost-effective solution available." Under the terms of the VSCS Display Module Replacement (VDMR) contract modification, Harris will replace more than 8000 cathode tube-based displays with modern, flat-panel technology. The upgraded displays will provide enhanced functionality for air traffic controllers and significantly lower equipment life cycle costs for the agency. The Harris-developed VSCS, based on independent, distributed processors and switches, allows air traffic controllers to establish air-to-ground and ground-to-ground communications with pilots as well as other traffic controllers. The system offers unprecedented voice quality, dynamic reconfiguration capabilities to meet changing needs and an operational availability of greater than 0.9999999, which equates to less than three seconds of downtime per year.

XTAR Awarded a Multi-year Contract to Provide Diplomatic Communications

XTAR LLC announced that it has been awarded a contract with the US Department of State's Diplomatic Telecommunications Service Program Office (DTS-PO), Fairfax, VA, to provide X-band communications services to embassies and consulates in Africa and Asia. The five-year contract has an estimated maximum value of up to $137 M. XTAR is a joint venture between Loral Space & Communications and HISDESAT in Spain. Bernard L. Schwartz, chairman and CEO, Loral Space & Communications, commented, "XTAR's agreement with the State Department will provide for the first use of XTAR by the US Government, an important milestone in validating Loral's innovative investment in XTAR's commercial X-band service model. Through our unique collaboration with HISDESAT, we are proud to be able to provide the US Government with this new, previously unavailable commercial X-band service in such a critical part of the world. "XTAR is designed to offset a portion of the ever growing shortfalls in bandwidth for military and government agency communications by providing a cost-effective commercial augmentation to the government's X-band satellites," said Denis Curtin, chief operating officer, XTAR LLC. "XTAR will allow DTS-PO to use its currently installed X-band terminals, maintain assured communication access and increase the system performance through the powerful XTAR-EUR satellite." The Diplomatic Telecommunications Service provides communications services for US Government activities at diplomatic and consular missions worldwide. The DTS network provides responsive, reliable, secure and cost-effective telecommunications services to users at more than 260 sites around the world, representing nearly 50 US Government entities. Built by Space Systems/Loral (SS/L), XTAR-EUR was launched in February 2005 aboard an Ariane 5 ECA rocket. Located at 29 degrees east longitude, the satellite carries twelve 72 MHz high power X-band transponders that provide coverage from Eastern Brazil and the Atlantic Ocean, across Europe, Africa and the Middle East to as far east as Singapore. XTAR-EUR is expected to provide services for nearly 20 years. The XTAR-EUR satellite features traditional global beams as well as on-board switching and multiple steerable beams, allowing users access to X-band capacity as they travel anywhere within the footprint of the satellite. XTAR-EUR is designed to work with existing X-band terminals, as well as the next generation X-band terminals that feature antennas smaller than 2.4 meters.

Lockheed Martin Selected for Continued Development of ISAT

The Air Force announced that Lockheed Martin has been selected to continue development of the Innovative Space Based Radar Antenna Technology, known as ISAT. The contract, valued at $19.5 M, is for the next phase of the Defense Advanced Research Project Agency's (DARPA) ISAT project, administrated by the Air Force Research Laboratory (AFRL). Lockheed Martin will continue development of the ISAT Flight Demonstration experiment design over the next 14 months, which will take it to the Critical Design Review (CDR) maturity level. Following the CDR, DARPA and the Air Force plan to select a contractor to build and deploy a scale version of the antenna for a one-year proof of technology experiment in low earth orbit. "We are very pleased DARPA and the Air Force have selected our team to continue development of the highly innovative technology that will lead to significant improvements in extremely large antenna capability in space," said Tom Scanlan, vice president of Special Programs at Lockheed Martin Space Systems. "Our novel design work during the previous phase of this program, developed together with our teammates at Harris Corp., has demonstrated the feasibility of deploying an extremely large, electronically scanning antenna in space that will help enable global persistent surveillance." The objective of the ISAT program is to create and demonstrate technology for a very long space-borne electronically scanning antenna. The demonstration experiment will use an antenna extending about 100 meters (325 feet) in length; the full scale version is designed to extend 300 meters. The full scale antenna payload would be folded up to about the size of a sport utility vehicle and placed inside a payload fairing atop the launch vehicle. Once deployed in space, the antenna's length would be similar to the height of the Empire State building. Such a lightweight and lengthy antenna could significantly increase global persistent surveillance coverage.

Northrop Grumman 'Tactical Internet' System Wins Award

A Northrop Grumman-developed system that provides joint coalition forces with a clear, continuous common operating picture of the battlefield in Iraq and Afghanistan has been honored as the "Best Program in Support of Coalition Operations." The Force XXI Battle Command Brigade and Below (FBCB2)-Blue Force Tracking System and its Coalition Force Tracker variant received the award at the Battlespace Information 2005 conference in London in April. FBCB2-Blue Force Tracking and Coalition Force Tracker are systems of ruggedized computer hardware and software that form a wireless "tactical Internet" on the battlefield, linking satellites, sensors, communications devices, vehicles, aircraft and weapons in a seamless, secure digital network. Coalition Force Tracker is interoperable with US systems while complying with US security measures. NATO's Allied Command Transformation conducted "NATO Friendly Force Tracker," a seven-month experimental program in Afghanistan to assess how Coalition Force Tracker can benefit NATO commanders. Although the experiment officially ended in January, Coalition Force Tracker's demonstrated success resulted in its continuing operational use in the region today. Northrop Grumman's Mission Systems sector, based in Reston, VA, is the prime contractor for FBCB2-Blue Force Tracking and Coalition Force Tracker. "The importance of this award is magnified by a study released earlier by the Pentagon Office of Force Transformation that detailed how Blue Force Tracking enhanced operational effectiveness for both American and British forces," said Otto Guenther, vice president and general manager of Northrop Grumman's Tactical Systems Division. Worlwide Business Research, which produced the Battlespace Information 2005 conference, established the awards to honor, recognize and promote initiatives that have made a significant contribution to network-centric warfare and support military transformation. ■

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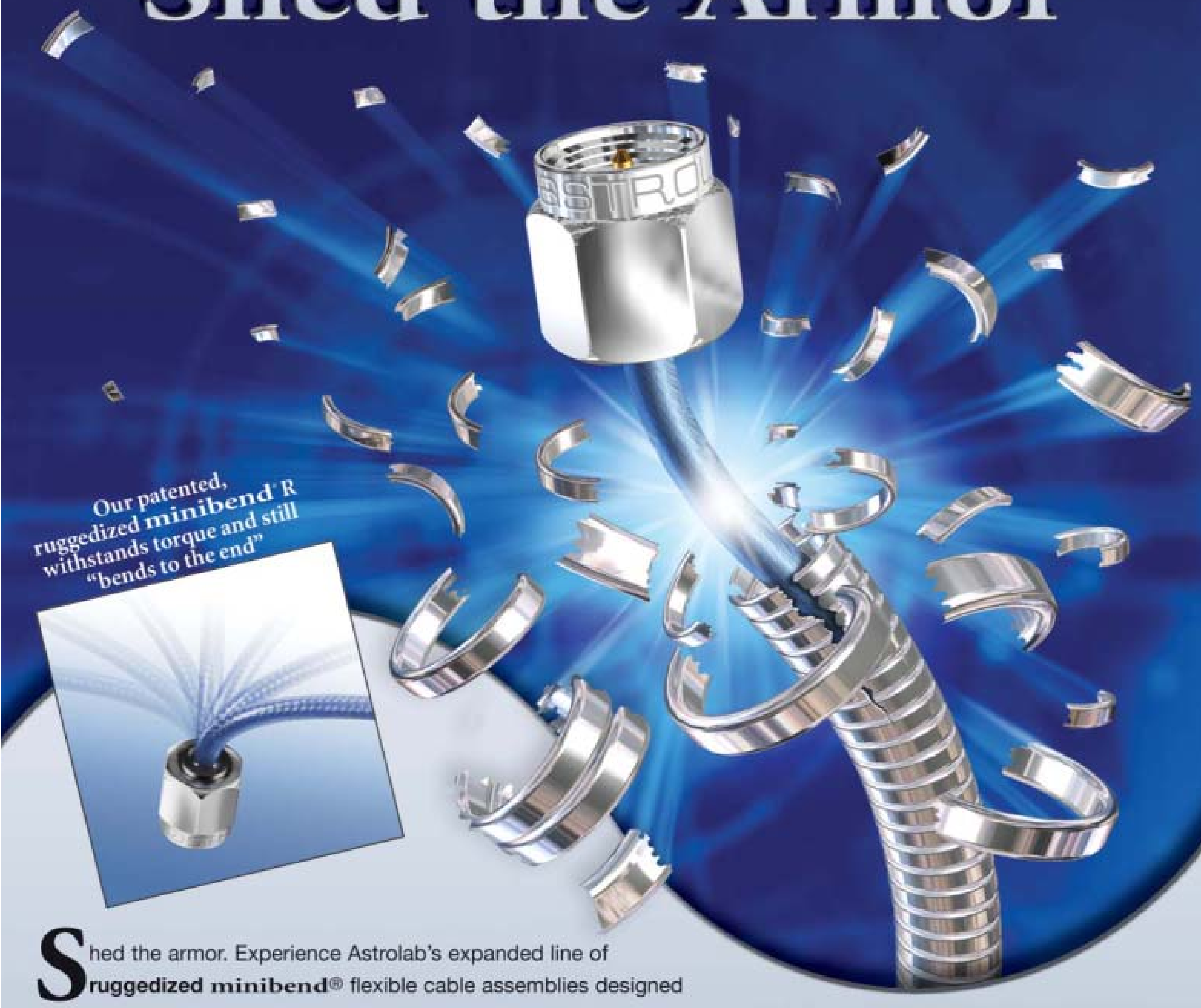

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INTERNATIONAL REPORT

Richard Mumford, European Editor

Forecast is Good as Microwave Sounders Go Into Orbit

A new era in global meteorological forecasting has begun with the launch of the first of five EADS Astrium state-of-the-art microwave humidity sounder (MHS) instruments on board the US polar orbiting satellite NOAA-N. The contract was awarded by EUMETSAT and the microwave sounders will form part of the instrument suite on three European (METOP) spacecraft and two US (NOAA) spacecraft being launched between 2005 and 2015.

The sounders scan the Earth's atmosphere to measure emitted radiation in various spectra bands and from this can determine the water vapour content (clouds, precipitation, humidity) at various altitudes. Each MHS instrument weighs 63 kg and occupies only a 0.8 m^3 on the spacecraft. By adopting a common suite of instruments on both sets of spacecraft, data utilisation is vastly simplified. Data from the instruments will be provided to several meteorological organisations across the world (UK Met Office, Meteo France and USA National Oceanic & Atmospheric Administration NOAA), significantly enhancing their databases and enabling more accurate weather forecasting.

The development is pan-European as EADS Astrium, with its experience and expertise in microwave radiometry undertook the overall instrument design, final assembly and testing in Portsmouth, UK; the receiver and electronics in Vélizy and Toulouse, France; the scan mechanism in Friedrichshafen, Germany; and the Q-band source oscillators in Stevenage, UK.

Harris Corp. Provides Microwave Backbone in Nigeria

A new contract valued at $4.4 M has been awarded to Harris Corp. to supply TRuepoint microwave digital radios to Vmobile Nigeria. The contract represents an expansion of an existing long-term relationship between the two companies, through which Harris provides a 'super-highway' microwave radio backbone covering more than 1,500 km from southwest of Ibadan to southeast of Calabar.

Scheduled for deployment by August 2005, the TRuepoint links will allow Vmobile to significantly increase its market penetration by expanding into new territories, and will offer capacity for 500,000 new subscribers. Currently, the company covers over 60 cities and 2,500 communities across the six geo-political regions of Nigeria.

"This deal underscores our confidence in Harris' equipment and services," said Mr. Frikkie Vermeulen, chief engineering officer of Vmobile. "In addition to the success of our existing relationship, Harris offers exactly what we need to pursue our aggressive expansion plans, namely excellent in-country support, high performance technology with TRuepoint and a rapid delivery schedule."

Cornell Selects e2v Klystrons

e2v technologies has been selected to supply narrowband CW klystrons for use in Cornell University's prototype energy-recovery linear accelerator (ERL), a new and advanced synchrotron radiation machine. The klystrons will aid the university with its research into building future machines for unprecedented materials science and bio-molecular structure analysis.

The move follows the award of $18 M to Cornell earlier this year from the National Science Foundation to start development of the energy-recovery LINAC. e2v klystrons, chosen on the basis of their high signal gain and high output power, will provide the microwave energy used to accelerate the beam in the injector stage of the test ERL.

Information gleaned from the prototype machine will be used in the design of a full-scale machine that will produce intense X-rays for use in applications, such as materials science and bio-molecular structure analysis. This stage of synchrotron radiation research will enable future study of these structures at an unprecedented level of detail. Nanoscale investigations of materials will also be feasible, leading to improved pharmaceutical systems and increased efficiencies in optoelectronics, amongst other technologies.

Cambridge Consultants to Develop Next-generation Terminals

Iridium Satellite LLC has appointed Cambridge Consultants as a strategic wireless technology development consultant, charged with helping the company to evolve the design of its ground-based terminal equipment. The consultancy has assembled a multi-disciplinary engineering team with expertise in satellite communications to work on the multi-million dollar program.

Specifically, Cambridge Consultants is developing next-generation radio frequency (RF) hardware and software to enhance the functionality of the terminals. The focus will be on moving much of the radio functionality into the digital domain to provide greater performance and flexibility. The consultancy is also adding new features to Iridium's advanced packet-based data communications capability. These will extend the performance of the network in application areas such as supply chain management and remote monitoring.

"We are tremendously excited to be working with Iridium to assist in the creation of their next-generation products," said Richard Traherne, manager of Cambridge Consultants' wireless business unit. "Their system is an engineering marvel that our team has found extremely fulfilling to work on. The network has unique attributes that we look forward to leveraging for Iridium in the form of compelling new products."

HAI and INDRA Espacio Form Strategic Alliance

A significant European strategic alliance has been agreed between Hellenic Aerospace Industry S.A. (HAI), the largest defence company in Greece operating in the field of aerospace, electronic and satellite communication systems, and INDRA Espacio SA, the leading defence electronics and information systems company in Spain. This co-operation is the result of the recognition both countries have of each other's defence industry capabilities and is the latest development in HAI's focus on the establishment of strategic alliances with leading companies in the aerospace field.

Under the agreement, the work to be assigned by INDRA Espacio to HAI will be worth €50 M over the next five years, with both companies confirming their intention to co-operate on specific areas of mutual interest including electronic system upgrades and the development and design of tactical and strategic communication network surveillance systems, simulation systems, etc.

Motorola Launches 5.4 GHz System for Brazil

Brazil's wireless broadband market is being addressed with the launch by Motorola of a new version of its Canopy portfolio, authorized for sale by Anatel, the National Telecommunications Agency, in the 5.4 GHz band. In point-to-multipoint networks, Canopy's Advantage 5.4 GHz solution offers aggregate data transmission rates up to 14 Mbps with a range of 1.6 km and 7 Mbps with coverage of up to 3.2 km.

The portfolio also offers products for the country's 5.8 GHz band that have been designed from a feature and price perspective. With the provision of both the 5.4 and 5.8 GHz products, companies will be able to offer high data speeds, and increased performance and quality of service to their customers. ■

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MCA1-12GL	4	3800-12000	6.5	38	11.95
MCA1-24	7	300-2400	6.1	40	5.95
MCA1-42	7	1000-4200	6.1	35	6.95
MCA1-60	7	1600-6000	6.2	30	7.95
MCA1-85	7	2800-8500	5.6	38	8.95
MCA1-12G	7	3800-12000	6.2	38	10.95
MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
MCA1-60LH	10	1700-6000	6.3	30	8.45
MCA1-80LH	10	2800-8000	5.9	35	9.95
MCA1-24MH	13	300-2400	6.1	40	6.95
MCA1-42MH	13	1000-4200	6.2	35	7.95
MCA1-60MH	13	1600-6000	6.4	27	8.95
MCA1-80MH	13	2800-8000	5.7	27	10.95
MCA1-80H	17	2800-8000	6.3	34	11.95

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Bluetooth/UWB Compatibility Plans Introduced

The Bluetooth Special Interest Group (SIG) announced its intent to work with the developers of the wireless technology commonly known as ultra-wideband (UWB) to combine strengths of both technologies. This decision will allow Bluetooth technology to extend its long-term roadmap to meet the high speed demands of synchronizing and transferring large amounts of data as well as enabling high quality video applications for portable devices. According to the joint announcement, UWB will benefit from Bluetooth technology's manifested maturity, qualification program, brand equity and comprehensive application layer. ABI Research senior analyst Dan Benjamin comments: "The potential merger of Bluetooth and UWB is something that has been openly speculated about for some time. UWB could replace the existing air interface used by Bluetooth for the purpose of drastically increasing the total bandwidth available for Bluetooth devices. At the same time, the Bluetooth profiles and network stacks could easily be used to limit the amount of development needed for new devices, since Bluetooth and UWB target the same market for short range cable replacement. The downside is that backwards compatibility will be limited. Bluetooth implementing UWB could serve to limit interest in Wireless USB, which also uses UWB as an air interface and targets a similar market, but is still very much unsettled with regard to software and authentication."

Chase "Blink" Will Be a Catalyst for Contactless RFID Payments

Chase card services announced that it is introducing "Blink," a new faster, easier way to pay, using RFID chips and contactless payment systems. With the Chase Blink announcement, the North American contactless payment market-starting gun has sounded and the race to redefine cashless payments is on. Erik Michielson, ABI Research director of RFID and ubiquitous networks, comments: "Mass issuer contactless deployment such as Chase Blink reinforce what card associations and merchants have seen in trials after trials — secure contactless payments provide consumers with a faster, less-hassle-prone way to pay and benefit issuers, merchants and consumers. Moreover, this announcement demonstrates that merchants, point-of-sale technology vendors, card associations and issuers are working together to connect dependent components of the payment value chain." Trials have successfully reduced lines and addressed consumer pain point in settings where there are tiresome queues and lengthy waits, such as movie theatres, gas stations, fast food restaurants, coffee shops and convenience stores. In ABI Research's recent 2005 RFID Contactless Payment study, the company noted that joint MasterCard and Visa contactless momentum was building at the issuer level. JP Morgan Chase, Citibank and MBNA have been involved in PayPass deployment for months, all the while progressively building contactless credibility with merchants and familiarity with consumers. The ABI Research report forecasts the contactless market by convenience store, coffee shop, gas station, quick serve restaurant, big box retail and other specific applications directly tied to acquiring, issuing, car association, merchant and technology developer interests.

SOHO/Consumer WLAN Vendors Struggle for Profits

While SOHO/home WLAN equipment shipment volumes have increased strongly since Apple first launched its AirPort line of 802.11b-compliant consumer WLAN gear in 2000, prices have eroded sharply over the past several years, and few vendors are making much money in the market segment at present, reports In-stat. The SOHO/consumer AP market will rise from approximately 17.6 million units in 2004 to roughly 32.6 million units in 2009, the high tech market research firm forecasts. A major story in this market is a transition from the 802.11g air standard to MIMO-based products. "In-Stat believes that there will be a gradually shrinking price premium for MIMO/802.11n throughout the forecast period," says Sam Lucero, In-Stat analyst. "The benefits of dramatically increased range appear to be resonating with consumers, actually more so than the increased throughput offered, and we believe customers are willing to pay the extra amount for whole-home coverage." A recent report by In-Stat found the following:

- Eventually, while 802.11g will remain throughout the forecast period in very cost-optimized equipment, MIMO/802.11n will become the primary air standard; having a "universal" air standard is less confusing for consumers and easier to manage for vendors.
- Shipment volumes for MIMO-based equipment were small in 2004, but at least five vendors have now introduced products, with more expected in 2005.
- In contrast to the enterprise WLAN market, 802.11a/g equipment is not expected to gain traction in the SOHO/consumer WLAN market.

The report, "Here Comes MIMO: SOHO/Consumer WLAN Analysis," covers the SOHO/consumer WLAN equipment market. Unit shipment and revenue market shares for 2004 are provided for SOHO/consumer APs, wireless routers, wireless Residential Gateways (RG) and external SOHO/consumer WLAN NICs. Five-year forecasts, from 2005 to 2009, are provided for SOHO/consumer APs, wireless routers, wireless RGs and external/embedded SOHO/consumer WLAN NICs. Brief vendor profiles are included.

MBOA and WiMedia Alliance Merge to Benefit Uptake of UWB

The WiMedia Alliance and the MultiBand OFDM Alliance Special Interest Group, or MBOA-SIG, recently announced the two groups' merger. Although the entity will often be referred to as WiMedia-MBOA, the entity will operate officially as the WiMedia Alliance Inc. The merged group is designed to take advantage of the strengths of both groups to drive the standardization and adoption of ultrawideband (UWB). The WiMedia-MBOA is conducting an intellectual property review of MBOA-SIG's physical (PHY) layer specification, which has already been distributed to MBOA-SIG members who are building products. The organization is also financing the MBOA-SIG's medium access control (MAC) layer specification. Applications such as Wireless USB, Wireless 1394 and Wireless AP will use the WiMedia-MBOA's common radio platform based on the MBOA-SIG's PHY and MAC specifications. Development on application profiles for UPnP/IP, the WiMedia convergence architecture (WiMCA) and the WiMedia network protocol adaptation (WiNet) layer are continuing. Also extremely important is the task of interoperability and certification. The WiMedia-MBOA has begun to define its certification and interoperability program that will address WiMedia-MBOA usage in Wireless USB and Wireless 1394 applications to the total IP UWB technology stack. Promoter companies include: Aleron, HP, Intel, Kodak, Nokia, Philips, Samsung, Sharp, Staccato Communications, Texas Instruments and Wisair. In the near term, other companies are expected to be added to this list as well. A waiver ruling is expected soon based on the MBOA request by the Federal Communications Commission. In-Stat believes that UWB presents attractive opportunities, primarily for fast video transfer between peripheral devices, such as digital camcorders, TVs and PCs, and between set top boxes and TV monitors. With the high bandwidth gap left by Wi-Fi in the home networking space, UWB is seen as the wireless technology that can deliver the bandwidth and QoS that many customer electronics companies have been looking for to enable sending multiple video streams throughout a home. UWB supporters have been working toward a standard and commercial solutions since the FCC allowed its use in February 2002. With UWB's perceived ability to fill the high bandwidth gap left by Wi-Fi in the home networking space, UWB node/chipset shipments will experience an emerging market compound annual growth rate of over 400 percent from 2005 to 2008. ■

Gigs Galore.

1S1G4A 1 Watt .8-4.2 GHz	20S4G11 20 Watt 4-10.6 GHz	200S1G4 200 Watt .8-4.2 GHz	800S1G3 800 Watt .8-3.0 GHz	200T1G2 200 Watt 1-2 GHz	250T8G18 250 Watt 7.5-18 GHz	1000T2G8B 1000 Watt 2.5-7.5 GHz	1500T2G8 1500 Watt 2.5-7.5 GHz	4000TP2G4 4000 Watt 2 - 4 GHz
1S4G11 1 Watt 4-10.6 GHz	25S1G4A 25 Watt .8-4.2 GHz	240S1G3 240 Watt .8-3.0 GHz	10ST1G18 10 Watt .8-18 GHz	200T1G3A 200 Watt .8-2.8 GHz	300T2G8 300 Watt 2.5-7.5 GHz	1000T8G18B 1000 Watt 7.5-18 GHz	1500T8G18 1500 Watt 7.5-18 GHz	4000TP4G8 4000 Watt 4 - 8 GHz
5S1G4 6.5 Watt .8-4.2 GHz	30S1G3 30 Watt .8-3.0 GHz	400S1G4 400 Watt .8-4.2 GHz	20ST1G18 20 Watt .8-18 GHz	200T2G4 200 Watt 2-4 GHz	500T1G2 500 Watt 1-2.5 GHz	1000TP1G2A 1000 Watt 1-2.5 GHz	2000TP1G2A 1700 Watt 1-2.5 GHz	4000TP8G12 4000 Watt 8 - 12 GHz
5S4G11 5 Watt 4-10.6 GHz	50S1G4A 50 Watt .8-4.2 GHz	450S1G3 450 Watt .8-3.0 GHz	15T4G18 15 Watt 4.2-18 GHz	200T2G8A 200 Watt 2.5-7.5 GHz	500T2G8 500 Watt 2.5-7.5 GHz	1000TP2G8B 1000 Watt 2.5-7.5 GHz	2000TP2G8A 2000 Watt 2.5-7.5 GHz	4000TP12G18 4000 Watt 12 - 18 GHz
10S1G4A 13 Watt .8-4.2 GHz	60S1G3 60 Watt .8-3.0 GHz	540S1G4 540 watts 0.8-4.2 GHz	20T4G18 20 Watt 4.2-18 GHz	200T4G8 200 Watt 4-8 GHz	500T8G18 500 Watt 7.5-18 GHz	1000TP8G18B 1000 Watt 7.5-18 GHz	2000TP8G12 2000 Watt 8.2-12.4 GHz	
10S4G11 10 Watt 4-10.6 GHz	100S1G4 100 Watt .8-4.2 GHz	600S1G3 625 watts 0.8-3.0 GHz	40T18G26A 40 Watt 18-26.5 GHz	200T8G18A 200 Watt 7.5-18 GHz	750TP1G3/200T* 750/500 Watt 1.15-3.1 GHz	1000TP1G3* 1400/500 Watt 1.15-3.1 GHz	2000TP8G18 2000 Watt 7.5-18 GHz	
15S1G3 15 Watt .8-3.0 GHz	120S1G3 120 Watt .8-3.0 GHz	700S1G4 700 Watt .8-4.2 GHz	40T26G40A 40 Watt 26.5-40 GHz	250T1G3 250 Watt 1-2.5 GHz	1000T1G2B 1000 Watt 1-2.5 GHz	1500T1G3 1500 Watt 1-2.5 GHz	4000TP1G2 4000 Watt 1 - 2 GHz	

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*1.15-1.45 and 2.7-3.1 GHz for radar simulation.
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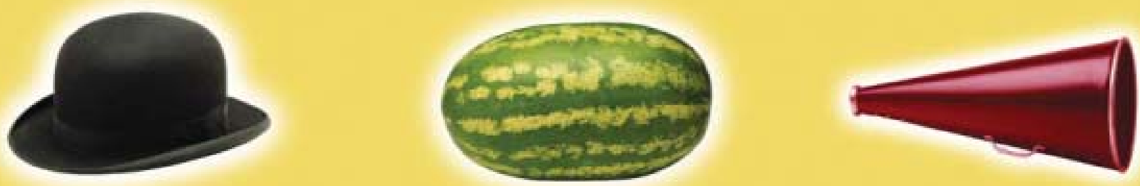
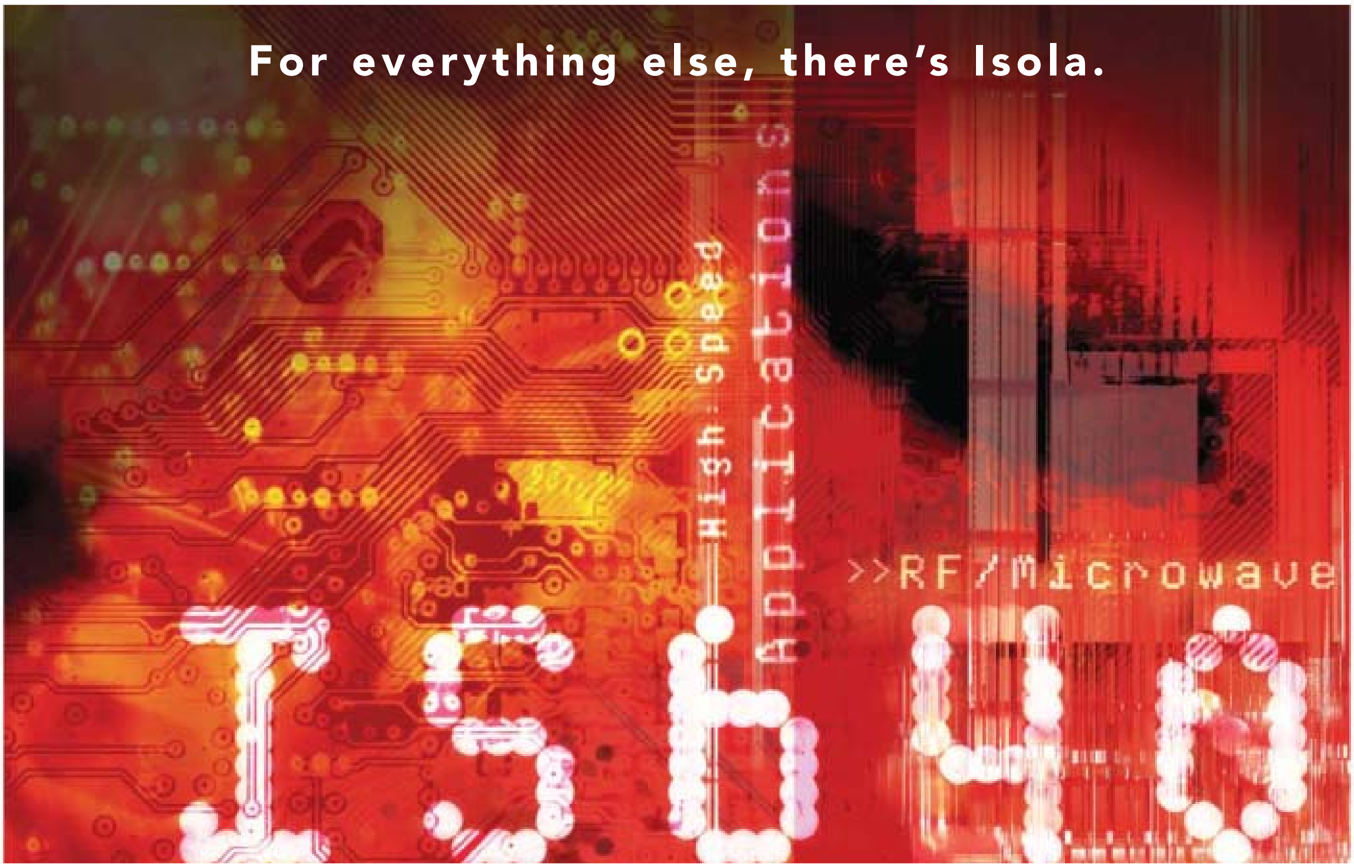


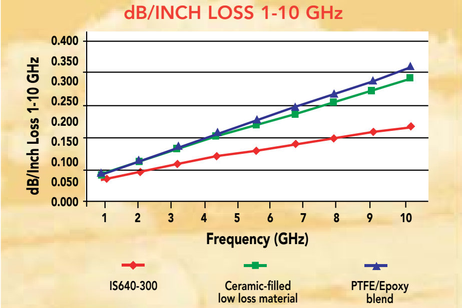
Yes, there are a few things we don't make laminates for.



IS640 PRODUCT STRENGTHS

- Superior signal integrity from 2 to 20 GHz
- Customized Dk – 3.00, 3.20, 3.25, 3.38, 3.45
- Utilizes standard E-glass
- Conventional FR-4 type processes
- Tack-free prepreg
- Standard prepreg glass styles – 106, 1080, 3070, 2113, 2116 and 1652
- Superior drilling performance – no ceramic filler
- Standard thicknesses available from 0.0027" to >0.120"
- Compatible with Isola grades FR406, IS410 and FR408 for hybrid MLB

IS640 VS. COMPETITION dB/INCH LOSS 1-10 GHz



Based on 0.030" material — Microstrip with 0.008" line

Isola IS640 – Laminates For RF/Microwave and High Speed Digital Applications Using Conventional Processing. Introducing Isola's IS640 family of laminates – the first resin matrix laminate in the RF/Microwave and High Speed Digital class to satisfy all design-critical requirements: superior electricals with a flat response over frequency, laminate and prepreg forms in typical thicknesses and sizes, and ease of known conventional processes. Contact Isola today for more details.

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Introducing the IS640 family–
A full selection of resin-based laminates and prepreg for RF/Microwave and High Speed Digital applications.

IS640 laminate and prepreg material is a unique formulation for the RF/Microwave and High Speed Digital markets. IS640 exhibits stable electrical properties over a broad frequency range of 2 to 20 GHz. Produced with stringent thickness and electrical tolerances, IS640 provides designers with consistent line impedance.

IS640 is available in multilayer core thicknesses (0.0027"- 0.010") and thicker core material (0.020", 0.030" and 0.060") for RF and Microwave applications. Standard panel sizes are available, providing a complete materials package solution.

ALL IS640 PRODUCTS AVAILABLE IN:

0.020", 0.030" and 0.060" thicknesses

Dk AND Df VALUES AT 10 GHz

- **IS640-345 =** Dk 3.45, Df 0.0045
- **IS640-338 =** Dk 3.38, Df 0.0042
- **IS640-325 =** Dk 3.25, Df 0.0035
- **IS640-320 =** Dk 3.20, Df 0.0035
- **IS640-300 =** Dk 3.00, Df 0.0034

IS640 High Speed Digital Laminate Electrical Properties

Core Thickness	Dk 2.0 GHz	Dk 5.0 GHz	Dk 10.0 GHz	Df 2.0 GHz	Df 5.0 GHz	Df 10.0 GHz
0.0030	3.10	3.10	3.10	0.0033	0.0034	0.0034
0.0040	3.49	3.49	3.49	0.0038	0.0039	0.0039
0.0050	3.43	3.43	3.43	0.0037	0.0038	0.0038
0.0060	3.46	3.46	3.46	0.0038	0.0038	0.0038
0.0060	3.10	3.10	3.10	0.0033	0.0034	0.0034
0.0080	3.45	3.45	3.45	0.0038	0.0039	0.0039
0.0100	3.43	3.43	3.43	0.0037	0.0038	0.0038

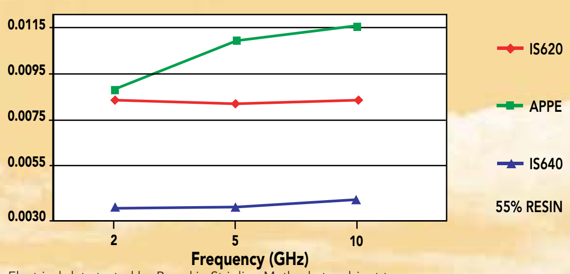
Electrical data tested by Bereskin Stripline Method at ambient temp.

IS640 Prepreg Electrical Properties

Glass Fabric	Resin Content (%)	Pressed Thickness Nominal	Dielectric Constant 2 GHz	5 GHz	10 GHz	Dissipation Factor 2 GHz	5 GHz	10 GHz
106	72 +/-1.5%	0.0022"	3.00	3.00	3.00	0.0031	0.0031	0.0031
1080	65 +/-1.5%	0.0030"	3.07	3.06	3.06	0.0033	0.0034	0.0034
2113	57 +/-1.5%	0.0035"	3.29	3.28	3.28	0.0036	0.0036	0.0036
3070	54 +/-1.5%	0.0040"	3.37	3.36	3.36	0.0037	0.0037	0.0037
2116	54 +/-1.5%	0.0050"	3.37	3.36	3.36	0.0037	0.0037	0.0037
1652	52 +/-1.5%	0.0060"	3.43	3.42	3.42	0.0037	0.0038	0.0038

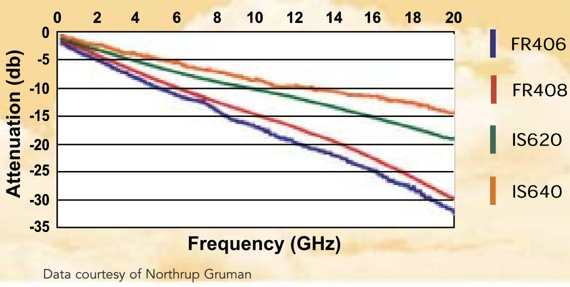
Pressed Thickness: Calculated using a dielectric thickness model developed by Isola for its resin systems. The pressed thickness values should be used as a starting point. Thicknesses will be slightly different depending on inner layer retained copper (signal vs. ground) and the copper foil weight.

IS640 Df COMPARISON



Electrical data tested by Bereskin Stripline Method at ambient temp.

ATTENUATION (16" TRANSMISSION LINE)



Data courtesy of Northrup Gruman

The data, while believed to be accurate and based on analytical methods considered to be reliable, is for information purposes only. Any sales of these materials will be governed by the terms and conditions of the agreement under which they are sold.

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INDUSTRY NEWS

■ **Radiall** has bought New Haven, CT-based **Applied Engineering Products Inc.** (AEP). The newly acquired company ranks among the largest of the independent designers and manufacturers of the subminiature coaxial connectors and cable assemblies, used in high reliability radio and microwave frequency applications. Their products are sold primarily to manufacturers of military and avionics electronics equipment. The acquisition of AEP is seen as a vital step in enabling Radiall to offer a complete interconnection range to its US customers in the defense and avionics industries, and highlights the company's commitment to the industry as a growing US manufacturer.

■ **Mimix Broadband Inc.** announced that it has completed the purchase of substantially all of **Celeritek**'s assets. The purchase price was $2.8 M in cash, plus the assumption of approximately $6 M in liabilities.

■ **Flomerics** announced the acquisition of **MicReD**, a Hungarian-based company formed in 1997 as a spin-off from Budapest University of Technology and Economics. MicReD's main product is the "T3Ster," which provides fast, repeatable and accurate thermal characterization of IC devices, including stacked-die and system-in-package devices.

■ **Teledyne Technologies Inc.** announced that a subsidiary, **Teledyne Investment Inc.**, has entered into an agreement to acquire **Cougar Components Corp.**, Sunnyvale, CA for $26.5 M. The transaction was expected to close on or about June 30, 2005, and was subject to customary closing conditions.

■ **Colibrys SA**, Neuchâtel, Switzerland, announced signing a Preferred Supply Agreement with **BAE Systems**, Plymouth, UK. Within this agreement, Colibrys will be a preferred supplier of high performance accelerometers for use within BAE Systems' Inertial Measurement Units (IMU) commonly supplied for use into various defense and aerospace applications.

■ **Compel Electronics SpA**, a designer and manufacturer of interconnection systems and cable assemblies, has signed a joint venture contract with **Junper Interconnection**, joining under the brand name **Juncom**. The new company, taking advantage of the long-standing technological experience and commercial know-how available in Compel and Junper, will concentrate its efforts in the manufacture of low frequency cable assemblies and of 2 mm metric connectors.

■ A small business joint teaming agreement was signed by three US government and defense contractors: **M2 Global Technology Ltd.**, **Patterson Machine Inc.** and **Engineered Mechanical Systems Inc.** The three companies will be marketed under the name **Trilogy Defense Services**. Trilogy Defense Services offers US Government and defense contractors the ability to easily and conveniently do business with one supplier providing an umbrella of diversity including a disabled veteran-owned, an 8(a), small disadvantage business, Native American-owned and a woman-owned small business company.

■ **Focus Microwaves** announced a new West Coast sales and support office, in order to improve local support of numerous customers in the area. **Steve Reyes** has been appointed as a manager for this local office covering California, Arizona, Texas, Washington and Oregon. Reyes has held sales and support engineering positions in the microwaves test and measurement industry (Anritsu/Wiltron, Gigatronics) for more than 25 years. Reyes can be contacted at (650) 851-1977 or e-mail: steve@focus-microwaves.com.

■ **Andrew Corp.** has increased its manufacturing capabilities and engineering design workforce in Suzhou, China, to better support customers with local production of base station antennas for current and next generation wireless networks.

■ **Avtech** celebrates 30 years of serving the test and measurement and R&D communities. The company provides a unique line of general purpose and high performance pulse generators, laser diode drivers and related equipment.

■ **M/A-COM** announced it has joined the WiMAX Forum™ to assist in the advancement of interoperability standards for the broadband wireless access industry around the IEEE 802.16 standard. Through M/A-COM's participation in the WiMAX Forum, all applicable M/A-COM products will be interoperable with all WiMAX Certified™ equipment.

■ **Agilent Technologies Inc.** announced it is now shipping hundreds of millions of lead-free LEDs annually into applications that range from consumer electronics to industrial applications. Driven by market demand, legislation and adverse environmental impact, Agilent is working toward removing lead from its products. Agilent LEDs meet the European Union requirements, which take effect in 2006.

■ **Sypris Data Systems Inc.**, a provider of high performance data acquisition and storage systems, announced that the US Patent and Trademark Office issued US Patent No. 6,892,167 for the company's real-time data acquisition network technology.

CONTRACTS

■ **EMS SATCOM**, a division of EMS Technologies Inc., disclosed that Turkey has selected EMS SATCOM's comprehensive system for its search-and-rescue (SAR) operations. The contract is valued at approximately $1.2 M.

■ **TECOM Industries Inc.**, a Smiths Interconnect company, announced it has been selected by **L-3 Communi-**

cation Systems West, Salt Lake City, UT, to supply tactical common data link (TCDL) ground terminal antenna systems for operational demonstrations scheduled this year. This Ku-band ground terminal antenna is used for high bandwidth connectivity between a tactical UAV and a command and control station on the ground, and provides an integral, key component for an information-gathering and dissemination mission.

■ **DCM Industries Inc.** announced a contract to supply **BAE Systems** with turnkey solutions for the test and measurement of coaxial cable assemblies used in the F-35 Joint Strike Fighter (JSF) program. The DCM model HPCC-3000 test system provides complete automation of vector network analyzer insertion loss and VSWR testing of high performance coaxial cables. Using the DCM developed graphical user interface combined with the Agilent 20 GHz PNA network analyzer, the HPCC-3000 system enables users with little or no network analyzer experience to easily and accurately test coaxial cable assemblies.

■ **IKE Micro** announced that it has successfully completed an order for high power switches ultimately for use by a branch of the United States Armed Forces. The high power switch units, assembled by IKE Micro at its Nashua facility, are used as a key part of a system that is used to counter the threat of improvised explosive devices.

■ **MI Technologies** announced it has been selected by the University of Salerno, Fisciano, Italy, to supply and commission a state-of-the-art antenna measurement, acquisition and analysis system for an existing anechoic chamber located on the university campus. Under terms of the contract, MI will install a cylindrical near-field test facility that will feature the MI-3000 acquisition and analysis software.

■ **MEMtronics Corp.** announced that it has successfully passed into the second phase of a $3.69 M, three-year development contract from the **Defense Advanced Research Projects Agency** (DARPA) entitled "Robust, Reliable RF MEMS Capacitive Switches." Teamed with MEMtronics on this project are Innovative Micro Technology, Lehigh University and Exponent Inc. The focus of this contract is to improve the environmental robustness and reliability of radio frequency microelectromechanical systems operating under extreme environmental conditions.

FINANCIAL NEWS

■ **Ansoft Corp.** reports sales of $21.7 M for the fourth quarter of fiscal 2005 ended April 30, 2005, compared to $17.8 M for the same period in 2004. Net income for the quarter was $4.7 M ($0.36/per diluted share), compared to a net income of $2.8 M ($0.21/per diluted share) for the fourth quarter of last year.

■ **Sirenza Microdevices Inc.** reports sales of $12.2 M for the first quarter of 2005 ended March 31, 2005, compared to $13.8 M for the same period in 2004. Net loss was $1.8 M ($0.05/per basic share), compared to a net income of $162,000 ($0.00/per basic and diluted share) for the first quarter of last year.

■ **WJ Communications Inc.** reports sales of $7.8 M for the first quarter of 2005 ended April 3, 2005, compared to $7.1 M for the same period in 2004. On a US GAAP basis, the company reported a net loss of $7.7 M ($0.12/per common share) for the quarter, compared to a net income of $3.6 M ($0.05/per common share) for the first quarter of last year.

■ **Paratek Microwave Inc.**, a developer of electronically tunable miniaturized 3D RF devices, announced that it has completed a Series C financing of $15 M. Previous venture capital investors in the company, including Polaris Venture Partners, Morgenthaler Ventures, Novak Biddle Venture Partners, Investor Growth and ABS Ventures, all participated.

■ **Jacket Micro Devices Inc.** (JMD) announced the closing of a new funding round with investors Noro-Moseley Partners, Sevin Rosen Funds, Imlay Investments, the ATDC Seed Fund and Atlanta Technology Angels. The $6 M funding proceeds will be used to expand the technical and sales and marketing team, and ramp volume production to support customer demand. JMD has raised a total of $8.2 M in funding to date.

■ **Applied Wave Research Inc.** (AWR®) announced record sales and revenue with the closure of fiscal year 2005, ending March 31. Key achievements included: major product upgrades and shipments, strategic new customer accounts, expansion of existing accounts, the addition of key EDA partners, and continued expansion of AWR's research and development efforts and sales and support networks.

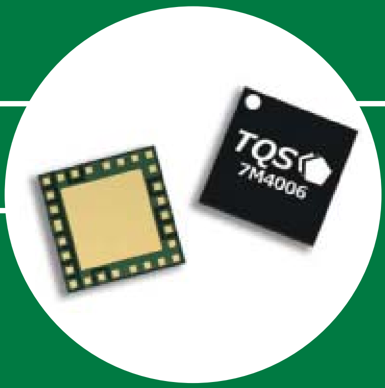
NEW MARKET ENTRY

■ **mWAVE Industries LLC**, founded in 2004, is an antenna design, development and manufacturing company based in Gorham, ME. mWAVE offers independent antenna testing, consulting, build-to-print, improvement studies and volume antenna manufacturing services. mWAVE's engineering team has experience designing antennas and antenna components from 100 MHz to 40 GHz. The company can be reached at (207) 857-3083 or e-mail: info@mwavellc.com.

PERSONNEL

■ **Anthony J. Cieri**, former vice president of sales at Sage Laboratories Inc., passed away on May 23, 2005. A graduate of Merrimac College and a Korean War veteran with the US Navy, Cieri spent 35 years in the microwave industry facilitating passive product sales into a vast array of military, space and medical programs and applications.

■ Global Communications Semiconductors Inc. (GCS), a pure-play III-V compound semiconductor wafer foundry service provider, announced that its board of directors has appointed **Jerry L. Curtis** to succeed Sam Lee as the company's president and chief executive officer. Curtis



DID YOU KNOW?

FACT #1: THE HUMMINGBIRD IS THE WORLD'S SMALLEST BIRD; SOME WEIGHING ONLY 2 GRAMS. BUT FOR THEIR SIZE, THEY HAVE THE LARGEST HEART AND BRAIN OF ALL ANIMALS.

FACT #2: TRIQUINT'S TINY NEW PA MODULE ALSO PACKS A LOT INTO A SMALL PACKAGE, MAKING IT THE WORLD'S SMALLEST FULLY MATCHED, SPEC COMPLIANT GSM / GPRS QUAD-BAND PAM.

'Small wonder' describes the hummingbird. The only avian that truly hovers. 200+ heart beats per minute. Amazingly designed – perfect for its environment. TriQuint's newest quad-band GSM / GPRS power amplifier module is a lot like that amazing bird. It's the smallest of its kind, and yet it packs an astounding amount of performance into a tiny 5x5x1.1mm package. It's highly efficient, fully matched and spec compliant. While nature makes the hummingbird so amazing, TriQuint relies on advanced InGaP HBT technology and CuFlip™ flip-chip assembly to make our little wonder the talk of designers across the globe. Fully integrated and optimized, the TQM7M4006 includes closed-loop power control with wide dynamic range and on-board reference voltage. No external matching or bias components are required.

For a marvel of nature, TriQuint says: Consider the hummingbird. For a marvel of engineering, look no farther than TriQuint's new TQM7M4006 – with power control – available now in samples for your next-generation GSM design. Only from TriQuint Semiconductor.

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brings more than 30 years of successful business and leadership experience in the semiconductor industry. Before joining GCS, Curtis was president and chief operating officer of EiC Corp. from 2000 to June 2005.

■ Park Electrochemical Corp. announced the appointment of **John C. Weidner** as the president of Neltec Europe SAS, Park's high technology printed circuit materials business unit located in Mirebeau, France. Weidner has over thirty years of management and engineering experience in the advanced composite industry.


▲ Sean Redmond

■ Cadence Design Systems has appointed **Sean Redmond** to be the company's new vice president of sales for Europe, the Middle East and Africa (EMEA). He will be based in Bracknell, UK. Redmond joined Cadence as part of the acquisition of Verisity, where he was the vice president and general manager, responsible for all sales and business operations for Europe and Israel. Prior to that he had worked for both EDA and semiconductor companies in a range of engineering and sales roles.

■ CAP Wireless Inc. announced the appointment of **Scott Behan** as vice president of marketing. Behan has more than twenty years of design and product marketing experience in the microwave and RF industry, having most recently served as director of LDMOS products with Sirenza Microdevices. Previously, he served in several capacities at AML Communications.


▲ Roman Boroditsky

■ Raltron Electronics Corp. announced the appointment of **Roman Boroditsky** to the newly created position of vice president for research and development. Boroditsky comes to Raltron after an extensive career with Valpey-Fisher Corp., Hopkinton, MA, as the vice president/CTO, and with NEL Frequency Control, Burlington, WI, as senior design engineer.


▲ Evan Taylor

■ **Evan Taylor** has joined Trilithic Inc. as regional sales manager, RF and microwave division. Taylor has been a part of the electronics industry for over 20 years with experience in RF and microwave technologies, including telecommunications, radar, SIGINT, commercial broadcasting, electronic warfare, UAV command, and control and fiber optic applications.

■ G Squared Technologies Inc. announced that **Fred Boone** has joined the sales staff as government account specialist. During his 15 years as materials manager for M/A-COM SIGINT Products, Boone attained extensive knowledge of the RF and microwave industry. Boone can be contacted at (410) 995-4648 or e-mail: fboone@gsquaredtec.com.

REP APPOINTMENTS

■ **IMS Connector Systems**, headquartered in Germany, has further extended its international sales network with the appointment of two new distribution partners in North America — **Reichenbach International Inc.** and **Utech Electronics**. The former was founded in 1988 and specializes in importing and reselling optical and electronic components, and will support the company's sales in California, Nevada, New Mexico and Arizona. Utech Electronics has been selling electronic components in Canada for 14 years and supplies customers locally with SMT components from international OEM manufacturers.

■ **Valpey-Fisher Corp.** announced the addition of **Daito Electron** to the Valpey Fisher global distribution and rep network as its exclusive authorized sales distributor for all company product lines to the Japanese market.

■ **Locus Microwave**, a manufacturer of custom and standard RF amplifier and converter products, announced the appointment of several representatives spanning the United States. **MC Microwave** will represent northern California, **E.G. Holmes & Associates** will cover the southeast US and **CMI Technical Sales** will cover Washington DC, northern Virginia and Maryland. Locus Microwave is located in State College, PA, and can be contacted at (814) 861-3200, fax: (814) 861-5195 or visit: www.locusmicrowave.com.

■ **AMI Semiconductor**, a designer and manufacturer of integrated mixed-signal and structured digital products, has announced the appointment of **Soanar Pty Ltd.** as a distributor and technical representative for the company in Australia and New Zealand.

WEB SITES

■ **W.L. Gore & Associates Inc.**, a supplier of microwave cable assemblies, expands its on-line store offering with the addition of GORE™ microwave test assemblies. The electronic products now available to purchase through the store include GORE VNA microwave test assemblies and GORE PHASEFLEX® microwave test assemblies.

■ **Spectrum Control** unveiled three new product Web sites under the umbrella of its corporate Web site, www.spectrumcontrol.com. The corporate Web site will continue to provide company-related and investor relations information, as well as direct users to the appropriate product Web site.

■ **Sullins Electronics Corp.**, a designer and manufacturer of connectors and interconnect systems, announced the launch of a new Web site (www.sullinselectronics.com) to better represent the growth and profile of the company.

MICROWAVE JOURNAL REVIEWED EDITORIAL BOARD

TECHNICAL FEATURE

A MONOPOLE WITH A TWIST REVISITED

Several years ago, a new antenna was developed to address the increasing need for compact wideband antennas.[1,2] The new antenna was presented as a novel spiral configuration best described as a Tapered Area Small Helix (TASH). The original work drew the interest of the US Army Communications — Electronics Research Development and Engineering Center (CERDEC), Ft. Monmouth, NJ, an Army agency requiring wideband low profile antennas. At CERDEC's request, one of the original TASH monopoles was provided for field evaluation. The results were encouraging enough that a proposal was requested for frequency extension of the basic TASH monopole structure. A proposal to optimize the VSWR bandwidth of the TASH antenna was accepted. The accepted proposal had several interrelated objectives. The first objective was to determine if a TASH monopole antenna could provide a low VSWR over much more than an octave band, and if so, what limitations exist. Once the antenna limitations were understood, a set of design guidelines was developed to produce a TASH monopole for any desired frequency range. The final objective was to use the design guidelines to design, assemble and test one or more prototype antennas suitable for field demonstration of wideband performance over the 225 to 2000 MHz range. Comparison tests were to be performed by a government agency after delivery of the prototype antennas.

TECHNICAL APPROACH

The initial task was to define the technical requirements for the desired TASH antenna covering the 225 to 2000 MHz range. The technical approach to meet those requirements was to perform both computer simulation and hardware verification of potential TASH configurations. The prior 225 to 450 MHz TASH antenna work[1] was used as a starting point. Prior work showed that a TASH monopole of 1.5 to 2.0 turns would give a higher VSWR than a 2- to 3-turn TASH monopole, but with much wider bandwidth. It was also noticed that many versions of 10:1 height to diameter ratio TASH monopoles (225 to 450 MHz designs) had low VSWR except for a single region one to two octaves above the lowest useful frequency. These observations and a comparison antenna were used as a baseline for a series of simulations.

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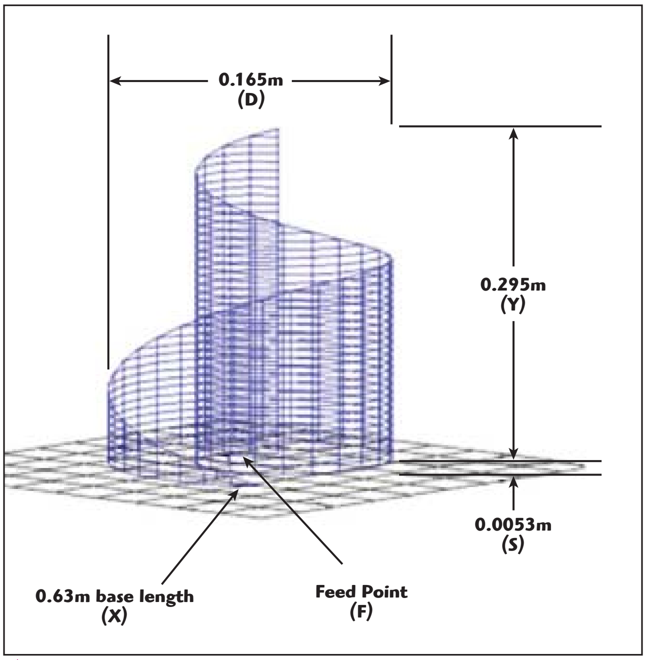

▲ *Fig. 1 Early configuration of a 225 to 2000 MHz TASH monopole.*

The comparison antenna for the TASH frequency extension effort was the discone. The discone is an unbalanced, single polarization radiator capable of VSWR less than 3:1 over more than four octaves. Other antennas in the discone family include the bicone and single cone above a ground plane. All these antennas are capable of low VSWR over wide bandwidths, although the discone is probably more popular because it can be used with or without a ground plane. Discone VSWR and radiation characteristics represented the wideband performance goals for the wideband TASH monopole.

SIMULATION

Eventually, hundreds of GNEC-4 and WIPL-D (another MoM software application) simulations were run to evaluate the VSWR bandwidth of various TASH antenna configurations. In early simulations, it was found that the base length-to-height ratio of the triangular TASH element could be varied to produce many simulations with low VSWR. The ratio was consequently reduced to produce the minimum element area still capable of low VSWR over the 225 to 2000 MHz range. The thinking was that it would be more difficult to reproduce a large area element than a smaller one, even though the rolled diameter might be the same. Using this approach, several simulations were produced that gave acceptable results (nominal 3:1 VSWR or less from 225 to 2000 MHz).

One of the early configurations representative of these simulations is shown in ***Figure 1***. The simulated element height is 0.295 m and the diameter 0.165 m. The simulated VSWR for that configuration is shown in ***Figure 2***.


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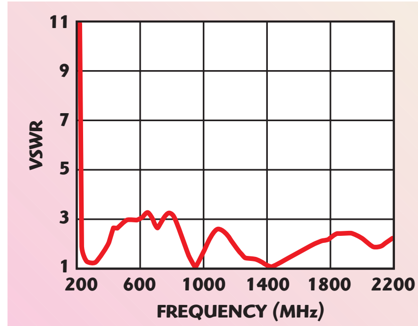

▲ *Fig. 2 Simulated VSWR versus frequency for the early TASH monopole.*

Further simulations were performed in conjunction with brass board measurements resulting in further antenna size reduction and improved VSWR.

Simulation results showed that a low VSWR (< 3) was possible only when the diameter of the TASH element was large (0.5 to 1.0 times the TASH element height). The spiral spacing did not affect the VSWR significantly (increase more than 3) if the diameter was within 50 ±10 percent of the element height. It was found that the spacing from the ground plane was more important. A spacing of the order of two percent of the TASH element height produced the lowest wideband VSWR. Lower or higher percentage spacings degraded the VSWR at some frequencies over a 10 to 1 range. The feed point location on the TASH element base is the most critical parameter of a TASH monopole simulation. Varying the feed point location essentially varies the current distribution on the TASH element. Moving the feed point toward the center of the base (x-y intersection) results in high VSWR over a narrow frequency range near the lower end of the band of interest. The VSWR becomes better and the poor VSWR frequency range narrower as the feed point is moved away from the center. A feed point can usually be found where the VSWR is acceptable (< 3) at most frequencies over at least a 10 to 1 range.

DESIGN OPTIMIZATION

The measurements made during the project were primarily input VSWR and radiation antenna patterns over the frequency range of interest. A number of tests were performed on TASH antennas mounted on a small laboratory (indoor) ground plane and a large outdoor ground plane. VSWR measurement of various TASH configurations and brass boards were initially performed in the laboratory on a small ground plane. If the configuration showed promise, then additional tests were performed on a large outdoor ground plane to validate the simulation results. Good VSWR correlation was found between simulation and measurements on a small ground plane (0.47 × 0.56 m) and an outdoor ground plane VSWR over the full 225 to 2000 MHz range.

Initial simulations concentrated on TASH monopoles with height-to-diameter ratios of 5 to 10. It was later discovered that the ratio should be on the order of 2 to remove the high VSWR condition above the first octave. After many simulations and brass board measurements, the focus was on VSWR optimization of two TASH monopole configurations. The first configuration was a 1.8 height-to-diameter TASH monopole fed at a point approximately 10 to 20 percent in from the vertical edge on the base spiral. The second configuration was also approximately 2 in height-to-diameter, but of smaller volume. The second configuration, as shown in ***Figure 3***, differed from the

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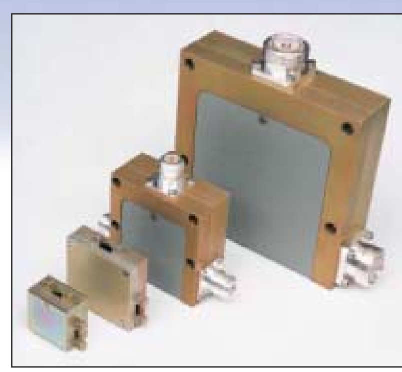

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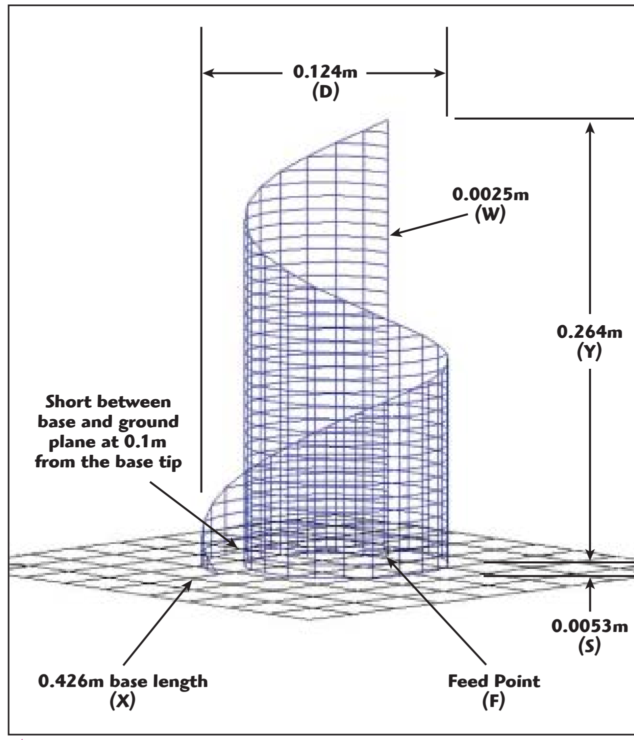
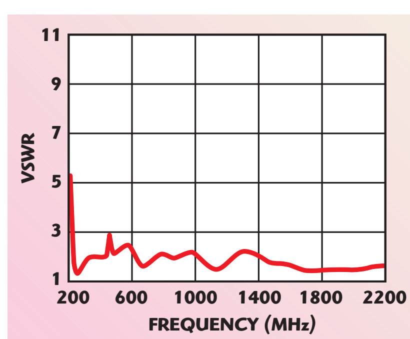
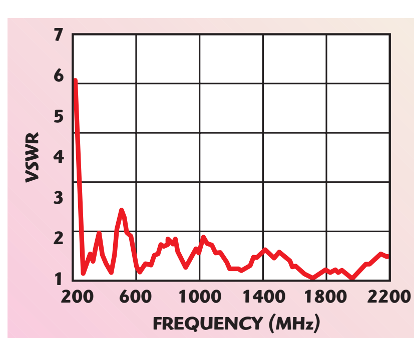


▲ *Fig. 3 Reduced size 225 to 2000 MHz TASH monopole.*

first in that it was fed at the base of the vertical edge, although the base was also shorted to the ground plane approximately 25 percent in from the base tip. This second configuration was selected as the final prototype configuration primarily because of its smaller volume. ***Figure 4*** is a simulated VSWR versus frequency plot for this second configuration; ***Figure 5*** is a measurement of the prototype configured as in the simulation.



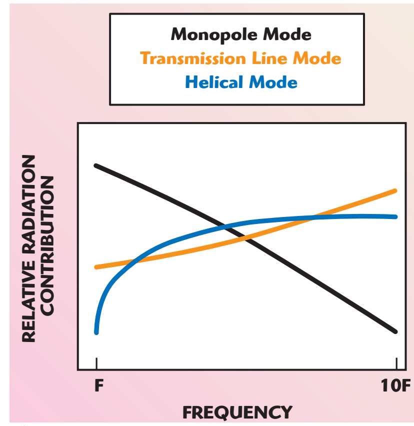
▲ *Fig. 4 Simulated VSWR versus frequency for the reduced size TASH monopole.*



▲ *Fig. 5 Measured VSWR versus frequency for the reduced size TASH monopole.*

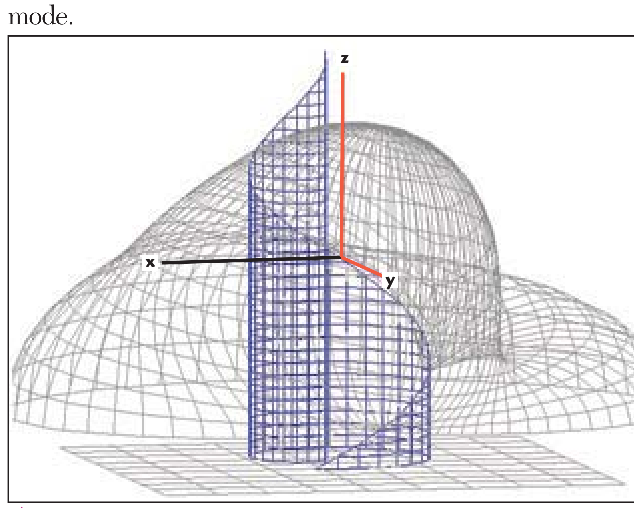
RADIATION

The radiation from a TASH antenna is complex. In addition to linear monopole mode and helical modes of radiation, the TASH structure supports a third radiation mode, exemplified by a class of antennas known as transmission line antennas. Examples of transmission line antennas include the well known "towel bar" antenna and the directly driven resonant radiator (DDRR) antenna.[3–5] The directly driven reso-

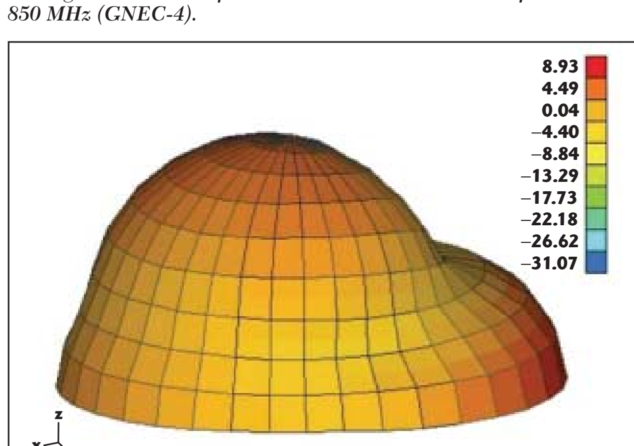


▲ *Fig. 6 Relative radiated power contribution for each TASH mode versus frequency.*

nant radiator antenna is a type of transmission line antenna characterized by its compact size compared to its radiation wavelength. DDRR antennas are often produced in a spiral pattern, since the interaction between the conductors is minimal if the spacing is less than 2.5 times the spacing of the transmission line (element base) to the ground plane. Ground plane-to-element spacing of the TASH monopole is generally similar to the spacing found in spiral transmission line antennas (0.002 to 0.01 wavelengths). The transmission line mode of the TASH monopole antenna produces vertically polarized radiation at frequencies above the first resonance of the TASH base spiral. This is illustrated by the diagram in ***Figure 6***, which shows the relative radiation contribution of each mode.



▲ *Fig. 7 TASH monopole three-dimensional radiation pattern at 850 MHz (GNEC-4).*



▲ *Fig. 8 TASH monopole three-dimensional radiation pattern at 850 MHz (WIPL-D).*

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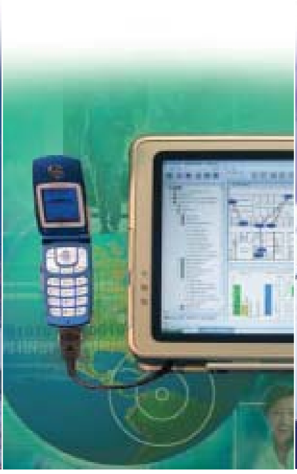
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Another way to analyze the TASH antenna is to consider the base spiral as a continuously tapped transmission line feeding contiguous vertical elements of varying length. The transmission line is optimized to feed each element at the proper phase for minimum VSWR over the bandwidth of interest.

The radiation patterns of 225 to 2000 MHz TASH monopoles were investigated by both simulation and measurement. ***Figures 7*** and ***8*** show three-dimensional radiation patterns for a TASH monopole from GNEC-4 and WIPL-D simulation software, respectively. Inspection of a series of radiation patterns from WIPL-D and GNEC-4 in addition to the measured patterns indicates that the TASH antenna radiation is similar to a linear wideband antenna, such as the discone, at frequencies within the lowest frequency octave. At higher frequencies it was verified that the TASH monopole produces both axial and linear radiation with pattern irregularities at the highest frequencies (1000 to 2000 MHz). At the higher frequencies, the pattern irregularities are significant (> 3 dB), but not as great as the elevation nulls observed in conventional monopole and discone radiation patterns. ***Figure 9*** shows WIPL-D TASH three-dimensional radiation patterns at frequencies between 200 and 1800 MHz.

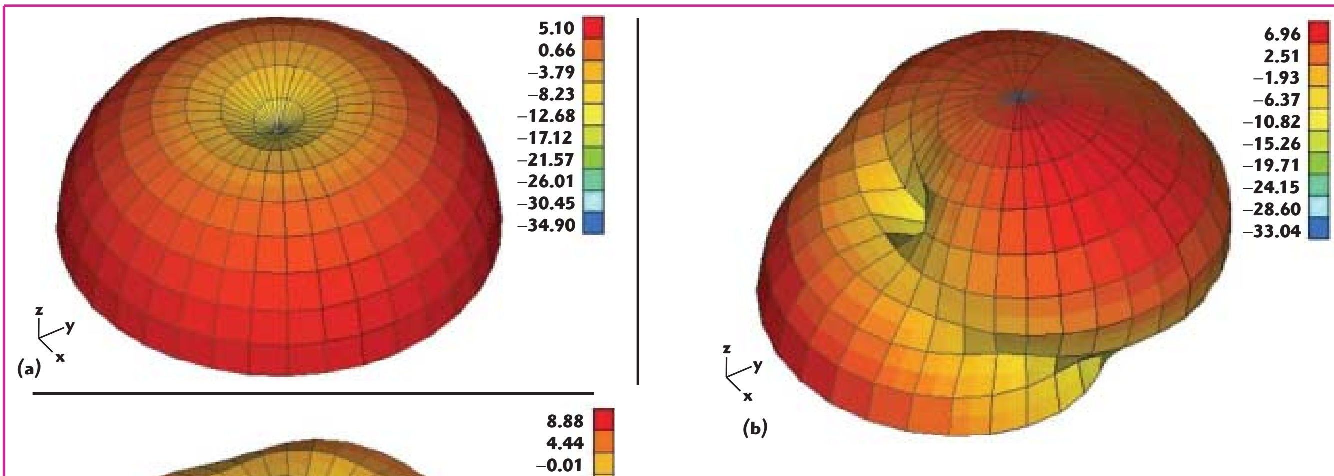
The radiation pattern of the completed 225 to 2000 MHz prototype TASH monopole was measured in an anechoic chamber over the full frequency range. A calibrated turntable (0.33 × 0.36 m ground plane) rotated the antenna at a point 4.9 meters from a receiving antenna. The receiving antenna was a wideband discone covering the same frequency range as the TASH antenna under test. The discone is only sensitive to linear polarization. Therefore, the patterns measured at frequencies more than an octave above 225 MHz did not include contributions from other than linear radiation. ***Figure 10*** shows the 225 to 2000 MHz prototype TASH antenna on the turntable. ***Figure 11*** is a measured example of the azimuth pattern referenced to a discone.

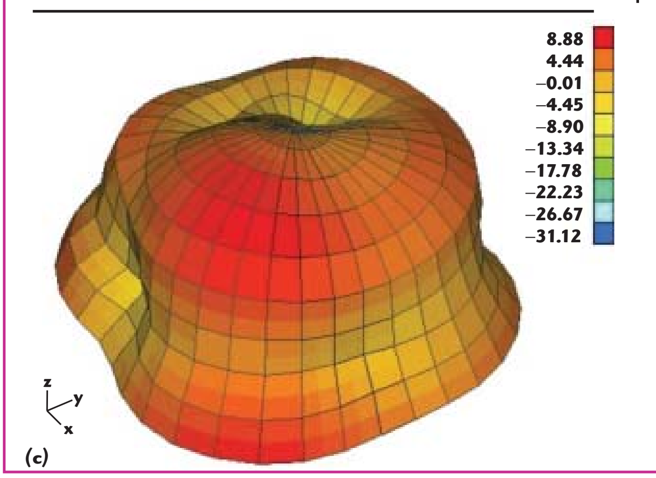
Even though measurements were made in the near field at low frequencies (200 to 400 MHz), the pattern was essentially omni-directional where the anechoic chamber performance was poor. The pattern developed irregularities as the frequency increased, which was in good agreement with simulated pattern data.

PROTOTYPE DESIGN

A TASH prototype antenna evolved as simulation analysis and brass board measurements converged on a design capable of low VSWR over the 225 to 2000 MHz range. The final TASH 225 to 2000 MHz monopole antenna, resulting from the design effort, was built with a height-to-diameter ratio of approximately 2. The element consisted of a triangular sheet of copper mesh 0.259 m (0.2 λ) high and a base of 0.42 m (0.32 λ) rolled, as shown in ***Figure 12***. The element was mounted on a base plate with the feed point at the inner most edge of the base spiral and shorted to the ground plane (base plate) approximately 0.1 m (0.08 λ) in from the


SIMULATION



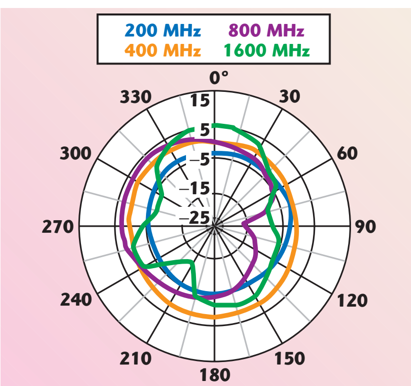


▲ *Fig. 9 Simulated (WIPL-D) TASH monopole radiation patterns at (a) 200, (b) 1000 and (c) 1800 MHz.*

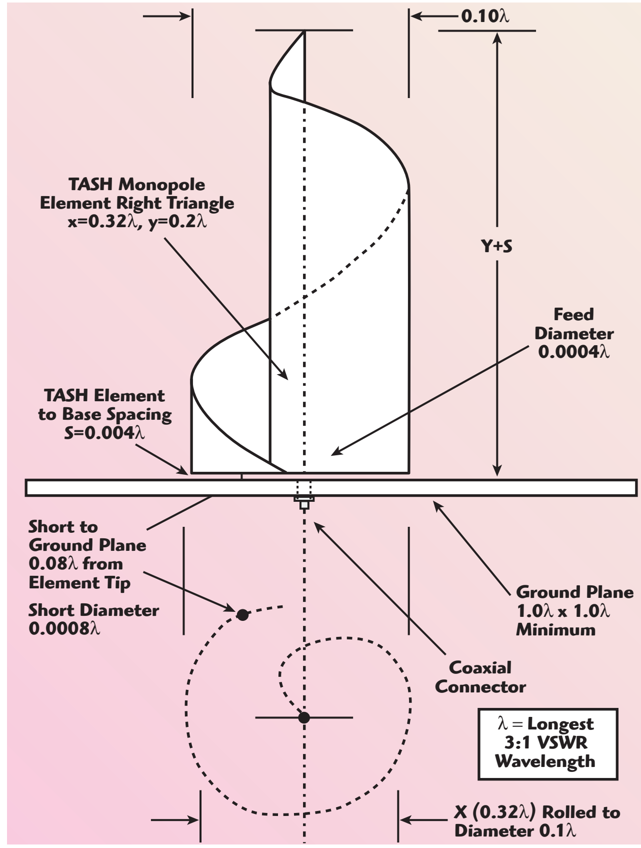
base tip. The spacing to the ground plane was 0.005 m (0.004 λ). ***Figure 13*** shows the finished prototype antenna element with its radome removed.

Figure 14 shows the complete 225 to 2000 MHz prototype antenna installed on a large outdoor ground plane. After installation no adjustments were made to the antenna prior to measurement. The measured VSWR and impedance results are shown in ***Figures 15*** and ***16***, respectively.

▲ *Fig. 10 TASH monopole mounted in the anechoic chamber for azimuth pattern measurements.*



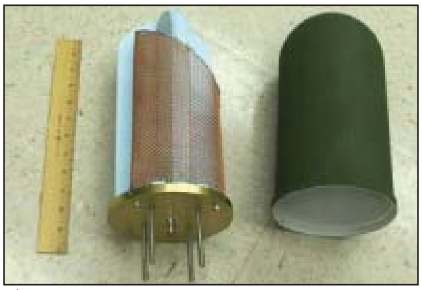
▲ *Fig. 11 TASH monopole azimuth pattern measured at 0° elevation at various frequencies.*



◀ *Fig. 12 The 225 to 2000 MHz TASH monopole configuration.*

DESIGN ISSUES

Although the TASH antenna is inherently simple, the asymmetry of the TASH element makes construction slightly more complicated than would be the case for symmetrical antennas such as discones. However, once the mechanical design has been established, it is no more difficult to fabricate TASH monopoles than other antenna types. The electrical design of a conventional TASH monopole generally follows the method



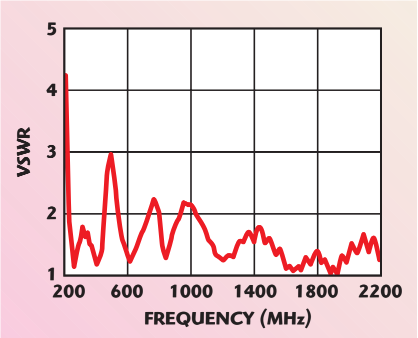
▲ *Fig. 13 Prototype TASH monopole element with radome removed.*

▲ *Fig. 14 Complete TASH 225 to 2000 MHz prototype on an outdoor ground plane.*

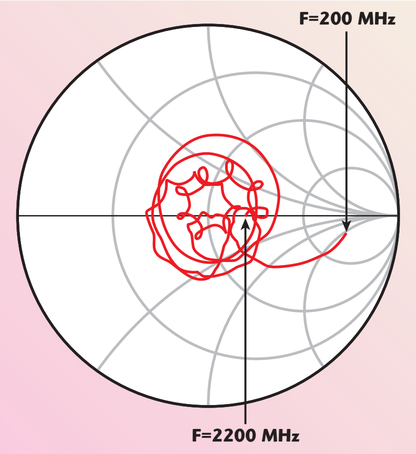
shown in this article and as described in ***Table 1***.

The primary TASH antenna variables are element height, base length, outside diameter, base-to-ground spacing, base pattern and feed point. Through simulation and measurement it was determined that the overall length of the TASH element establishes the lowest 50 Ω VSWR in a 10:1 bandwidth. Typically, the lowest frequency with a VSWR of 3 will be set by the overall height of the TASH element Y plus the element-to-ground spacing S. The total of Y+S will equal approximately 0.2 λ. To some extent the lowest frequency is also a function of the diameter D of the TASH element. For height-to-diameter ratios ranging from 2:1 to 1:2, the lowest frequency will decrease as the height-to-diameter ratio decreases.

A TASH element base length of almost any value X produces multiple transmission line resonances as the frequency increases. For longer base lengths, more resonances will be produced for a given bandwidth. Although



▲ *Fig. 15 Measured VSWR of the TASH 225 to 2000 MHz prototype on an outdoor ground plane.*



▲ *Fig. 16 Measured impedance of the TASH 225 to 2000 MHz prototype on an outdoor ground plane.*

TABLE I
TASH MONOPOLE PHYSICAL DESCRIPTORS

W	wire diameter (if planar mesh) or material thickness
C	base spiral configuration (spacing between turns, space variation, etc.)
Y	height of the TASH element (not including S)
X	length of the TASH element
S	spacing of the TASH element to the ground plane
F	feed point (the point on the base at which the element is fed)
D	diameter of the rolled element

a large number of resonances improves cancellation of the reactance, the extra complexity of the additional length can be challenging to control and reproduce. The best element base length for reproducibility is the minimum length that produces acceptable VSWR over the design bandwidth. Lengths of 1.5 to 2.5 times the element height are typical. For the shorted base final prototype the base length X was 0.32 λ. For TASH monopoles in general, the outside diameter is limited by the length of the element base X as rolled to form the minimum diameter possible for the desired bandwidth.

The base-to-ground spacing S affects the characteristic impedance of the transmission line mode. The nominal spacing should be 0.4 ±0.2 percent of the longest wavelength λ of interest. Although VSWR is a function of the spacing between the TASH element turns, the effect on VSWR is minimal over that range. Less spacing reduces the high frequency VSWR while increasing the low frequency VSWR and vice versa.

The primary feed point can be at any point on the base of the element. The bottom of the innermost edge generally provides a good feed point for TASH element heights that are nominally a quarter wavelength at the lowest frequency of interest. For shorter height TASH elements a feed point approximately 10 percent of the base length for each 10 percent reduction in element height will give the best match to 50 Ω. However, the overall VSWR becomes worse as the element height is reduced further.

Mechanically, the TASH element can be either a solid planar surface or a grid structure. A grid surface should have grids with dimension less than 0.1 wavelengths at the highest frequency of interest. Grid surfaces offer several other advantages. They are generally lighter and easier to shape than solid planar surfaces. When encapsulated the mesh allows the encapsulating material to flow freely within and around the element. They also correlate well with grid simulation models.

The TASH element has a significant mechanical advantage over most linear wideband antennas (cone, discone and capped cone). The majority of the TASH element mass is located at the base. This makes it easy to fabricate a ridged antenna by attaching the TASH element to the base using dielectric spacers. The spiral structure is much more stable than that for comparable wideband omni-directional antennas.

The feed point diameter is normally not critical unless a short is placed between the TASH element

TABLE II

PHYSICAL CHARACTERISTICS OF WIDEBAND (MULTI-OCTAVE) TASH MONOPOLES

Physical Property	*Code*	*Parameters for an Unshorted TASH Monopole*	*Parameters for a Shorted TASH Monopole*	*Criticality for Low VSWR*
Wire diameter (if planar mesh) or material thickness	W	< λ/1000	< λ/1000	low
Base spiral configuration (spacing between turns, space variation, etc.)	–	rolled right or left hand with maximum spacing between turns	rolled right or left hand with maximum spacing between turns	low
Height of the TASH element (not including S)	Y	0.22 λ	0.2 λ	high (only at or near λ)
Width of the TASH element (planar)	X	0.475 λ	0.32 λ	medium
Space between the TASH element and the ground plane	S	0.004 λ	0.004 λ	medium
Feed point, i.e., the point on the base at which the element is fed	F	at 0.03 λ from the innermost point (longest vertical edge) of the element base	at the innermost point (longest vertical edge) of the element base with a short to ground plane 0.08 λ in from the base tip	high
Diameter of the rolled element	D	0.125 λ	0.10 λ	medium
Diameter of feed and shorts	–	< λ/1000	< λ/1000	medium

and the ground plane, in which case the feed point diameter to short diameter ratio becomes a factor in establishing the characteristic impedance within the first octave.

A short to ground along the base offers some advantages. The short allows direct mechanical connection to the base ground plane, which provided another rigid support for the TASH spiral element. It also reduces the potential for damage to equipment connected to the TASH element should high voltage be inadvertently applied or induced into the TASH element. ***Table 2*** sum-

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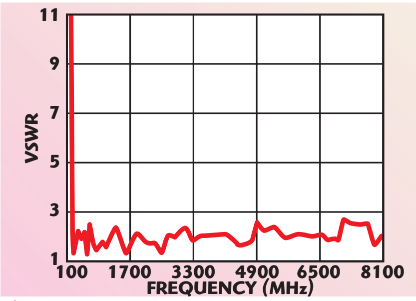

▲ *Fig. 17 GNEC-4 simulated wideband VSWR of a TASH antenna.*

marizes the physical characteristics of the wideband TASH monopoles as currently optimized.

Although the optimization effort concentrated on the 225 to 2000 MHz range, it was determined that the TASH structure has the potential for much wider bandwidth. ***Figure 17***, for example, shows the simulated VSWR of a TASH monopole configuration over the 100 to 8100 MHz range.

CONCLUSION

The TASH monopole represents a new class of composite antennas combining the radiation modes of several basic antenna elements in one structure. Through measurement and simulation it was concluded that the radiation pattern of a TASH monopole is predominately linear at frequencies within the first octave above c/λ with some circular polarization even at frequencies above c/λ. However, a large percentage of the radiation remains linear and omni-directional at frequencies well above c/λ. The radiation pattern is less affected by ground plane size and irregularities than comparable wideband antennas such as the discone. ■

ACKNOWLEDGMENTS

The author wishes to thank the US Army CERDEC for supporting this work. Particular thanks go to both Steve Goodall and Yoram Levy of CERDEC for their technical support and continuing interest in this antenna development.

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Tom Warnagiris *received his BSEE degree from Pennsylvania State University and has performed graduate work at the University of South Florida. He is currently a staff engineer in the Signal Exploitation and Geolocation Division of the Southwest Research Institute. He previously worked as an engineer at ARINC Research, the ECI Division of NCR, C-COR Electronics and HRB Singer. He holds several communications related patents and is a registered engineer in both Pennsylvania and Florida.*

VCO Part Number	Frequency (MHz)	Vtune (Vdc)	Kvco (MHz/V)	$Ø_N$@10KHz (dBc/Hz)	Output Power (dBm)	2nd Harmonic (dBc)	Pulling (MHz)	Pushing (MHz/V)	Vcc (Vdc)	Icc (mA)	Operating Temp (°C)
V150ME03	100 to 200	0 to 12.5	10	-111	7 ± 5	-10	<1	<1	12.0	26	-40 to 85
V220ME01	200 to 239	0.5 to 4.5	14	-120	7.5 ± 2.5	-22	<0.5	<0.5	5.0	16	-40 to 85
CLV1277A	1213 to 1341	0.5 to 4.5	38	-108	2.5 ± 2.5	-15	<1	<1	5.0	22	-40 to 85
CRO2155A*	***1960 to 2350***	***1 to 14***	***40***	***-106***	***7 ± 2***	***-10***	***<2***	***<0.5***	***6.0***	***27***	***0 to 85***
CRO2780A*	***2650 to 2910***	***0.5 to 15***	***20***	***-111***	***3 ± 3***	***-10***	***<0.5***	***<0.5***	***10.0***	***34***	***-40 to 85***
CRO2880A	2760 to 3000	0 to 15	18	-110	12.5 ± 2.5	-20	<1	<1	10.0	29	-40 to 85
V950ME07	3900 to 6000	0 to 20	126	-80	4.5 ± 4.5	-14	<36	<14	5.0	21	-40 to 85
CRO4500A	4499 to 4501	0.5 to 4.5	12	-104	2 ± 2	-15	<1	<2	5.0	20	-20 to 70

PLL Part Number	Frequency (MHz)	Step Size (kHz)	Output Power (dBm)	$Ø_N$@ 10KHz (dBc/Hz)	$Ø_N$@ 100KHz (dBc/Hz)	2nd Harmonic (dBc)	Ref Sup (dBc)	Lock Time (msec)	Vcc (Vdc)	Icc (mA)	Operating Temp (°C)
PCA1445C	1444 to 1446	1000	5 ± 2	-120	-140	-20	-59	3	5.0	40	-40 to 85
PCA1550A	1500 to 1600	1000	1.5 ± 2.5	-103	-124	-15	-70	3	5.0	40	-40 to 85
PSA2000C*	***1970 to 2030***	***100***	***2 ± 2.5***	***-107***	***-128***	***-15***	***-70***	***2.5***	***5.0***	***30***	***-40 to 85***
PCA3040C*	***3040 to 3040***	***1000***	***3 ± 3***	***-112***	***-132***	***-8***	***-60***	***1***	***5.0***	***35***	***-40 to 85***
PSA3330C	3305 to 3335	125	0 ± 3	-106	-130	-12	-70	1	5.0	35	-40 to 85
PSA3500A	3400 to 3600	1000	0 ± 3	-85	-109	-15	-70	2	5.0	40	-40 to 85
PSA3707C	3675 to 3738	250	0 ± 3	-105	-128	-15	-70	2	5.0	40	-40 to 85
PSA4202C*	***4144 to 4260***	***250***	***0 ± 3***	***-96***	***-119***	***-12***	***-70***	***1***	***5.0***	***40***	***-40 to 85***

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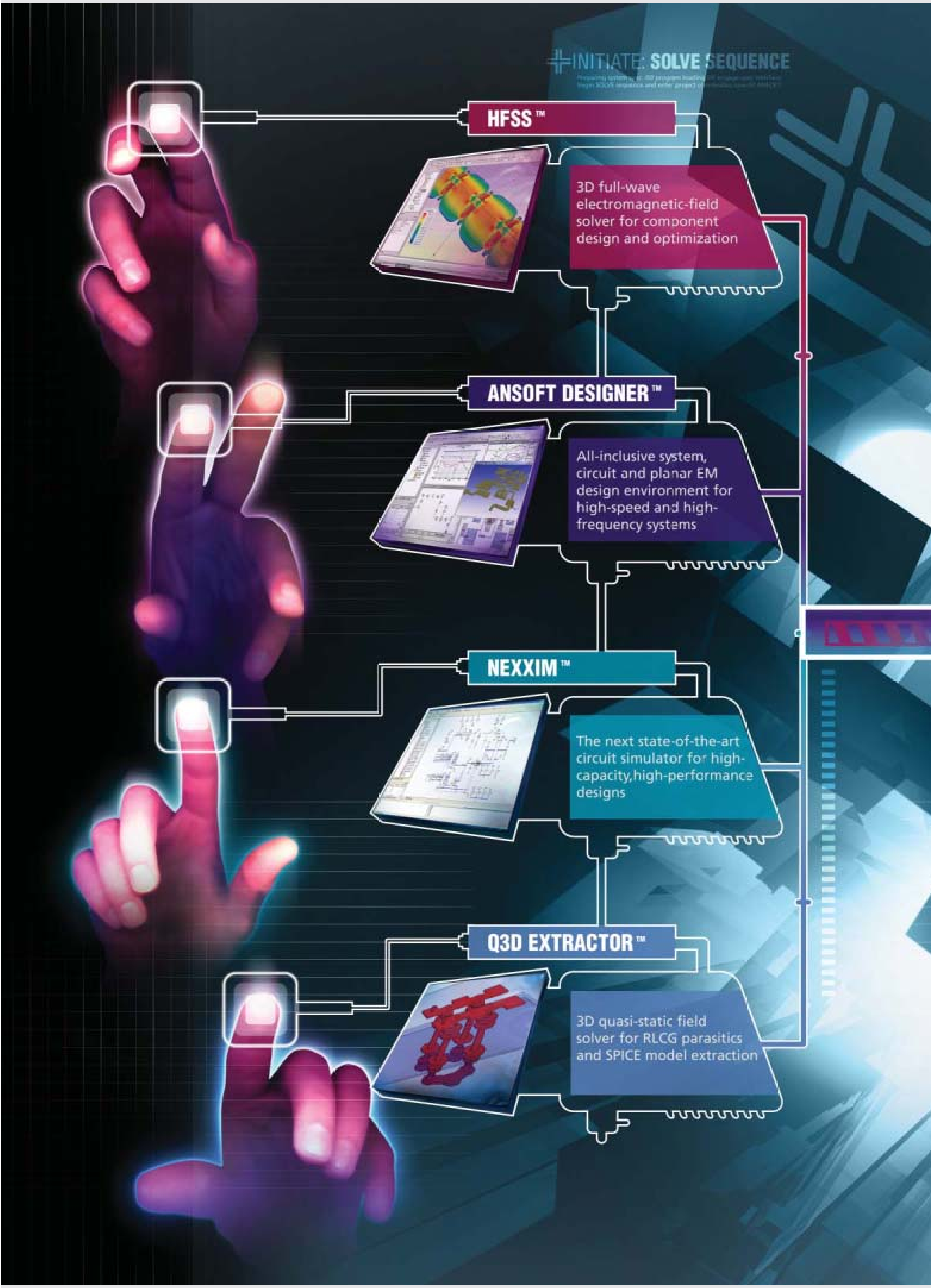
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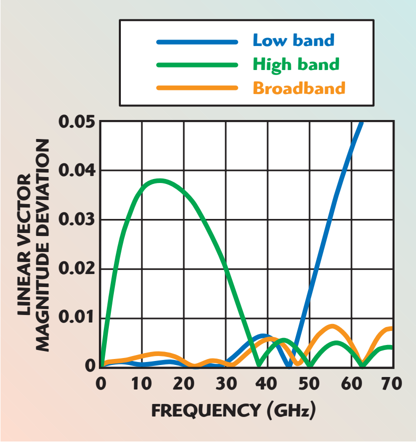
LATEST ADVANCES IN VNA ACCURACY ENHANCEMENTS

A vector network analyzer (VNA) measurement accuracy depends on the accuracy of the calibration standards, the calibration method employed and the instrumentation accuracy. Advances in signal processing technology, computation technology, manufacturing technology and computer modeling have pushed instrumentation and calibration standards accuracies to their limit. To improve accuracy, new calibration methodologies are being explored. This article presents some of the new developments in network analyzer accuracy enhancements, including data-based calibration standard models, weighted least squares calibration and "unknown through" calibration. Comparisons are made between these new methods and the current widely used traditional methods.

Calibration standards such as opens and shorts have traditionally been modeled by fitting the actual response of the standard to a third-order polynomial.[1] This approach has limitations as the frequency range of the standards increases. Multiple-band models for the same calibration standard were created in an effort to minimize the fitting errors. This required the user to measure the same standard several times — once for each model.

Figure 1 shows a comparison of the accuracy of three different polynomial models for an offset short. Model accuracy is the difference between the polynomial model and the data used to fit the polynomial. The low band and high band models optimize the accuracy over portions of the frequency band while the broadband model optimizes the accuracy over the full frequency band. A new calibration standard model type, the data-based standard model, has been introduced to overcome this limitation and to reduce the errors in calibration that had previously been introduced by the fitting process, as illustrated in ***Figure 2***.

Fig. 1 Comparison of 1.85 mm short 1 (5.4 mm offset) polynomial models accuracy.



Often, more calibration standards than the minimum required are measured. This may be necessary to maintain distinction between calibration standards over a very wide fre-

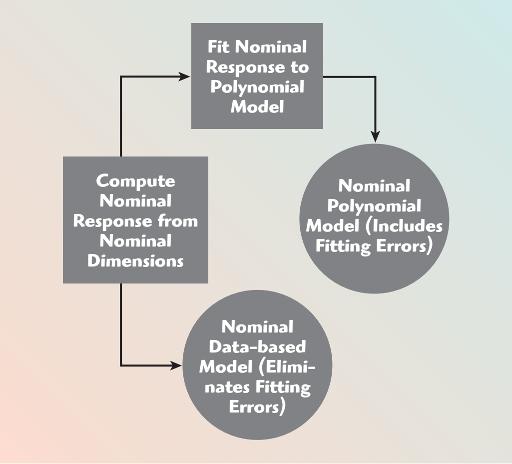


Fig. 2 Data-based and polynomial models data flow.

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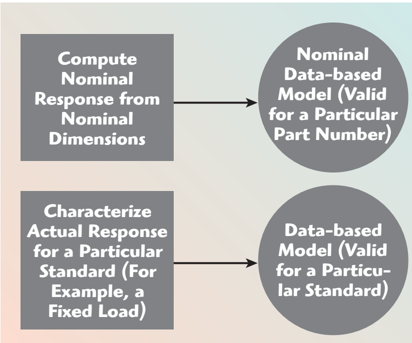

Fig. 3 Data-based models used as a generic nominal model or as a model for a specific device.

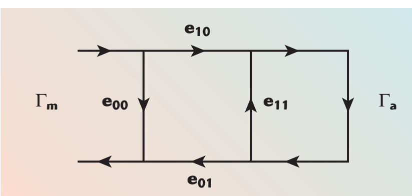

Fig. 4 Flow graph representation of a measured reflection coefficient.

quency range. When the accuracy of a single standard is not adequate over the full frequency range, more standards are required, such as a fixed load and sliding load combination. Traditionally, in each of these cases, all of the standards are measured over the entire frequency range, although some of the data is simply ignored. This can lead to discontinuities in subsequent error corrected measurements. Weighted least squares (WLS) calibration uses all of the data measured on multiple standards, while seamlessly weighting each standard relative to its accuracy. The data-based standard model includes uncertainties as part of the definition. For non-data-based calibration standard models, default uncertainties are assigned to these models, based on the specifications of the calibration standard.

The "unknown through" calibration method was introduced by Andrea Ferrero and Umberto Pisani[2,3] in 1992. It was based on the general theory of VNA calibration that brought about the TRL family of calibrations in the mid-1970s.[4,5] This full two-port calibration technique is well suited for calibrating a vector network analyzer with immovable test ports, to measure non-insertables, odd shape and multi-port devices. The through "standard" does not need to be known and does not need to be perfect.

DATA-BASED CALIBRATION STANDARDS

Data-based calibration standards eliminate the requirement to fit the response of calibration standards to a set of predefined calibration models, such as coaxial or waveguide. This increased flexibility will also enable users to define more easily their calibration standards and virtually eliminates any error that previously would have been introduced by the curve fitting process. An example of the data-based standard model data file, based on the CITIFILE format, is shown in ***Appendix A***. The data may be obtained by device modeling based on physical dimensions and properties or from accurate measurements, as illustrated in ***Figure 3***. Uncertainties in the data are included.

The generic VNA model for a fixed load is that its reflection coefficient is equal to zero. The actual reflection coefficient of the load is the dominant factor in the directivity and source match errors. If a fixed load can be characterized using a more accurate calibration, the resulting characterization data, with uncertainties, is used as the data-based standard definition. Calibrations using the fixed load and its associated data-based model will have an accuracy approaching the accuracy of the system that characterized the fixed load. Residual calibration errors now depend on the uncertainty of the characterization rather than the specification of the load.

WEIGHTED LEAST SQUARED (WLS) CALIBRATION

Basic Theory[6]

Figure 4 is a signal flow graph representation of the relationship between the measured reflection coefficient (Γ_m) and the actual reflection coefficient (Γ_a) plus systematic errors of directivity (e_{00}), reflection tracking ($e_{10}e_{01}$) and source match (e_{11}). Equation 1 can be derived from the signal flow graph:


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$$\Gamma_m = e_{00} - (e_{11}e_{00} - e_{10}e_{01})\,\Gamma_a + e_{11}\Gamma_m\Gamma_a \qquad (1)$$

To determine the systematic errors at least three distinct and known devices must be measured. The general solution may be formulated in matrix form:

$$\begin{bmatrix} 1 & \Gamma_{m1}\Gamma_{a1} & -\Gamma_{a1} \\ 1 & \Gamma_{m2}\Gamma_{a2} & -\Gamma_{a2} \\ 1 & \Gamma_{m3}\Gamma_{a3} & -\Gamma_{a3} \\ \vdots & \vdots & \vdots \\ 1 & \Gamma_{mn}\Gamma_{an} & -\Gamma_{an} \end{bmatrix} \times \begin{bmatrix} e_{00} \\ e_{11} \\ e_{11}e_{00} - e_{10}e_{01} \end{bmatrix} = \begin{bmatrix} \Gamma_{m1} \\ \Gamma_{m2} \\ \Gamma_{m3} \\ \vdots \\ \Gamma_{mn} \end{bmatrix} \qquad (2)$$

Better accuracy can be achieved by measuring more than three standards. Electronic calibration, (ECal), introduces a least squares solution to increase the accuracy obtainable with the over-determined system.[7] Equation 2 can be rewritten as a matrix equation:

$$\mathbf{A} \times \mathbf{x} = \mathbf{b} \qquad (3)$$

The optimal least squares solution to Equation 3 is given as

$$\mathbf{x} = (\mathbf{A}^H \times \mathbf{A})^{-1} \times \mathbf{A}^H \times \mathbf{b} \qquad (4)$$

where

$\mathbf{A}^H$ = conjugate transpose of $\mathbf{A}$

The least squares solution works well when all observations of calibration standards are known with the same accuracy. This is a reasonable assumption for ECal, but may not be valid when it is applied to calibrations using other calibration kits.

A weighted least squares solution approach provides a simple solution to handle the case where the calibration standards do not have the same accuracy.[8] If the uncertainties of the standards are uncorrelated, an optimal solution is best obtained by multiplying each equation by a weighting factor that includes both the accuracy of the standard's model and the proximity of the standard's response to the other measured calibration standards.

Equation 2 becomes

$$\begin{bmatrix} \frac{1}{\sigma_1} & \frac{\Gamma_{m1}\Gamma_{a1}}{\sigma_1} & \frac{-\Gamma_{a1}}{\sigma_1} \\ \frac{1}{\sigma_2} & \frac{\Gamma_{m2}\Gamma_{a2}}{\sigma_2} & \frac{-\Gamma_{a2}}{\sigma_2} \\ \frac{1}{\sigma_3} & \frac{\Gamma_{m3}\Gamma_{a3}}{\sigma_3} & \frac{-\Gamma_{a3}}{\sigma_3} \\ \vdots & \vdots & \vdots \\ \frac{1}{\sigma_n} & \frac{\Gamma_{mn}\Gamma_{an}}{\sigma_n} & \frac{-\Gamma_{an}}{\sigma_n} \end{bmatrix} \times \begin{bmatrix} e_{00} \\ e_{11} \\ e_{11}e_{00} - e_{10}e_{01} \end{bmatrix} = \begin{bmatrix} \frac{\Gamma_{m1}}{\sigma_1} \\ \frac{\Gamma_{m2}}{\sigma_2} \\ \frac{\Gamma_{m3}}{\sigma_3} \\ \vdots \\ \frac{\Gamma_{mn}}{\sigma_n} \end{bmatrix} \qquad (5)$$

where

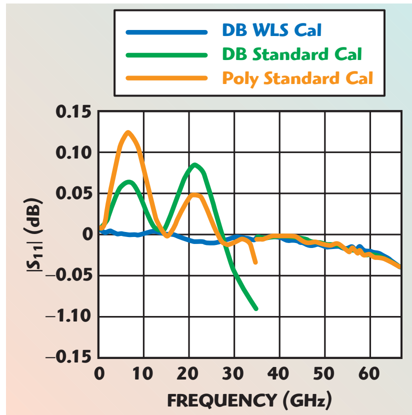
σ_i = weighting factor for the i^{th} equation.

MEASUREMENT RESULTS

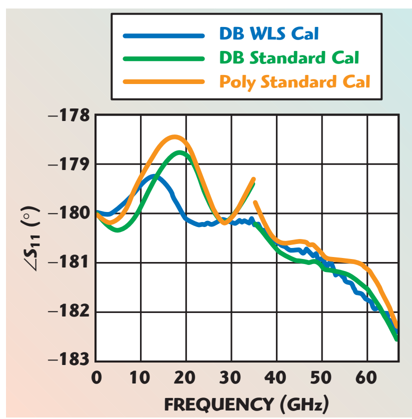
The benefits of the weighted least squares calibration in conjunction with the data-based model are evaluated using the Agilent 85058B calibration kit. This kit has similar calibration standards for each sex, consisting of a low band load, an open, a 5.4 mm offset short, a 6.3 mm offset short, a 7.12 mm offset short and a 7.6 mm offset short.

The improvements due to the weighted least squares calibration and the data-based model become readily apparent when comparing measurements made with this technique to measurements made after a traditional frequency limited, three standard, one-port calibration and to the traditional polynomial model-based weighted least square calibration.

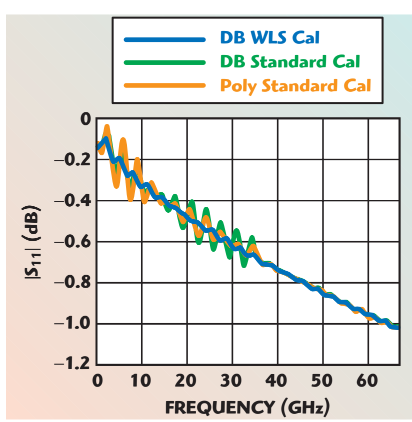
Measurements of devices that were not used in the calibration process, a flush short and the flush short connected to a 5 cm airline, were performed. ***Figures 5*** and ***6*** compare the measured S_{11} magnitude and phase of a flush short. The S_{11} parameter of a perfect flush short should have a magnitude of 1 (or 0



▲ *Fig. 5 Comparison of the measured S_{11} magnitude of a flush short.*



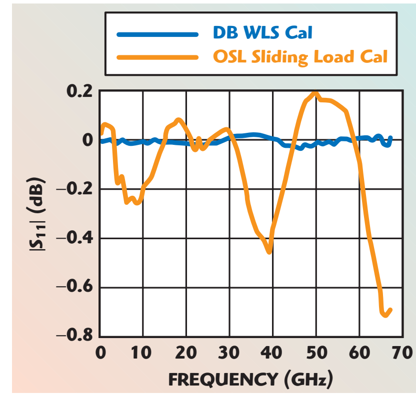
▲ *Fig. 6 Comparison of the measured S_{11} phase of a flush short.*



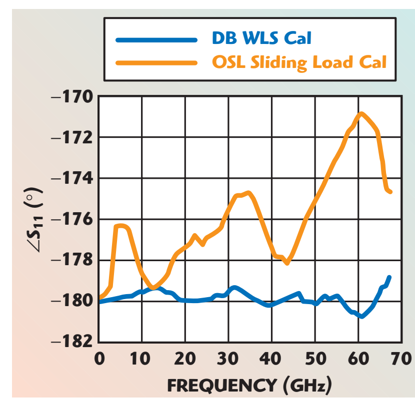
▲ *Fig. 7 Comparison of the measured S_{11} magnitude of an airline terminated in a short.*

dB) and a phase angle of 180°. Deviations from those ideal values indicate errors in the measurement. The DB WLS (data-based standard, weighted least squares) calibration results are much closer to the ideal values.

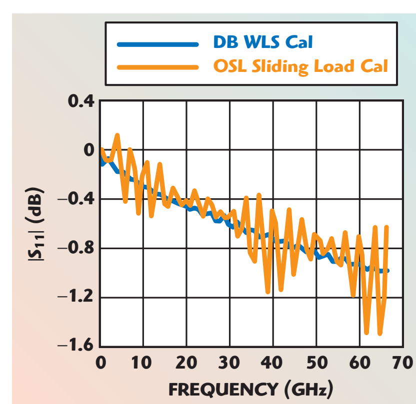
A precision bead-less coaxial airline introduces very low reflections. When terminated with a short, the magnitude of the measured reflection at the input of the coaxial line should be similar to its insertion loss. Ripples



▲ *Fig. 8 Measured S_{11} magnitude of a flush short.*



▲ *Fig. 9 Measured S_{11} phase of a flush short.*



▲ *Fig. 10 Measured S_{11} magnitude of a 5 cm long airline terminated in a short.*

in the measured data indicate measurement errors caused by residual directivity, source match and reflection tracking errors. ***Figure 7*** shows how the three calibration methods compared.

The benefits of both weighted least squares calibration and data-based calibration standard models are clearly demonstrated by comparing them to a commercially available sliding load kit. The sliding load calibration kit uses the traditional modeling for the coaxial open, short, load and

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AMF-5B-040080-60-30P	4–8	33	1.5	6	30	2:1	1400
AMF-5B-040080-70-33P	4–8	33	2	7	33	2:1	2200
AMF-6B-040080-60-33P-2	4–8	40	2	6	33	2:1	2400
AMF-5B-080120-80-30P	8–12	24	1.5	8	30	2:1	1650
AMF-6B-080120-70-30P	8–12	30	1.5	7	30	2:1	1800
AMF-6B-080120-50-33P	8–12	33	1.5	5	33	2:1	2000
AMF-5B-080120-50-35P	8–12	35	2	5	35	2:1	2800
AMF-5B-060130-50-35P	6–13	35	2	5	35	2:1	2800
AMF-8B-060180-60-30P-2	6–18	31	2.5	6	30	2:1	2000
AMF-6B-060180-60-33P	6–18	35	2.5	8	33	2.2:1	2800
AMF-8B-080180-60-30P	8–18	31	2	6	30	2:1	2000
AMF-6B-080180-80-33P	8–18	35	2.5	8	33	2:1	2800
AMF-5B-120180-60-28P	12–18	18	2	6	28	2:1	1600
AMF-6B-120180-50-28P	12–18	24	2	5	28	2:1	1700
AMF-8B-120180-60-30P	12–18	33	2	6	30	2:1	2000
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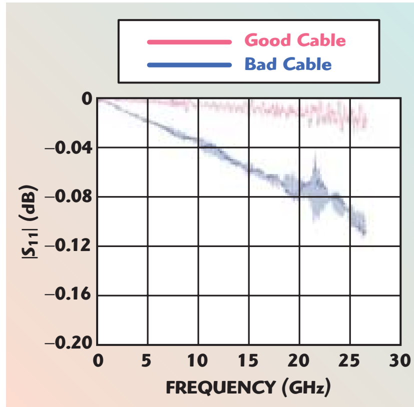
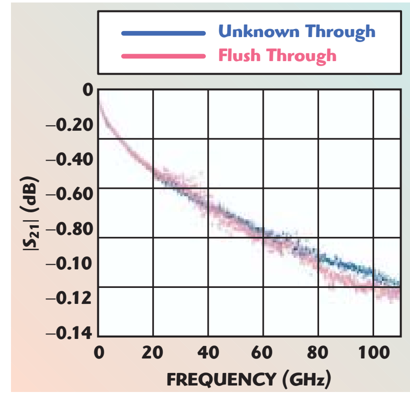
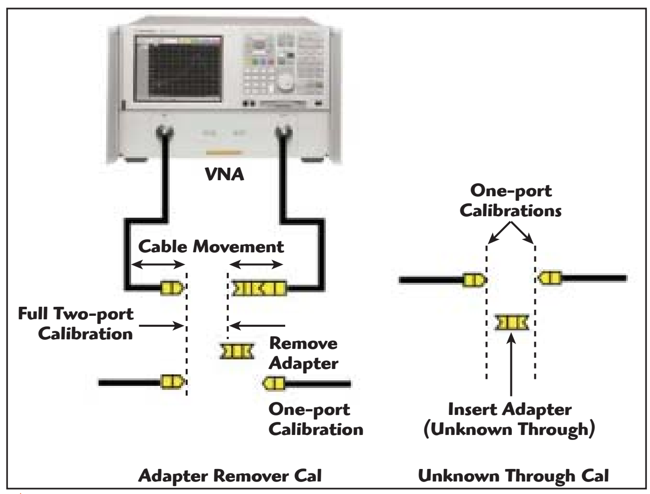


▲ *Fig. 11 Errors caused by cable bending.*

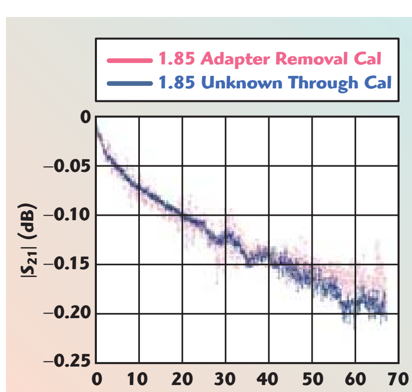


▲ *Fig. 12 Comparison of S_{21} measurements of a 3.5" long cable.*



▲ *Fig. 13 Adapter removal calibration sequence versus unknown through calibration.*

sliding load. A customized set of definitions for each calibration device was provided. A standard open, short, load (OSL) sliding load calibration was performed using this kit. The Agilent 85058B kit, with data-based calibration standard models, used the WLS calibration. After calibration, two different devices were measured, a flush short and the flush short at the end of a 5 cm airline. Each device was connected and then measured with each calibration activated. None of the comparison devices were used as calibration standards during either calibration. ***Figures 8***, ***9*** and ***10*** compare the measurements based on the two calibrations.



▲ *Fig. 14 Comparison of S_{21} magnitude measurements of a 1.85 mm female-to-female adapter.*

UNKNOWN THROUGH CALIBRATION

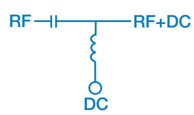
The theoretical base for the unknown through calibration is provided in the literature.[8] This method has the following requirements:

- The systematic errors, directivity, source match and reflection tracking of each test port can be completely characterized.
- The unknown through must be reciprocal, $S_{ij} = S_{ji}$.
- The phase response of the unknown through must be known to within a quarter of a wavelength.
- The VNA signal path switch errors can be quantified. A more detail treatment of this topic was presented in References 9 and 10.

APPLICATIONS

Immobile Test Ports or Physically Long Devices

Quite often, a direct port 1 to port 2 through connection cannot be made because of physical restrictions, such as wafer probe stations and some test fixtures. To calibrate such a system, the traditional SOLT calibration re-



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•TCBT-6G NEW	50-6000	0.7	28	1.2	11.95

TCBT Actual Size .15"x.15" *LTCC*

•*Patent Pending*

Model	Freq (MHz)	Insertion Loss (dB)	Isolation (dB)	VSWR (:1)	Qty.1-9
JEBT-4R2G	10-4200	0.6	40	1.1	39.95
JEBT-4R2GW	0.1-4200	0.6	40	1.1	59.95
PBTC-1G	10-1000	0.3	33	1.10	25.95
PBTC-3G	10-3000	0.3	30	1.13	35.95
PBTC-1GW	0.1-1000	0.3	33	1.10	35.95
PBTC-3GW	0.1-3000	0.3	30	1.13	46.95
ZFBT-4R2G	10-4200	0.6	40	1.13	59.95
ZFBT-6G	10-6000	0.6	40	1.13	79.95
ZFBT-4R2GW	0.1-4200	0.6	40	1.13	79.95
ZFBT-6GW	0.1-6000	0.6	40	1.13	89.95
ZFBT-4R2G-FT	10-4200	0.6	N/A	1.13	59.95
ZFBT-6G-FT	10-6000	0.6	N/A	1.13	79.95
ZFBT-4R2GW-FT	0.1-4200	0.6	N/A	1.13	79.95
ZFBT-6GW-FT	0.1-6000	0.6	N/A	1.13	89.95
ZNBT-60-1W	2.5-6000	0.6	45	1.10	82.95

NOTE: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports

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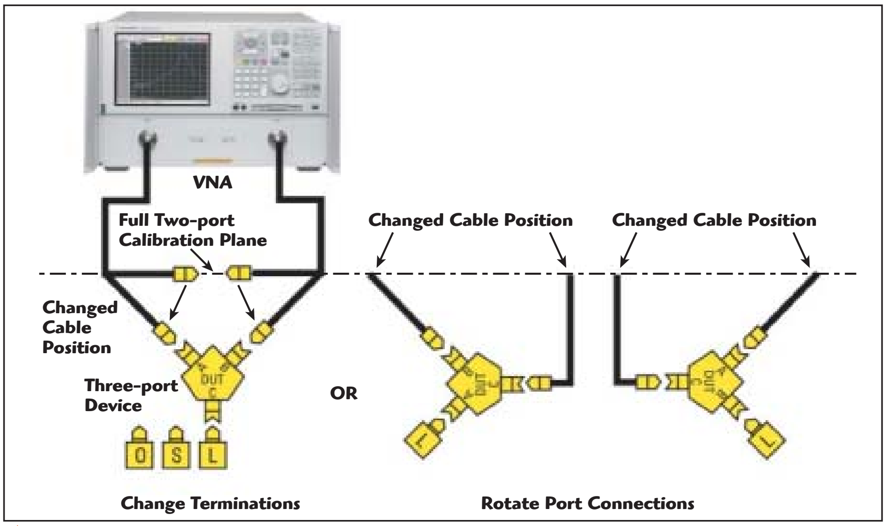

Fig. 15 Measuring a three-port device with a two-port VNA using the conventional method.

quires a known through adapter or cable assembly. These known devices require periodic re-characterization to maintain calibration accuracy. In addition, uncertainties of the known through characterization are propagated to the uncertainties of the transmission tracking terms and the load match terms. No characterization is needed using the unknown through calibration method.

Test port cables, even the best ones, degrade calibration accuracy when moved. ***Figure 11*** shows how much transmission error some cables can cause with a 90° bending. For physically long devices, the test ports must be moved substantially from the calibration through position. By using the unknown through calibration method, the test ports can be placed and calibrated at the connection point and thus cable movements are reduced. ***Figure 12*** shows the difference between a traditional flush through calibration and the unknown through calibration. Notice that the unknown through results are less noisy and less spurious. The total movement is only 3.5 inches.

Non-insertable Devices

To test non-insertable devices, the adapter removal calibration has been used. It usually requires two full two-port calibrations or one full two-port calibration plus a one-port calibration. In contrast, the unknown through calibration is as simple as a standard SOLT calibration, as illustrated in ***Figure 13***. ***Figure 14*** compares the measurement results of the two calibration methods. A 1.85 mm female-to-female adapter was measured using the two calibration methods. Again, the unknown through calibration provided a cleaner measurement.

Not In-line Test Ports and Multi-port Devices

When the test ports of the device under test are not in-line, the test port cable(s) must be bent and moved to accommodate their respective orientation. This is especially true for multi-port devices such as power splitters and directional couplers.

Many characterization methods have been proposed to extract three-port S-parameters from two-port measurements.[11] Because most three-port devices are non-insertable devices, an adapter removal calibration method must be used. To measure a three-port device with a two-port network analyzer, the device must be measured three times, as illustrated in ***Figure 15***. In addition, most three-port devices do not have in-line connectors. Test port cables need to be moved and bent to accommodate the device's connector orientations. These cable movements, after calibration, cause degradation to the measurement accuracy. The unknown through calibration method minimizes these cable bending and movements, as illustrated in ***Figure 16***.

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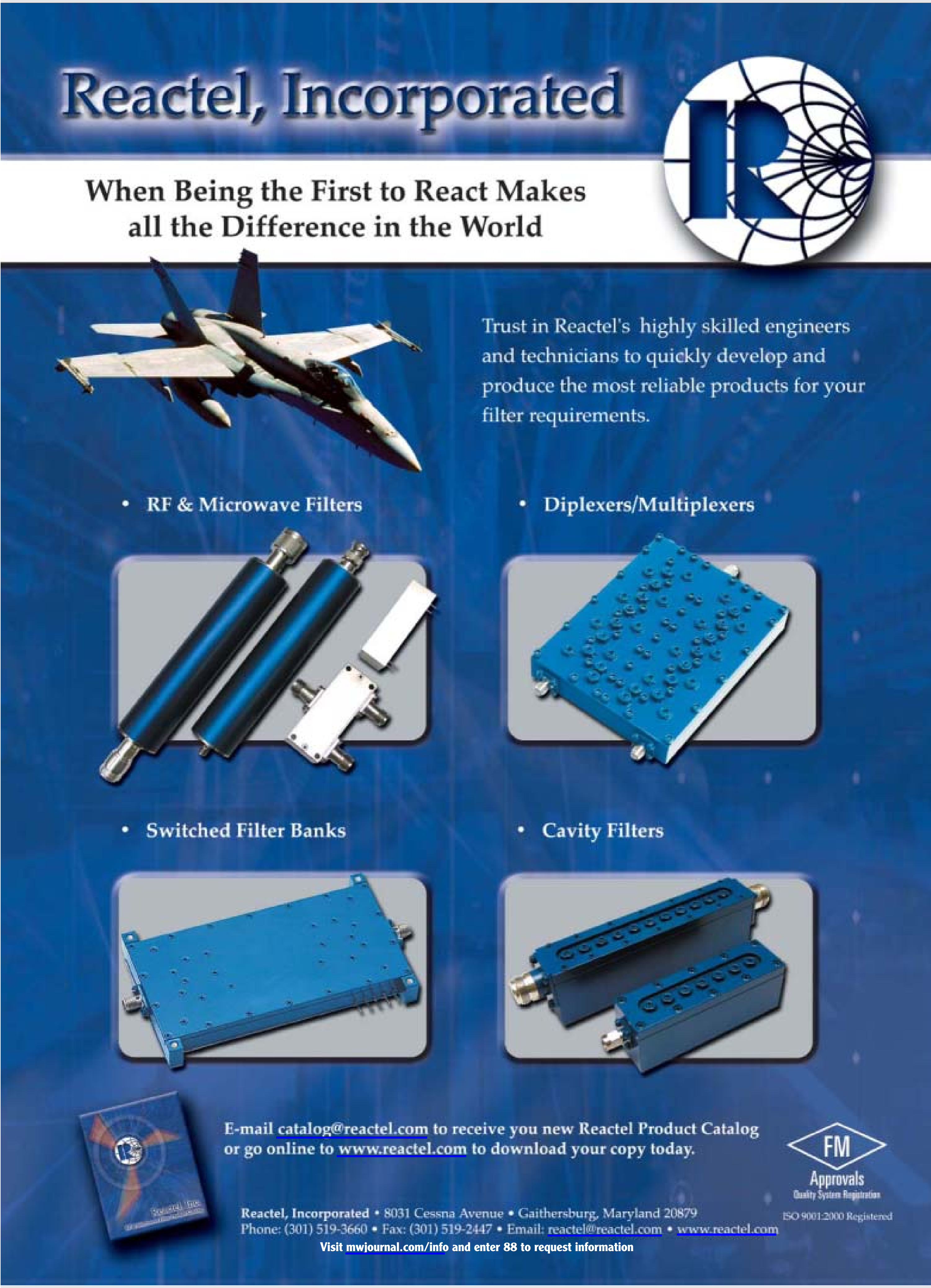
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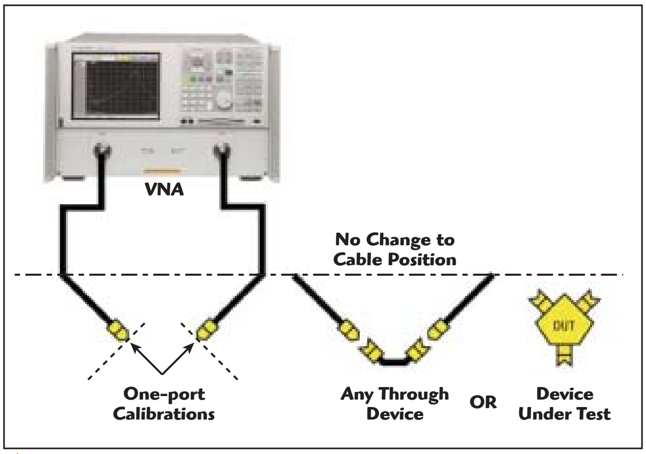
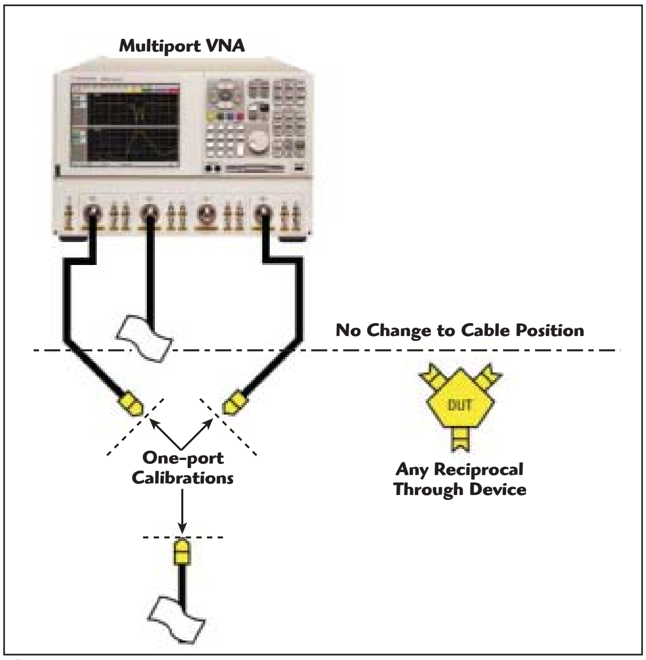


▲ *Fig. 16 Measuring a three-port device with a two-port VNA using the unknown through method.*

In conjunction with the unknown through calibration, a two-port to three-port reconstruction method is proposed to characterize the S-parameters of three-port devices.[12] This makes reciprocal three-port measurements almost as simple as two-port measurements.

If a multi-port VNA is available, the multi-port calibration is greatly simplified by using the unknown through method.[13] Each test port is calibrated first using the appropriate one-port calibration standards, mechanical or electronic. Any connector combination is allowed. A minimum set of adapters, cables or even the device under test can be used as the unknown through to finish the calibration. For example, a power splitter or a directional coupler can be the unknown through since it meets the reciprocity requirement, as shown in ***Figure 17.***



▲ *Fig. 17 Multi-port VNA using the unknown through calibration method.*

CONCLUSION

The enhancements to vector error correction, provided in the new generation of VNAs, open the possibility to more accurate measurements and greater flexibility in the calibration process. Data-based standards eliminate the standard modeling challenges previously faced. Now users have a convenient way to model accurately a variety of standards, including on-wafer standards, stripline standards, microstrip standards, etc. This article also demonstrates the unprecedented accuracy that weighted least squares calibration has achieved. The unknown through calibration makes non-insertable calibration as simple as insertable calibration and at the same time minimizes errors caused by test port cable movements. It also eliminates the need of a "perfect through" to calibrate a multi-port network analyzer. ■

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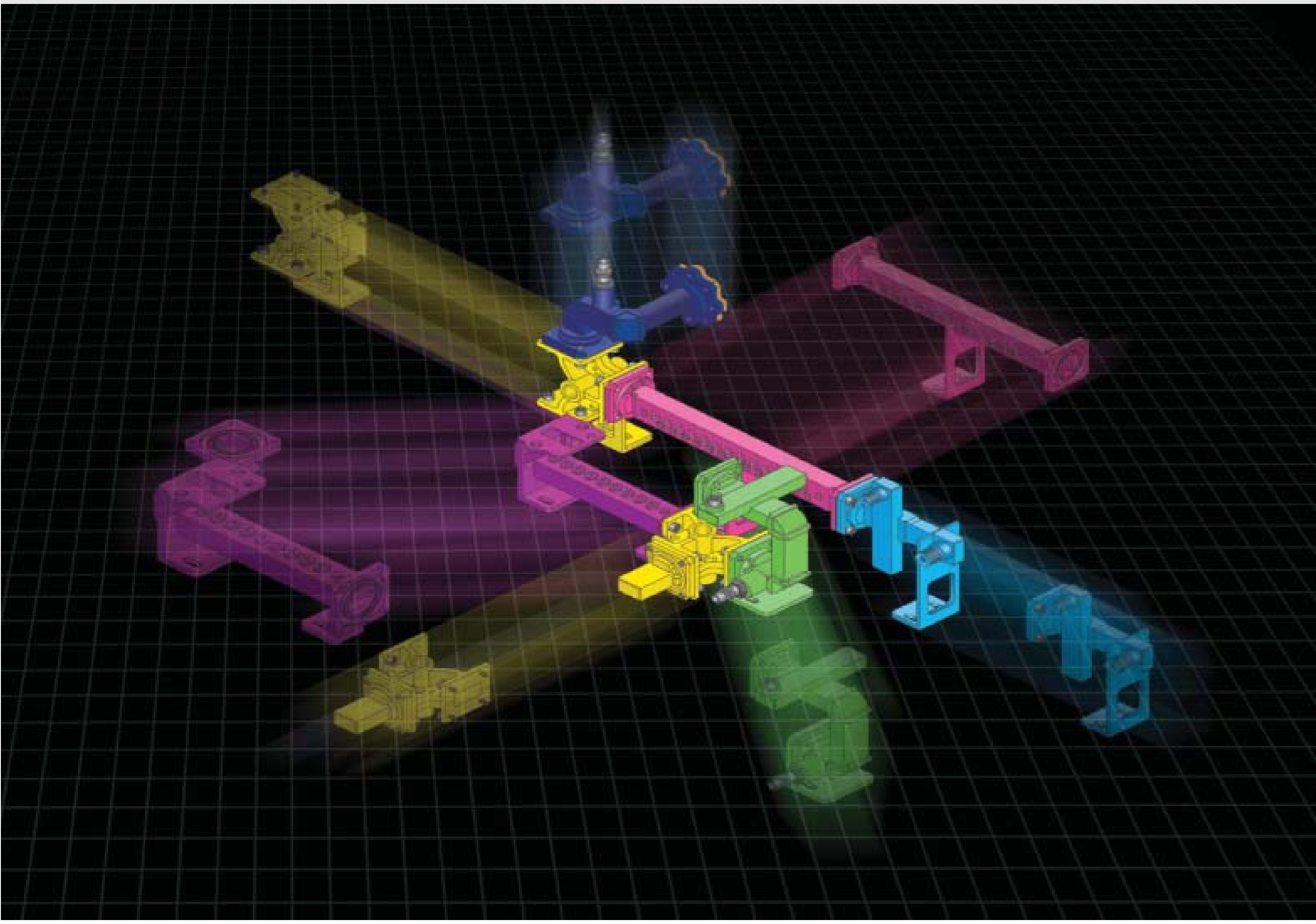

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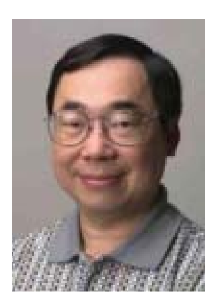

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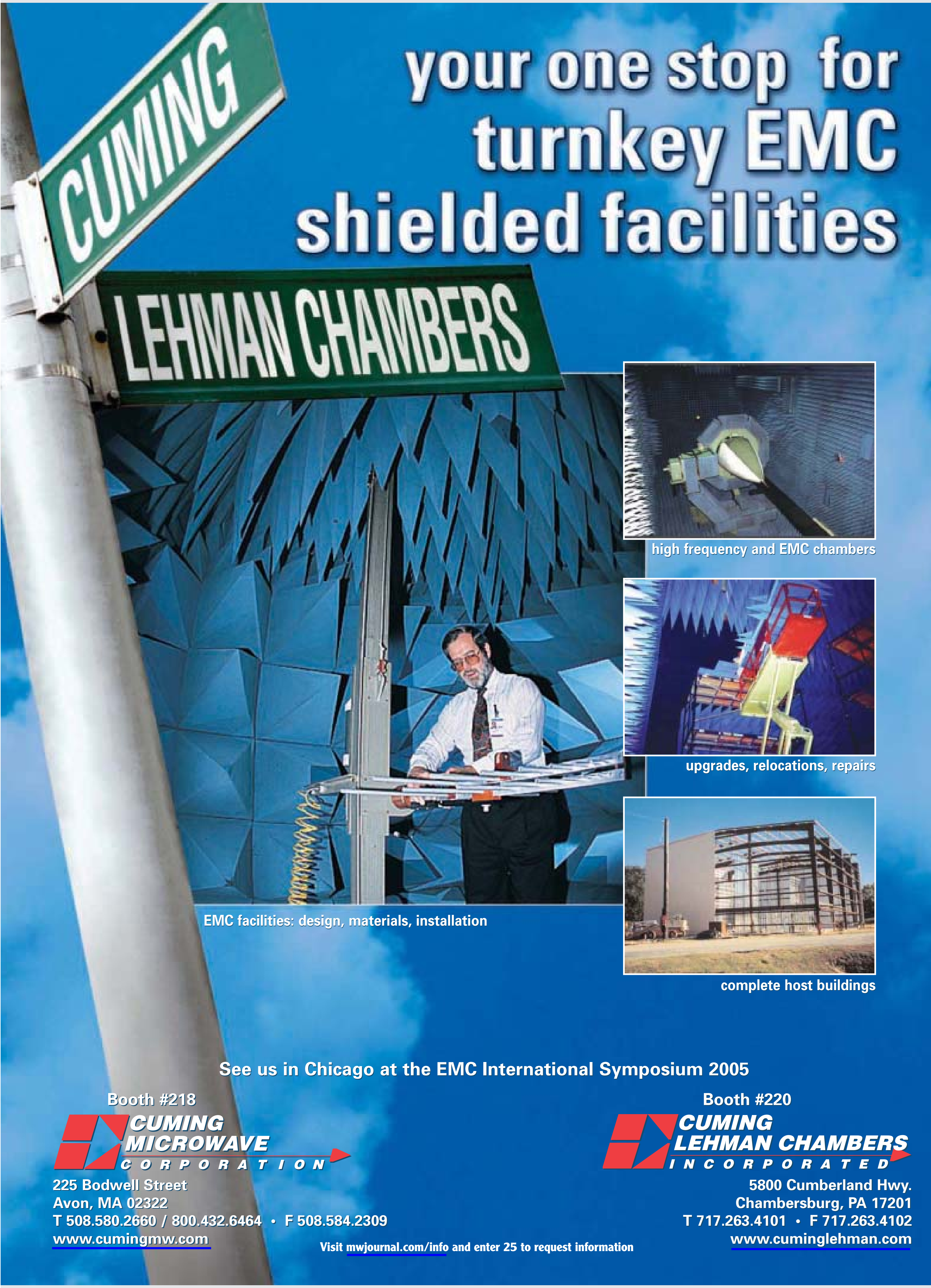
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APPENDIX A

Data-based standards are described by a data list. A data-based standard should include a list of frequencies, the actual response for each S-parameter at each frequency and an estimate of the accuracy of the actual response to be used in determining the weighting factor. The example file shows the most basic file format required to define a data-based calibration standard. The file must be saved as a text file with a ".dat" suffix.

EXAMPLE FILE

```
CITIFILE A.01.01
COMMENT MODEL: 85058-60101
COMMENT SERIAL NUMBER: NOMINAL
NAME DATA
COMMENT This section describes the s parameter data
and weighting
COMMENT factor for the calibration standard
COMMENT COVERAGEFACTOR is used to scale the
weighting factor
COMMENT S[i,j] is Sij for the standard. Supported formats: RI
COMMENT U[i,j] is the weighting factor for Sij
COMMENT Supported U[i,j] formats: RI, MAG
#PNA COVERAGEFACTOR 2
COMMENT note number of points is 509 below
VAR Freq MAG 509
DATA S[1,1] RI
DATA U[1,1] MAG
VAR_LIST_BEGIN
0
10000000
15000000
…
70000000000
VAR_LIST_END
BEGIN
–1,0
–0.99976354927,0.00249289367
–0.99970950119,0.00367766097
…
0.9772034982,–0.14575300423
END
BEGIN
0.00028
0.00028
0.00028
…
0.005
END
```

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M423	.01-220	300	55
M404	.01-220	500	57
M406	.01-220	1000	60
TCCX2000	.01-220	2000	63
TCCX2200	.01-220	2200	63
TCCX2500	.01-220	2500	64
CMX Series • .01-1000 MHz			
CMX3001	.01-1000	300/100	55/50
CMX3002	.01-1000	300/200	55/53
CMX3003	.01-1000	300/300	55/55
CMX5001	.01-1000	500/100	57/50
CMX5002	.01-1000	500/200	57/53
CMX5003	.01-1000	500/300	57/55
CMX10001	.01-1000	1000/100	60/50
CMX100010	.01-1000	1000/1000	60/60

Microwave Solid State and TWT Amplifiers

Model Number	Freq Range (GHz)	Min Pwr Out (Watts)	Min Sat Gain (dB)
T-200 Series • 200-300 Watts CW 1-21.5 GHz			
T251-250	1-2.5	250	54
T82-250	2-8	250	54
T188-250	7.5-18	250	54
T-500 Series • 500 Watts CW 1-18 GHz			
T251-500	1-2.5	500	57
T7575-500	2.5-7.5	500	57
T188-500	7.5-18	500	57
MMT Series • 5-150 Watts, 18-40 GHz			
T2618-40	18-26.5	40	46
T4026-40	26.5-40	40	46
S/T-50 Series • 40-60 Watts CW 1-18 GHz			
S21-50	1-2	50	47
T82-50	2-8	50	47
T188-50	8-18	50	47

Solid State Amplifiers

Model Number	Freq Range (MHz)	Min Pwr Out (Watts)	Min Sat Gain (dB)
SMCC Series • 200-1000 MHz			
SMCC350	200-1000	350	55
SMCC600	200-1000	600	58
SMCC1000	200-1000	1000	60
CMC Series • 80-1000 MHz			
CMC250	80-1000	250	54
CMC500	80-1000	500	57
CMC1000	80-1000	1000	60
SMX Series • .01-1000 MHz			
SMX100	.01-1000	100	50
SMX200	.01-1000	200	53
SMX500	.01-1000	500	57
SVC-SMV Series • 100-1000 MHz			
SVC500	100-500	500	57
SMV500	500-1000	500	57

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A BROADBAND DESIGN FOR A PRINTED ISOSCELES TRIANGULAR SLOT ANTENNA FOR WIRELESS COMMUNICATIONS

Microstrip-line-fed, printed isosceles triangular slot antennas, with a small rectangular slot for broadband operation, are proposed and experimentally investigated. Both impedance and radiation characteristics of these antennas are studied. Experimental results indicate that a 2:1 VSWR is achieved over a bandwidth of 2.9 GHz, between 2.33 and 5.23 GHz, which is nearly 4.6 times that of conventional microstrip-line-fed, printed isosceles triangular slot antennas.

In present-day wireless communication equipment, the need for antennas of high efficiency has generated much interest in the study of microstrip antennas. These printed microstrip antennas exhibit a low profile and are lightweight. However, microstrip antennas have inherently narrow bandwidths and, in general, are half-wavelength structures, operating in the TM_{01} or TM_{10} fundamental resonant mode.[1] In the proposed design, printed isosceles triangular slot antennas, fed by microstrip-line structures, have been designed with improved bandwidth. The printed slot antennas offer the advantages of low profile, lightweight, low cost, wide bandwidth, conformability to a shaped surface and compatibility with integrated circuitry.[2,3] In addition to these advantages, the design has another important point in that it has a simple feed structure, so it is suitable for many applications of wireless communication.

Researchers have made efforts to overcome the problem of narrow bandwidth in coplanar-patch antennas, and various configurations have been presented to extend the bandwidth. Adding a short on the upper slot of the coplanar-patch antenna and varying its length have achieved an impedance bandwidth of 30 to 40 percent[4] at high frequencies for radar applications. However, conventional printed wide slot antennas have an operating bandwidth on the order of 10 to 20 percent.[5] Hence, the broadband design of wide slot antennas has thrown new light on wireless communications. In recent years, several articles[5–7] have been devoted to the study of some printed wide slot an-

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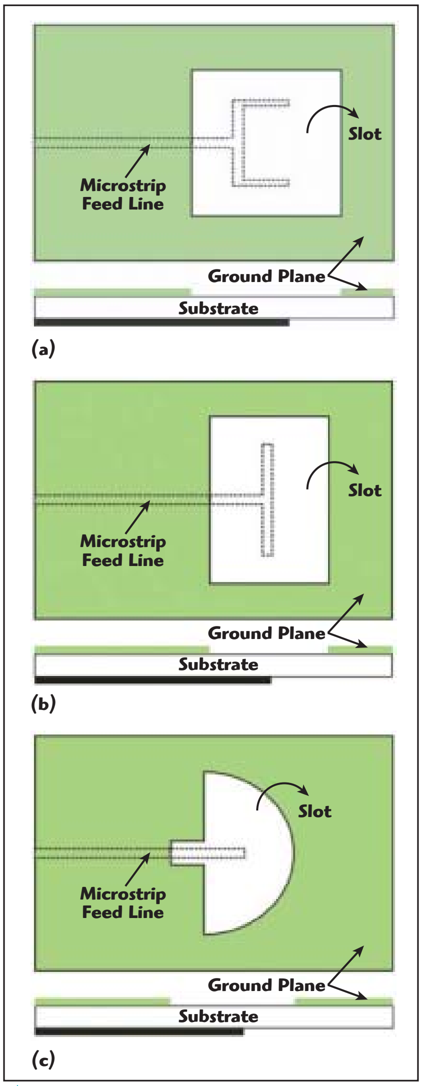


▲ *Fig. 1 Structures of (a) fork-shaped microstrip-line-fed antenna, (b) T-shaped microstrip-line-fed antenna and (c) semicircular slot antenna.*

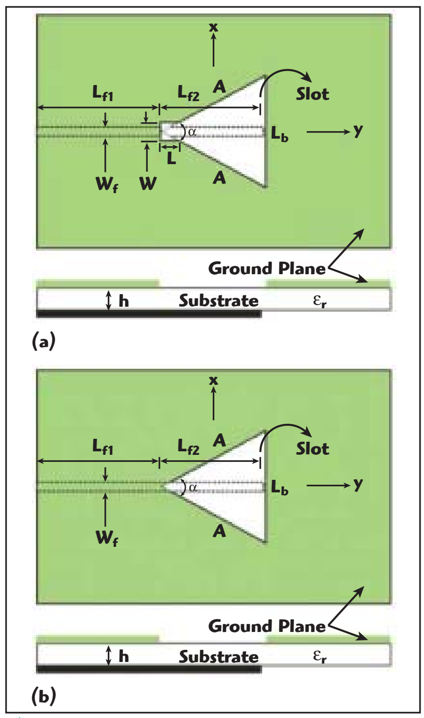
tennas for broadband operation (see ***Figure 1***). ***Table 1*** shows a comparison of the characteristics of these different antenna structures.

This article describes the investigation of the simple design of an isosceles triangular slot antenna for broadband operation. This new design consists of a microstrip-line-fed, printed isosceles triangular slot antenna with a small rectangular slot tuning for extended bandwidth. The radiation characteristics of such a design are also investigated. The microstrip-feed line used in the proposed design is different from the dual-offset microstrip-feed lines used for the excitation of an aperture-coupled patch antenna with a narrow coupling slot.[8–12] Through proper selection of the parameters of the small rectangular slot, it can be expected that the coupling between the microstrip line and the isosceles triangular slot can be controlled more effectively, which makes possible the very broad band of the printed isosceles triangular slot antenna. Experiments show that the impedance bandwidth (VSWR ≤ 2) obtained for the proposed antenna can reach approximately 4.6 times that of a conventional microstrip-line-fed, printed isosceles triangular slot antenna with a simple tuning microstrip line.

TABLE I

CHARACTERISTICS OF THE ANTENNA STRUCTURES

Antenna Structure	*Impedance Bandwidth (MHz, %)*	*VSWR*	*Antenna Gain (dBi)*
Coplanar-patch	2205 to 2695, 20.0	≤ 2.0	2.20 (2450 MHz)
Forked-shape	1821 to 2710, 39.2	≤ 1.5	4.60 (2400 MHz)
T-shape	1800 to 2710, 40.0	≤ 2.0	
Semicircular-slot	1700 to 2734, 46.6	≤ 2.0	4.10 (2400 MHz)
Proposed antenna	2330 to 5230, 76.7	≤ 2.0	4.28 (2450 MHz)



▲ *Fig. 2 Antenna structures; (a) with a slot, (b) without a slot.*

ANTENNA CONFIGURATION

The configuration of the proposed antenna (called Antennas 2 and 4 in this design) is shown in ***Figure 2***. The microstrip-line-fed, printed isosceles triangular slot antenna shows a small rectangular slot of dimensions L × W placed at the vertex of the isosceles triangular slot and centered above the microstrip-feed line. The isosceles triangular slot antenna is fed by a 50 Ω microstrip line, printed on the opposite side of the substrate and placed on the centerline (y axis) of the isosceles triangular slot. The simple tuning microstrip line is composed of a straight section of length L_{f2}. The isosceles triangular slot has sides of length A and a flare angle α. The width of the tuning line is equal to that of the 50 Ω microstrip line (W_f).

By selecting the proper dimensions for these parameters (listed in ***Table 2***), the proposed antenna shows a good impedance matching across a very broad band. The substrate is made of FR-4 material with a height *h* and a dielectric constant ε_r. For comparison, the geometry of a microstrip-line-fed, printed isosceles triangular slot antenna without a

TABLE II

DIMENSIONS OF THE ANTENNAS IN mm (W_f = 3.0 mm, h = 1.6 mm)

	W	*L*	*α (degree)*	L_{f1}	L_{f2}	*A*	L_b
Antenna 1	0	0	55	46.9	57.6	63.9	59.0
Antenna 2	7.6	23.0	55	28.5	67.4	63.9	59.0
Antenna 3	0	0	50	46.5	57.0	62.0	52.5
Antenna 4	6.0	6.0	50	25.6	56.0	62.0	52.5

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- Phase-noise -105 dBc/Hz @ 1 KHz
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Electrical Specifications

Frequency Range	2.0 to 18.0 GHz
Frequency Step	1 Hz
Settling Time	1 microsec max
Output Power	+10 dBm min
Output Power Variation	±3 dB typ.
Internal Reference	
• Frequency	100 MHz
• Accuracy and Temp. Stability	±0.1ppm (optional ±0.01 ppm)
External Reference (Requirements)	
• Frequency	100 MHz
• Input Level	7 dBm
• Impedance	50 Ohm
Spurious	-70 dBc max. up to ±100 MHz from carrier
Harmonics	-50 dBc max.
Phase Noise	- 60 dBc/Hz max @ 10 Hz -90 dBc/Hz max @ 100 Hz -105 dBc/Hz max @ 1 KHz -120 dBc/Hz max @ 10 KHz -125 dBc/Hz max @ 100 KHz -130 dBc/Hz max @ 1 MHz -135 dBc/Hz max @ 10 MHz
Noise Floor	-140 dBc
Wideband FM Modulation	
• Modulation Frequency	DC to 6 MHz
• Deviation	±250 MHz max.
• Modulation Rate	500 MHz / 1 usec
• Frequency Accuracy	±10 MHz
• FM Chirp	
Phase: Coherence	For steps of 1 MHz and above For steps below 1 MHz contact factory
Frequency is Coherent	
Narrowband FM Modulation	
• Modulation Frequency	±50 MHz max
• Modulation Rate	100 MHz / 1 microsec
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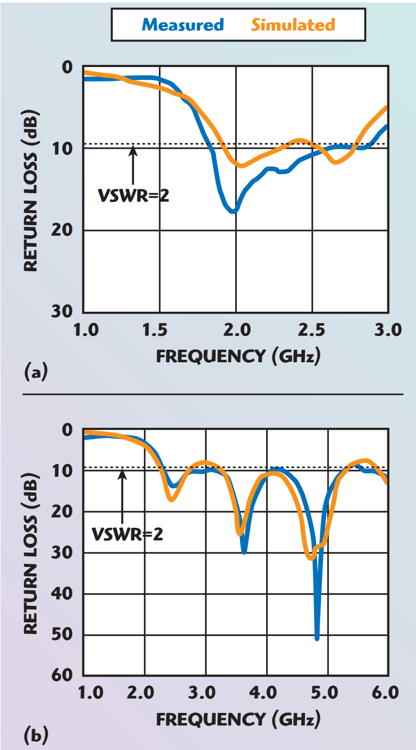


▲ *Fig. 3 Comparison of simulated and measured return losses; (a) Antenna 2, (b) Antenna 4.*

small rectangular slot (called Antennas 1 and 3) is also shown.

EXPERIMENTAL RESULTS AND DISCUSSION

The analysis was performed using the High Frequency Structure Simulator (HFSS) commercial computer software package from Ansoft Technologies, which is based on the finite element method (FEM) technique for arbitrary 3D volumetric passive devices. The simulation procedure was verified by comparison with the experimental results of the antenna's return loss measured with an HP-8753E network analyzer. ***Figure 3*** shows that the measured and simulated results of the proposed design are in good agreement.

The first parameter under design was the flare angle α. Its optimum value was found to be between 50° and 55°. From that numerical experiment, λ_g can be calculated[1]

$$\lambda_g = \lambda_0 \left\{ 0.9217 - 0.277\ln\varepsilon_r + 0.0322\left(\frac{W_f}{h}\right) \bullet \left[\frac{\varepsilon_r}{\left(\frac{W_f}{h}\right)} + 0.435\right]^{0.5} - 0.01\ln\left(\frac{h}{\lambda_0}\right) \bullet \left[4.6 - \frac{3.65}{\varepsilon_r^2\sqrt{\frac{W_f}{\lambda_0}}\left(9.06 - \frac{100W_f}{\lambda_0}\right)}\right]\right\} \quad (1)$$

Table 3 shows λ_g, λ_0, ε_{reff} and $\varepsilon_{reff}/\varepsilon_r$ for all of the proposed antennas designs. A comparison of the two tables shows that decreasing the base of the isosceles triangular slot (L_b) increases ε_{reff} slightly.

Table 4 shows the lowest frequency f_L and the highest frequency f_H of operation and the impedance bandwidth BW (in MHz and percent) for all of the proposed antenna designs.

It is observed that these antennas can be used for different applications. Antenna 2 is suitable for GSM (1900 to 1990 MHz), PCS (1900 to 1990 MHz), IMT-2000 (1920 to 2170 MHz), Bluetooth (2400 to 2484 MHz), IEEE802.11 b/g (2400 to 2484 MHz), PHS (1905 to 1915 MHz), PACS (1930 to 1990 MHz) and UMTS (Regular 1, 2, 3). Antenna 4 is also suitable for Bluetooth, IEEE802.11 b/g, and even for operation in UWB (lower band, 3100 to 5150 MHz), IEEE802.11a (5150 MHz) and HIPERLAN/1/2 (5150 MHz).

TABLE III

λ_0, λ_g AND ε_{reff} FOR THE DIFFERENT ANTENNA DESIGNS

	λ_0 (mm)	λ_g (mm)	ε_{reff}	$\varepsilon_{reff}/\varepsilon_r$
Antenna 1	136.36	107.84	1.598	36.3%
Antenna 2	164.84	131.68	1.567	35.6%
Antenna 3	128.75	101.51	1.608	36.5%
Antenna 4	128.75	101.51	1.608	36.5%

TABLE IV

BANDWIDTH OF THE DIFFERENT ANTENNAS

	f_L (MHz)	f_H (MHz)	BW (MHz, %)
Antenna 1	2200	2600	400, 16.6
Antenna 2	1820	2850	1030, 44.1
Antenna 3	2330	2750	420, 16.5
Antenna 4	2330	5230	2900, 76.7

TABLE V

DIMENSIONS OF THE ANTENNAS NORMALIZED TO λ_g

	λ_g (mm)	L_b	L_{f2}	$L_{circumference}$
Antenna 1	107.84	0.55	0.53	1.73
Antenna 2	131.68	0.45	0.51	1.88
Antenna 3	101.51	0.52	0.56	1.73
Antenna 4	101.51	0.52	0.55	1.98

By observing the influence of the various parameters on the antenna performance, it was found that the dominant factors in the proposed antenna designs are the base of the isosceles triangular slot in terms of λ_g and the perimeter of the slot, defined as $L_{perimeter} = 2(L + A) + W + L_b$. By studying the given designs, it was clear that L_b was about $0.5\lambda_g$ and $L_{perimeter}$ was about $2\lambda_g$. At the same time, the length of the tuning microstrip line (L_{f2}) in all designs was approximately $0.5\lambda_g$, as shown in ***Table 5***. In general, $L_{perimeter}$ controls the resonant frequency while the base of the isosceles triangular slot and the dimensions of the tuning microstrip line control the level of the return loss and the bandwidth.

Further study revealed that the resonant frequency decreases when adding the dimension of the small rectangular slot and by decreasing the length of L_{f1}. Increasing α decreases the impedance bandwidth, especially at the lowest frequency, such that α has an optimal angle. A comparison of Tables 2 and 4 shows that the optimal angle

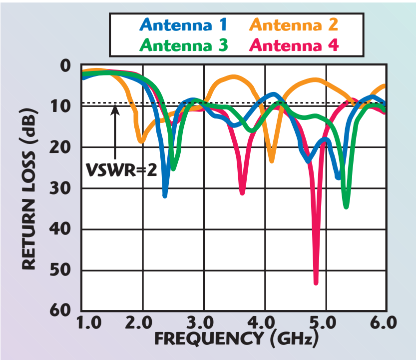


Fig. 4 Measured return loss of the proposed antennas.

is approximately 50°, leading to a broad bandwidth of the printed isosceles triangular slot antenna.

The proposed antenna was measured with an HP-8753E network analyzer. The measured return loss results of these design examples are shown in ***Figure 4***. These results show that there are a number of reasons for Antennas 2 and 4 to have good impedance matching. One is a new resonant mode, in the vicinity of the fundamental resonant mode of the isosceles triangular slot antenna, which can be excited by a 50 Ω microstrip line. Also, good impedance

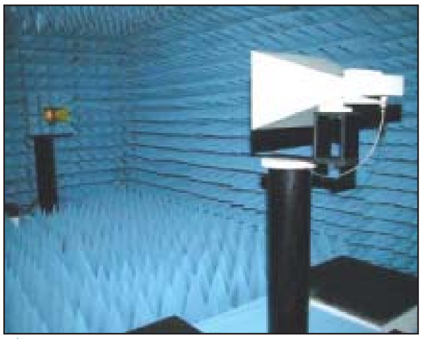


Fig. 5 The STUT Anechoic chamber.

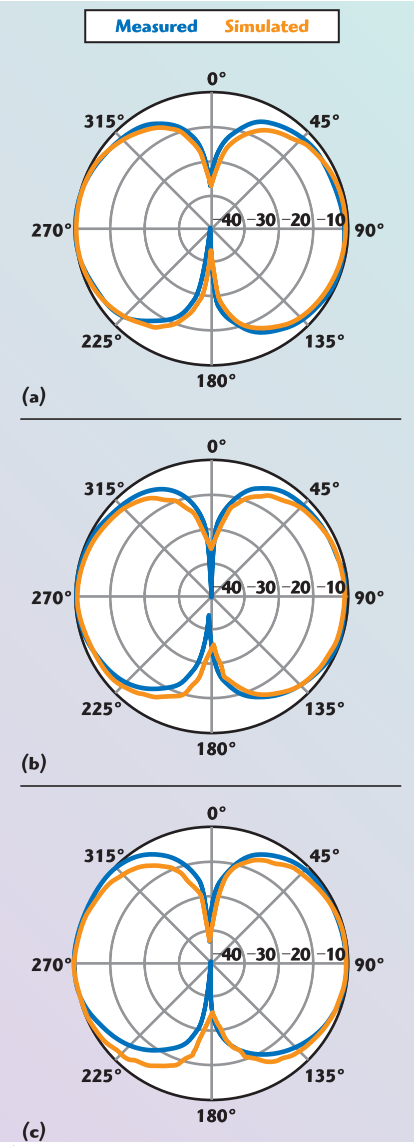
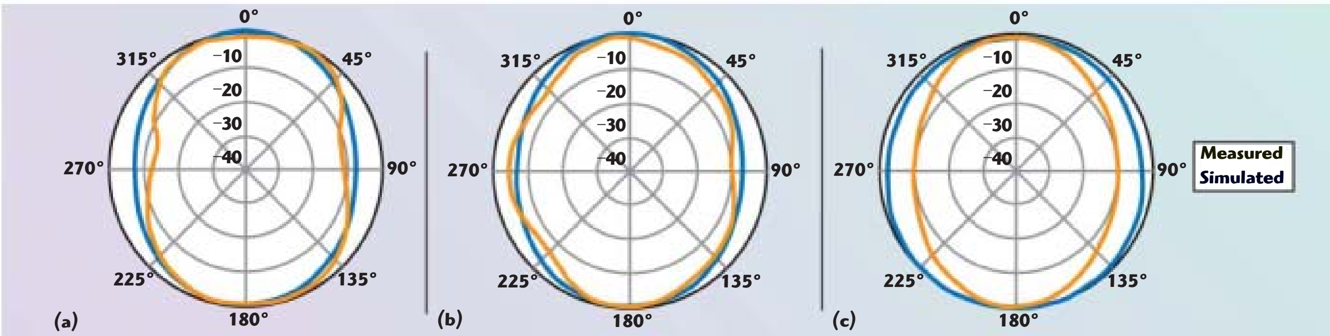


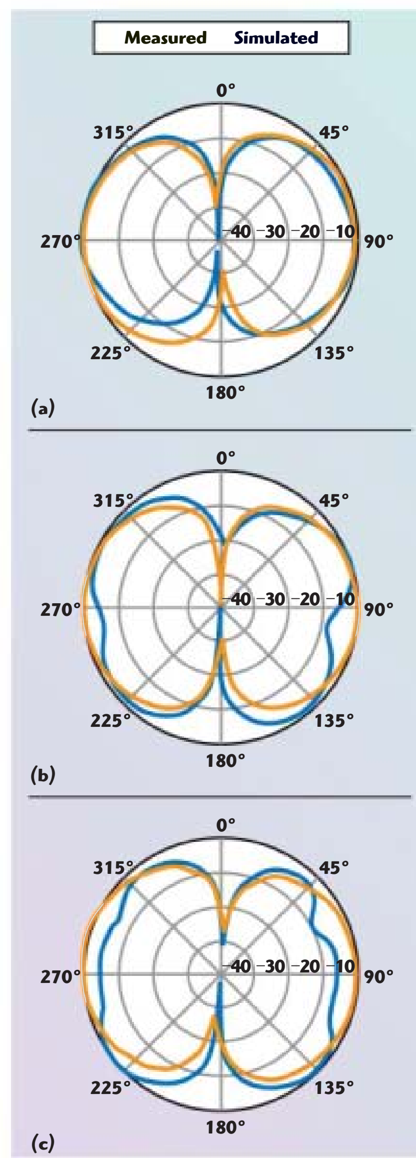
Fig. 6 Far-field radiation patterns of Antenna 2 in the y-z plane; (a) F=1.90 GHz, (b) F=2.20 GHz and (c) F=2.45 GHz.



▲ *Fig. 7 Far-field radiation patterns of Antenna 2 in the x-y plane; (a) F=1.90 GHz, (b) F=2.20 GHz and (c) F=2.80 GHz.*

matching at both the fundamental and the new mode can be obtained, which leads to a very wide operating bandwidth of Antenna 4.

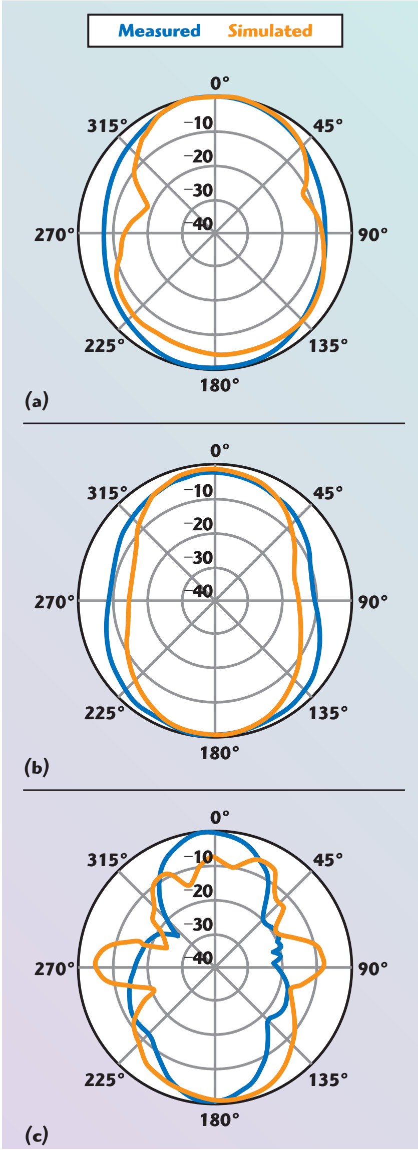
There is one other thing that is important for broadband bandwidth.



▲ *Fig. 8 Far-field radiation patterns of Antenna 4 in the y-z plane; (a) F=2.33 GHz, (b) F=3.65 GHz and (c) F=5.23 GHz.*

The size of the small rectangular slot determines the range of the lower frequency, while the length of the straight microstrip line determines the range of the higher frequency. By using the 50 Ω microstrip line-feed structure of Antenna 4, an impedance bandwidth of approximately 2.9 GHz (for α = 50°) can be obtained. The wider bandwidth of the Antenna 4 design can be greater than 1.7 times that of Antenna 2.

Note that a printed slot antenna without a reflecting plate is a bi-directional radiator, and the radiation patterns on both sides of the antenna are about the same. The proposed antenna shows the same characteristics. The radiation patterns were measured in the STUT Anechoic Chamber shown in ***Figure 5***. ***Figures 6*** and ***7*** show the measured and simulated radiation patterns at f =1.90, 2.20 and 2.80 GHz in the y–z



▲ *Fig. 9 Far-field radiation patterns of Antenna 4 in the x-z plane; (a) F=2.33 GHz, (b) F=3.65 GHz and (c) F=5.23 GHz.*

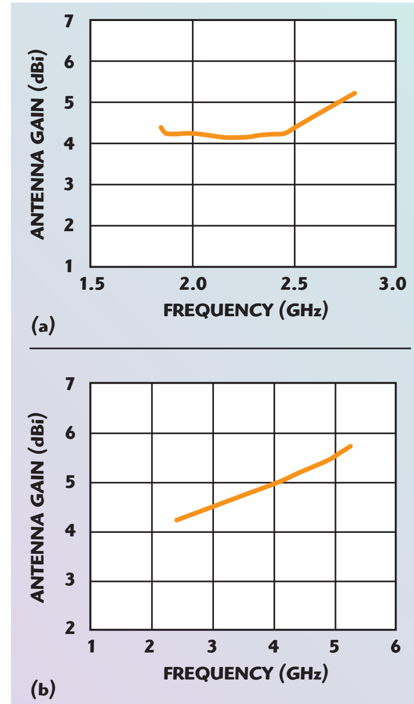
TABLE VI

GAIN OF ANTENNAS 2 AND 4 AT SELECTED FREQUENCIES

Frequency (MHz)	*G (dBi)*
Antenna 2	
1900	4.23
2000	4.28
2200	4.16
2450	4.26
2800	5.25
Antenna 4	
2330	4.13
2450	4.28
3650	4.84
4850	5.52
5230	5.85

plane and the x–z plane for Antenna 2, respectively. ***Figures 8*** and ***9*** show the measured and simulated radiation patterns at f = 2.33, 3.65 and 5.23 GHz in the y–z plane and the x–z plane for Antenna 4, respectively. There is a good agreement between the patterns obtained by measurement and simulation. To summarize, the simulation done by HFSS can predict the proposed antenna performance effectively.

These results can explain that all the operating frequencies have the same polarization plane and similar radiation patterns. It is noted that, for the frequencies within the impedance bandwidth of Antenna 4, approximately 2.9 GHz, the radiation patterns are found to be tilted by a small angle at the higher frequencies, and the maximum radiation direction is no longer in the broadside direction of the antenna. One reason is a mismatch between the microstrip-feed line and the isosceles triangular slot. The more important causes are the non-uniform phase distribution of the field in the isosceles triangular slot and some undesired higher order modes of the printed slot antenna that are also excited. These effects could cause some distortions in the resultant radiation patterns.



▲ *Fig. 10 Measured peak gain of Antenna 2 (a) and Antenna 4 (b).*

Table 6 shows the peak gain of Antennas 2 and 4 over the entire band by showing its values at particular frequencies. It is clear that two designs have similar properties in the entire band. They achieve good power gain, with impedance bandwidth ranges from 44.1 to 76.7 percent, which are required in wireless local area network communication applications. Also, ***Figure 10*** shows the peak gain of Antennas 2 and 4, where the gain variation of Antenna 4 is observed to be less than 1.8 dB and the peak antenna gain of Antenna 4 is about 5.9 dBi.

CONCLUSION

A microstrip-line-fed, printed isosceles triangular slot antenna, with a small rectangular slot for broadband operation has been implemented. Several design examples have been successfully demonstrated. Experimental results show that the impedance bandwidth of a printed isosceles triangular

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IR2640L17*	26–40	26–40	Note 1	15	10	15
M2640W1	26–40	26–40	DC–12	10–12	10	20
TB2640LW1	26–40	26–40	.5–20	10–15	10	20

* Image Rejection typically 15 dB. ** Sub Harmonic
Note 1: IF Option A: 20–40 MHz, B: 40–80 MHz, C: 100–200 MHz, Q: DC–1000 MHz

MULTIPLIERS

Model Number	Frequency (GHz) Input	Output	Input Power (dBm)	Output Power (dBm, Typ.)	Fundamental Leakage (dBc, Typ.)
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SYS2X1734	16–17.5	32–35	+12	+12	-50
SYS3X1442	14	42	+12	+12	-50
SYS4X1146	11	46	+12	+15	-60
SYS2X2040	10–20	20–40	+12	+15	-15
TD0040LA2	2–20	4–40	+10	-5	-20

MIXER/MULTIPLIER ASSEMBLIES

Model Number	Frequency (GHz) RF	LO	IF	LO Power (dBm)	Conversion Loss (dB, Typ.)	Input IP3 (dBm, Typ.)	Fundamental LO-RF Isolation (dB, Typ.)
SYSMM2X2335	23.67–35.33	11.385–17.665	.04–.230	13–15	12	+15	50
SYSMM3X2640	26.5–40	8.8–13.3	DC–.5	10	10	+15	40

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slot antenna can significantly be improved by selecting the proper dimensions of the small rectangular slot and choosing the optimal flare angle α of the printed isosceles triangular slot. The results of this study show that the impedance bandwidth of the proposed antenna can be approximately 2.9 GHz (2.33 to 5.23 GHz), which is approximately 4.6 times that of a conventional microstrip-line-fed, printed isosceles triangular slot antenna (16.6 percent). In this proposed design, an impedance bandwidth of approximately 76.7 percent (VSWR ≤2) has been obtained. This type of antenna will find applications in future wireless communications, such as IEEE802.11 a/b/g, PHS, PCS, GSM, Bluetooth, UMTS, PACS, UWB and HIPERLAN/1/2. ■

ACKNOWLEDGMENT

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A SIZE REDUCTION TECHNIQUE FOR MOBILE PHONE PIFA ANTENNAS USING LUMPED INDUCTORS

A size reduction technique for the planar inverted-F antenna (PIFA) is presented. An 18 nH lumped inductor is used in addition to a small 0.3 cm^3 PIFA. The PIFA is located on dielectric foam, 5 mm above a 40 mm × 100 mm ground plane. It is possible to reduce the center frequency ($|S_{11}|_{min}$) by 33 percent for a fixed physical size. The measured –6 dB bandwidth is 6.7 percent with a peak radiation efficiency of 88 percent.

The demand for smaller communication devices for personal communication systems has led to a constant search for methods to reduce the cellular phone dimensions. However, the wavelength does not decrease with the same speed as the size of the mobile phones due to the higher frequency bands used. Even a quarter wavelength antenna, such as the planar inverted-F antenna (PIFA) tends to become too large, thus creating a demand to decrease the volume of the antenna. Size reduction can be accomplished simply by shortening the antenna. However, at lengths shorter than the resonant length, the radiation resistance changes, and the impedance at the terminals of the antenna become reactive. The latter can be compensated for by the use of one or more inductors connected in series with the antenna for cancellation of the capacitance, thus improving the impedance match[1] and ultimately the efficiency.[2] The idea of using a lumped inductor in conjunction with an antenna has often been used in connection with low frequency antennas where the physical size might be several hundred meters.[3] To date, however, it has found very little use in mobile telephony.[4]

It has been demonstrated[3,4] that the highest advantage is gained by placing the inductor at the center of each antenna arm, instead of at the input. In this article, the results of investigations regarding both the location of the inductor as well as the inductance value are presented. For many practical applications, it is more suitable to place the inductor almost at the input. In this way, no inductor is located on the antenna element itself, but rather on the supporting structure or on the ground plane. In fact, the main objective of this article is to present the results of numerical and experimental investigations of the size reduction of a PIFA by the use of a lumped inductor. As an intermediate target, the aim is to reduce the center frequency by 33 percent for a fixed physical size of the antenna. The antenna performance, in terms of the radiation properties,

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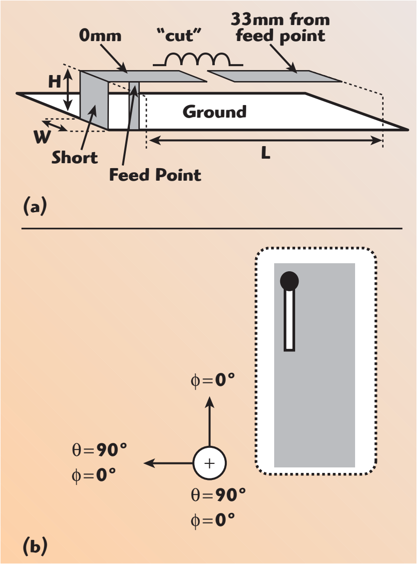
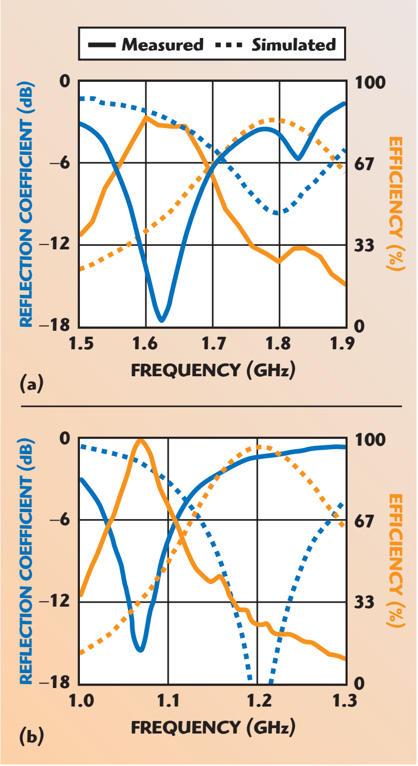


▲ *Fig. 1 Schematic of the PIFA located above a ground plane (a), and antenna orientation in spherical coordinates (b).*



▲ *Fig. 2 Simulated and measured reflection coefficient and radiation efficiency for the unloaded 40 mm (a) and the unloaded 60 mm (b) long PIFAs.*

scattering parameters, electrical near-field distribution and current distribution, is simulated and verified by measurements.[5-8] The evaluation of the antennas in terms of the electrical field distribution and current distribution on the antenna element as well as on the ground plane has been accomplished using planar near-field measurements.[9–12] The near-field is usually transformed to far-field data. Nevertheless, it is the raw unprocessed near-field data that is presented and used in this article.

MATERIALS AND METHODS

The antenna configuration considered consists of a 40 mm long, 1.5 mm wide and 5 mm high PIFA located on a 40 mm × 100 mm ground plane. In all the prototypes, Rohacell material ($\varepsilon_r = 1.06$) is used as the supporting structure of the antenna. The antenna is located at the edge and parallel to the 100 mm edge, as illustrated in ***Figure 1***. The feed point is located 5 mm from the edge where a 90° bend forms the short to the ground plane. In the cases where the inductor is incorporated on the antenna element, a 0.5 mm wide gap is cut in the antenna arm. In order to determine the optimal set-up with respect to the antenna performance, the location of the inductor is varied. Hence, the cut is moved from almost at the feed point, the 0.5 mm case, towards the open end, the 33 mm case.

A planar scanner is used to perform the measurements.[7] The step size is 4 mm leading to a total of 496 measurement points for a 60 mm × 120 mm area. This area covers the ground plane plus an additional 10 mm on each side of the ground plane.[9] A three-dimensional E-field probe is used for these measurements. The probe is designed for electrical near-field component measurements up to 3 GHz.[8] The measurements are carried out at 1.06 GHz, that is, the measured centre frequency ($|S_{11}|_{min}$) of both the 40 mm loaded as well as the 60 mm unloaded antenna. The measurement facility gives the total amplitude of the electrical fields. These measurements are compared to results obtained from the IE3D computer program used.[6]

In the planar scanning technique the probe is moved in a plane situated in front of the antenna and the received signal (amplitude) is recorded. The position of the probe is characterised by the coordinates (x, y, z_0) in the xyz coordinate system of the antenna. During the scanning, z_0 is kept constant, while x and y is varied. The field is measured at a distance z_0 = 3.2 mm, which corresponds to a free space distance of $\lambda_o/90$, equivalent to an electrical length of 4°. It should be noted that the distance between the ground plane and the measurement plane is 8.2 mm ($\lambda_o/35$), since the antenna height is 5 mm.

THE UNLOADED PIFA

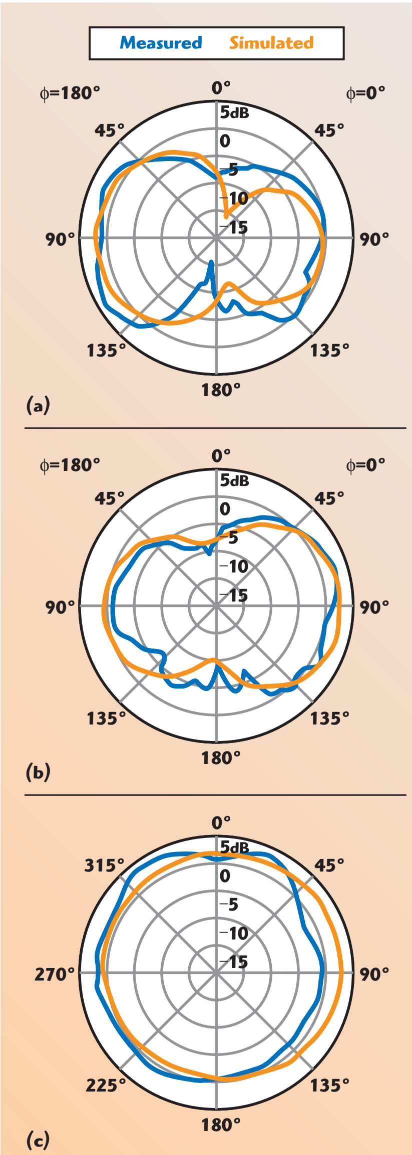
In order to validate the performance of the loaded antennas, an unloaded prototype having the same dimension has been fabricated (L × W × H) = (40 mm × 1.5 mm × 5 mm). This antenna has a somewhat higher centre frequency compared to the loaded antennas. Therefore, a larger unloaded antenna that has the same centre frequency ($|S_{11}|_{min}$) as the loaded antenna is also presented (60 mm × 1.5 mm × 5 mm). In this way, a more realistic comparison can be made.

The simulated and measured reflection coefficient and radiation efficiency for two unloaded antennas, 40 mm and 60 mm, are shown in ***Figure 2***. For the 60 mm PIFA the simulated centre frequency ($|S_{11}|_{min}$) is 1.2 GHz, 33 percent lower than the centre frequency ($|S_{11}|_{min}$) for the 40 mm long PIFA, which is 1.8 GHz.

For both antennas, the measured frequencies with the lowest reflection coefficient are approximately 10 percent lower than the simulated results. This difference could be caused by a slight difference in the simulated model and the prototype. The resolution used in the simulation can also cause some discrepancy. Here, converged results are obtained using 20 cells per wavelength and edge cells.[6]

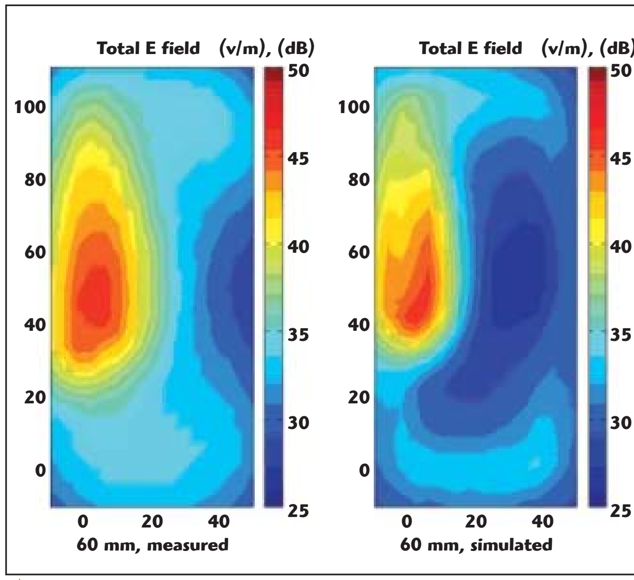
The measured total electrical field components of the radiation patterns for the 60 mm unloaded PIFA, shown in ***Figure 3***, indicate good agreement between the simulated and the measured results. Note that the radiation patterns are obtained at the centre frequency ($|S_{11}|_{min}$); therefore, the simulated patterns are at 1.23 GHz and the measured ones at 1.06 GHz. The measured maximum gain is 3.9 dBi, slightly higher than the simulated gain.

The total electrical near-field distribution at a distance of z_0 = 3.2 mm above the antenna element is shown in ***Figure 4***. Good agreement in terms of peak amplitude and shape of the electrical near-field distribution between



▲ *Fig. 3 Total electrical field components of the radiation patterns for the 60 mm unloaded PIFA; (a) θ cuts for ϕ=0°, (b) for ϕ=90° and (c) ϕ cut for ϕ=90°.*

the simulated and the measured results are obtained; however, more details could be observed from the simulated result. For instance, when observing just above the radiating element, especially at (x, y) = (0, 40–70), a local minimum is found and the edge peak radiation is higher above the ground when compared to that obtained at the side of the ground plane. This is also in accordance with the measured radiation pattern shown previously. In both cases, the peak values are associated with the open end of the antenna, that is at (x, y) = (0, 40). Also, in both cases a minimum is observed at (x, y) = (40, 40), that is at the opposite edge of the PIFA.



▲ *Fig. 4 Measured and simulated total electrical near-field distribution for the 60 mm long unloaded PIFA at 1.06 GHz.*

Either an inductor or a capacitor can be used to reduce the centre frequency ($|S_{11}|_{min}$) from 1.8 GHz as for the 40 mm long PIFA to 1.2 GHz. This frequency reduction corresponds to a size reduction of 33 percent, that is from 60 mm to 40 mm.

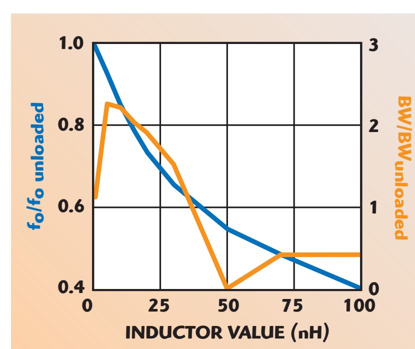
INDUCTOR-LOADED PIFA

Two different tests are made. First, for a fixed location of the inductor, the inductance is varied between 5 and 100 nH. Hereafter, the optimal location is found for a fixed inductance value.

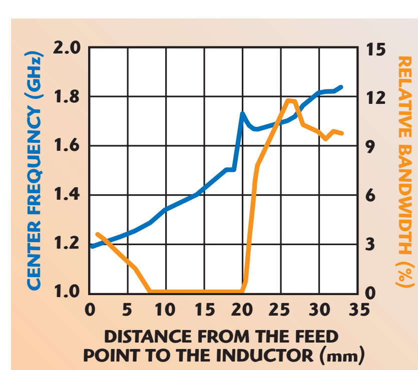
Numerical Results

Locating an inductor 10 mm from the feed point forms the inductor loading. For this fixed location, the simulation results for varying the inductor value between 5 and 100 nH are shown in ***Figure 5***. Here, the centre frequency ($|S_{11}|_{min}$) and the bandwidth are plotted with respect to the 40 mm unloaded case. The centre frequency ($|S_{11}|_{min}$) drops from 1.8 GHz towards 0.87 GHz for inductor values above 70 nH. For values above 35 nH, however, the bandwidth is lower than for the unloaded PIFA. This motivates the choice of an inductor value below 35 nH. Using 5 nH, the bandwidth is 2.3 times the bandwidth for the unloaded PIFA, which is due to the improved impedance match. Between 5 and 35 nH, the optimal inductor value is a trade-off between the decrease in centre frequency ($|S_{11}|_{min}$) and the actual bandwidth. As a compromise, 20 nH is chosen for the rest of the work. Here, the centre frequency ($|S_{11}|_{min}$) is lowered by 30 percent and the bandwidth is almost twice the bandwidth obtained for the unloaded 40 mm case.

For a fixed inductance of 20 nH, various locations of the inductor have been simulated, spanning from almost at the feed point (0.5 mm) toward the open end (33 mm). The simulated centre frequency ($|S_{11}|_{min}$) and relative bandwidth as a function of the location of the inductor, that is the distance from the feed point to the inductor, are shown in ***Figure 6***. The lowest reflection coefficient and the peak efficiency as a function of the inductor location are shown in ***Figure 7***.



▲ *Fig. 5 Center frequency and bandwidth as a function of inductance for a fixed location (10 mm) on the PIFA.*



▲ *Fig. 6 Simulated center frequency and bandwidth versus the inductor location.*

The centre frequency ($|S_{11}|_{min}$) increases almost linearly from 1.2 to 1.8 GHz, when the inductor is moved towards the open end, from a position at 0.5 mm to 33 mm from the feed point. Starting with a 45 MHz or 4 percent bandwidth at 1.2 GHz (0.5 mm) the bandwidth drops due to mismatch, for locations in the range from 5 to 20 mm; hence, no –6 dB bandwidth occurs. The maximum bandwidth of 14.5 percent is obtained at 26 mm, and stabilizes around 10 percent when the inductor is located at positions near the open end of the antenna (30 mm to 33 mm).

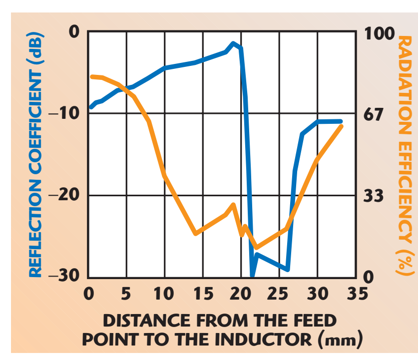
The peak efficiency starts at 75 percent and ends at 60 percent, close to the feed point (0.5 mm) and the open end (33 mm), respectively. At locations below 5 mm, the efficiency is higher than 75 percent. Above 5 mm, a decrease in the efficiency is observed, and the efficiency is below 50 percent from 10 to 30 mm. Above 31 mm, the reflection coefficient is –11 dB and the efficiency exceeds 50 percent, and reaches a peak of 60 percent at 33 mm. In between, the efficiency has dropped to 17 percent at the 21 mm location.

The lowest reflection coefficient changes from –9 to –1.5 dB when the distance from the feed point to the inductor increases from 0.5 to 20 mm. From 21 to 26 mm the reflection coefficient peaks at –30 dB, ending at –11 dB for locations above 30 mm.

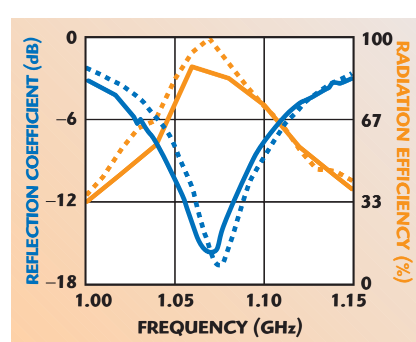
Experimental Results

Based on the results from the parameter study, a prototype 40 mm long PIFA, loaded with an inductor, has been measured with respect to radiation efficiency and reflection coefficient. A lumped 18 nH inductor is used in the experiments.[13] The inductor has an inductance of nearly 20 nH in the frequency range of interest. The results, compared to the unloaded 60 mm long PIFA, are shown in ***Figure 8***.

For the PIFA without any inductor, the centre frequency ($|S_{11}|_{min}$) is 1.06 GHz with a peak return loss of



▲ *Fig. 7 Simulated reflection coefficient and radiation efficiency versus the inductor location.*



▲ *Fig. 8 Comparison of the measured reflection coefficient and efficiency of a 60 mm long, unloaded PIFA (dashed line) and 40 mm long PIFA loaded with an inductor (solid line).*

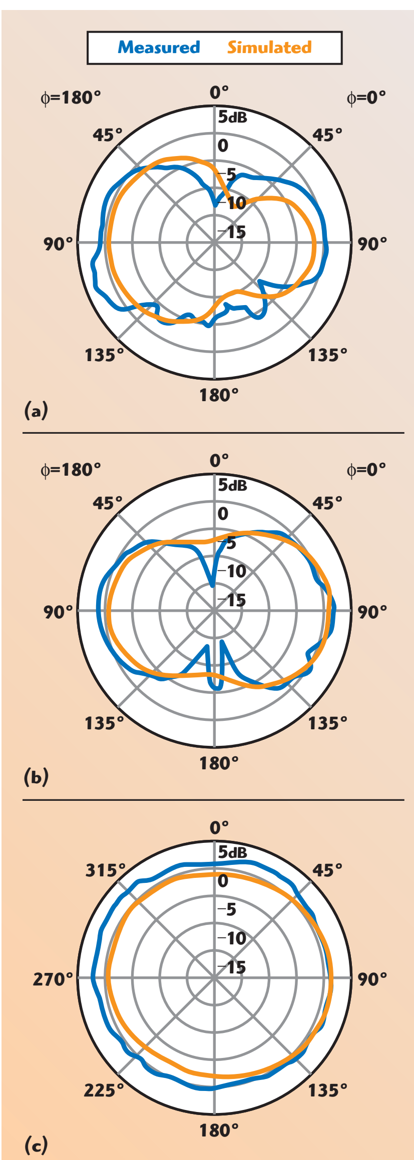
16.5 dB. The bandwidth is 7.3 percent (78 MHz). The measured efficiency is greater than 65 percent within this frequency range of interest, where the peak efficiency is 85 percent. By loading this antenna with an 18 nH inductor soldered at the gap, just 0.5 mm from the feed point, the centre frequency ($|S_{11}|_{min}$) is 1.07 GHz, with a bandwidth of 6.7 percent (71 MHz). The peak efficiency is 88 percent.

The total electrical field components of the radiation patterns, shown in ***Figure 9***, indicate almost omni-directional properties for the 40 mm long inductor-loaded PIFA. There is good agreement between the simulation and measurement results. The measured maximum gain is 3.3 dBi, slightly higher than the simulated gain.

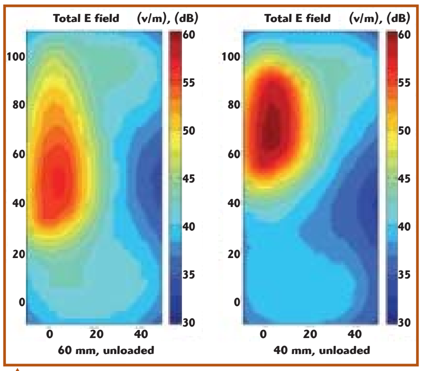
In ***Figure 10***, the measured total electrical field distribution of the 40 mm long, 18 nH inductor-loaded PIFA is compared with the one of the 60 mm long, unloaded PIFA. It indicates a higher amplitude above the inductor-loaded antenna, compared to the 60 mm one. This originates from the higher current distribution that is inevitably present, and thus higher radiation from this area.

In the lower half of the pictures, the electrical field distribution behaves identically, with slightly higher values for the 60 mm case. Also, the null that appears at the opposite side (x, y) = (40, 50) of the PIFA in the 60 mm case could be found in the 40 mm case.

The PIFA is basically an inverted-L antenna that actually comes from a



▲ *Fig. 9 Simulated and measured total electrical field components of the radiation pattern; (a) θ cuts for ϕ=0°, (b) θ cuts for ϕ=90° and (c) ϕ cuts for ϕ=90°.*



▲ *Fig. 10 Measured current distribution for the inductor loaded versus unloaded.*

monopole with a bend such that most of the arm is parallel to the ground plane. This means that the feed point is moved by a certain distance from the ground, here 5 mm from the bend and an additional 5 mm due to the antenna height; hence, the optimum location of the inductor is between 10.5 mm and 15 mm from the ground connection, that is almost one-third the total length of 45 mm (length plus height). Collin[4] argues that the optimum location of an inductor is at the centre of the arm of the monopole; of course, that cannot be compared directly to the PIFA. Nevertheless, this actually holds for the impedance match. If the inductor is located between 21 and 26 mm, a rather good simulated impedance match below –25 dB is observed. In this case the decrease in the frequency, with the lowest reflection coefficient, is not overwhelming, a reduction from only 1.8 to 1.7 GHz. Moreover, the radiation efficiency is below 25 percent. This could indicate that the optimum location for an inductor in the PIFA is closer to the feed point.

Above 21 mm no significant frequency reduction is obtained. At 30 mm, however, the bandwidth is 200 MHz (13 percent), which is higher than the case of no inductor (50 MHz or 3 percent). Thus, the higher bandwidth is at the expense of an inductor in terms of reduced efficiency and the cost of the inductor.

CONCLUSION

A small 0.3 cm^3 PIFA, located on dielectric foam 5 mm above a 40 mm × 100 mm ground plane, is investigated. Adding an inductor on the arm of the PIFA improves the performances for the shown PIFA. The best case with respect to centre frequency ($|S_{11}|_{min}$) reduction is obtained when an 18 nH lumped inductor is placed within the first few millimetres from the feed point. Here, the measured frequency point with the lowest reflection coefficient is decreased by 33 percent, from 1.60 to 1.06 GHz, the reflection coefficient is –16.5 dB, the measured –6 dB bandwidth is 6.7 percent and the radiation peak efficiency is 88 percent.

When comparing the 40 mm inductor-loaded antenna with the 60 mm unloaded antenna, the major benefit includes the reduced size for a fixed centre frequency ($|S_{11}|_{min}$). This, however, comes at the expense of reduced efficiency and bandwidth.

By the use of inductor loading, it is shown that for a fixed size the centre frequency ($|S_{11}|_{min}$) can be decreased. The principle could also be used for a fixed frequency, where a 30 to 40 percent size reduction is expected.

The PIFAs shown are not fully optimized with respect to the occupied volume or frequency, nor is any other component or cover included. Thus, for practical use, both the shape of the antenna and the shape of the distributed inductor should be carefully chosen in order to get the best frequency bandwidth and efficiency performance for a given application. ■

ACKNOWLEDGMENT

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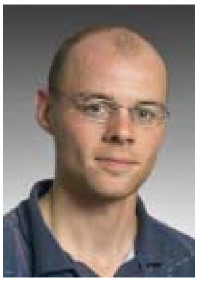

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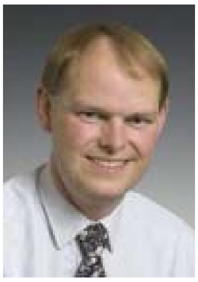

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MULTI-GIGABIT CONNECTIVITY AT 70, 80 AND 90 GHZ

In October 2003, the FCC announced that the frequency bands from 71 to 76 GHz, 81 to 86 GHz and 92 to 95 GHz were available for wireless applications. FCC chairman Michael Powell heralded the ruling as opening a "new frontier" in commercial services and products for the American people. The allocation provides the opportunity for a broad range of new products and services, including high speed, point-to-point wireless local area networks and broadband Internet access at gigabit data rates and beyond.

The significance of the 70, 80 and 90 GHz allocations cannot be overstated. Collectively referred to as E-band, these three allocations are the highest ever licensed by the FCC. Together, the nearly 13 GHz of allocated spectrum represents more than all previously existing commercial wireless spectrum combined. The FCC ruling also permits a novel licensing scheme, allowing cheap and fast allocations to prospective users. All this was achieved at unprecedented speed, from initial FCC petition to formal release of the rules in barely more than two years.

HISTORICAL BACKGROUND

In September 2001, Loea Corp., a spin-off of military research contractor Trex Enterprises, submitted a formal petition to the FCC requesting that spectrum at 71 to 76 GHz and 81 to 86 GHz be opened up for commercial wireless communications. At that time, these frequency bands were reserved for government and military operations, as well as some satellite and radio astronomy applications. The filing quickly received strong support from the wireless and networking community. The Wireless Communications Association (WCA), who was pushing its own 60+ GHz spectrum development initiative, quickly threw its weight behind the petition, as did Cisco and a number of leaders in the wireless communications industry.

Collaboratively, a full proposal for band use and a novel-licensing scheme was developed and presented to the FCC. Based on this proposal, the FCC quickly drafted a set of technical rules for licensed operation in the 71 to 76 and 81 to 86 GHz bands, adding some spectrum between 92 and 95 GHz for unlicensed use. On October 16, 2003, barely two years after Loea's original petition, the FCC wrote the new rules into law, opening up 12.9 GHz of new spectrum under Part 101 regulations.

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TC4-14+	4	A	200-1400	800-1100	1.29
TC8-1+	8	A	2-500	10-100	1.19
TC9-1+	9	A	2-200	5-40	1.29
TC16-1T+	16	A	20-300	50-150	1.59
*TC4-11+	50/12.5	D	2-1100	5-700	1.59
*TC9-1-75+	75/8	D	0.3-475	0.9-370	1.59

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TCML1-19+	1	G	800-1900	900-1400	1.09
TCM2-1T+	2	A	3-300	3-300	1.09
TCM3-1T+	3	A	2-500	5-300	1.09
TTCM4-4+	4	B	0.5-400	5-100	1.29
TCM4-1W+	4	A	3-800	10-100	.99
TCM4-6T+	4	A	1.5-600	3-350	1.19
TCM4-14+	4	A	200-1400	800-1000	1.09
TCM4-19+	4	H	10-1900	30-700	1.09
TCM4-25+	4	H	500-2500	750-1200	1.09
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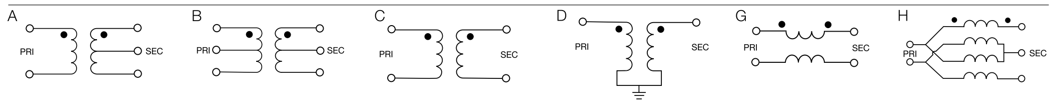

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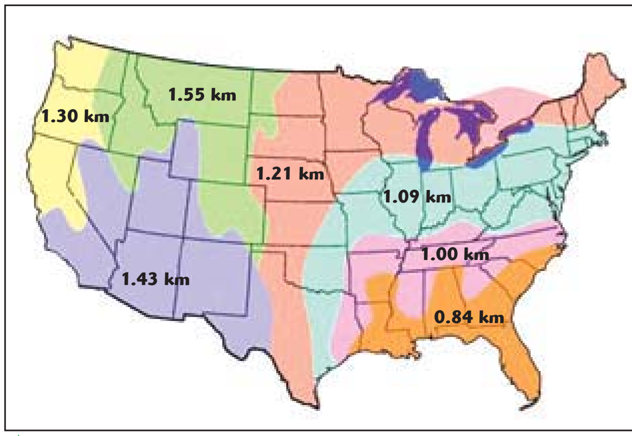

Fig. 1 Link distance for 99.999 percent availability with historical regional weather variations (20 mW transmit power and 2 ft. antenna) (courtesy of Loea Corp.).

WHY 70, 80 AND 90 GHz?

Of the three frequency bands opened up, the 70 and 80 GHz bands are widely viewed as of most interest. Designed to co-exist together, the 71 to 76 GHz and 81 to 86 GHz allocations allow 5 GHz of transmission bandwidth, enough to pass a gigabit of data even with a relatively simple AM modulation scheme. With a more spectrally efficient modulation scheme such as 4-level FSK, full duplex data rates of 10 Gbps (OC-192 or 10GigE) can be reached. With direct data conversion and low cost diplexers, relatively simple and thus cost efficient radio architectures can be realized.

The 92 to 95 GHz allocation on the other hand is far more difficult to work with. Segmented into unequal portions and separated by a narrow 100 MHz exclusion band at 94.0 to 94.1 GHz, the frequency allocation forces lower data throughputs and more complicated filtering schemes, both a deterrent to low cost commercial use.

Propagation characteristics at E-band allow for transmission in excess of a kilometer with carrier class performance (see ***Figure 1***). At 70 and 80 GHz, the atmospheric attenuation is not too much worse than at the popular microwave bands of 18 to 38 GHz. Atmospheric absorption at E-band is much less than at 60 GHz, where oxygen absorption causes high link attenuation, and significantly better than at optical frequencies, where free-space optic systems can experience 200 dB/km attenuation in thick fog. A comparison of typical 70/80 GHz radio performance against main competing technologies is illustrated in ***Table 1***.

E-LICENSING

At E-band, the FCC allows a novel "E-licensing" system for link deployment. Under the traditional auction-based system, the highest bidder (typically a behemoth service provider or a highly debt-leveraged start-up) would be awarded a license to

TABLE I

COMPARISON OF COMPETING TECHNOLOGIES

	70/80 GHz	Microwave Radio (18 to 38 GHz)	Free-space Optics	Buried Fiber
Data rates	to 10 Gbps	to 322 Mbps	to 10 Gbps	virtually unlimited
Typical link distances (99.999% availability)	1 km	5 km	200 m	virtually unlimited
Relative cost of installation and ownership	low	moderate	low	high
Installation time	hours	days	hours	months
Regulatory protection	yes	usually	no	yes

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4 PRINCIPAL JOB FUNCTION:
Select one category from the following list that most closely describes your principal job function.

DESIGN & DEVELOPMENT ENGINEERING
03 ☐ Engineering
02 ☐ Management

ENGINEERING SERVICES
(evaluation, QC, reliability, standards, test)
05 ☐ Engineering
04 ☐ Management

01 ☐ GENERAL AND/OR CORPORATE MANAGEMENT

RESEARCH & DEVELOPMENT
07 ☐ Engineering
06 ☐ Management

MANUFACTURING & PRODUCTION
09 ☐ Engineering
08 ☐ Management/Supervision

10 ☐ ENGINEERING SUPPORT *(draftsman, lab assistant, technician)*

11 ☐ PURCHASING & PROCUREMENT

12 ☐ APPLICATIONS ENGINEERING, SALES AND MARKETING

13 ☐ EDUCATORS

14 ☐ OTHER PERSONNEL *(explain)*

5 PRIMARY END PRODUCT OR SERVICE
Select a primary end product (or service performed) from the following list that most closely describes the end product of the company in which you work.

06 ☐ Communications Systems & Equipment
17 ☐ Cellular Systems & Equipment
26 ☐ WLAN, WiFi
10 ☐ Test & Measurement Equipment
27 ☐ Semiconductor, RFICs, MMICs, etc.
11 ☐ Active Components (including Power Supplies, Subsystems)
12 ☐ Passive Components (including Antennas, Devices, Subsystems)
16 ☐ Government/Military: Research, Design & Engineering
01 ☐ Radar Systems
04 ☐ Navigation, Telemetry Systems, GPS
08 ☐ Data Transmission, Computer Systems
28 ☐ Software Development
05 ☐ Electronic Warfare Systems
03 ☐ Ground Support Equipment, Aircraft/Missile
02 ☐ Weapons Control, Ordnance, Fusing Systems
13 ☐ Materials, Hardware
15 ☐ Industrial/Academic/R&D Laboratories, Consultants
14 ☐ Industrial/Commercial Control, Processing Equipment
29 ☐ Medical Equipment
20 ☐ Consumer Electronics
07 ☐ CATV Broadcast Systems
18 ☐ Automotives/transportation
19 ☐ Security/identification
09 ☐ Laser/Electro-Optical Systems, Equipment
21 ☐ Other *(please specify)*

USER
22 ☐ Government/Military
23 ☐ Industrial/Commercial
24 ☐ Technical Library
25 ☐ Other *(please specify)*

6 YOUR WORK IS PRIMARILY:
(check all that apply)
01 ☐ Below 1 GHz
02 ☐ 1–8 GHz
03 ☐ 9–18 GHz
04 ☐ 19–26.5 GHz
05 ☐ 26.6–40 GHz
06 ☐ Above 40 GHz
07 Other *(please specify)*

7 PLEASE ESTIMATE THE ANNUAL VALUE OF PURCHASES THAT YOU INFLUENCE.
06 ☐ $500,000 or more
05 ☐ $300,000 to $499,999
04 ☐ $100,000 to $299,999
03 ☐ $50,000 to $99,999
02 ☐ $10,000 to $49,999
01 ☐ less than $10,000

8 IS YOUR WORK PRIMARILY:
01 ☐ Commercial
02 ☐ Military

9 WHICH OF THE FOLLOWING PRODUCTS DO YOU RECOMMEND, SUPPORT OR AUTHORIZE TO PURCHASE
(check all that apply)

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01 ☐ Amplifiers (Low Noise)
02 ☐ Amplifiers (Power)
03 ☐ Tubes or Tube Amplifiers
04 ☐ Solid State Oscillators

07 ☐ ANTENNAS & ACCESSORIES
13 ☐ CAD SOFTWARE OR SERVICES

CABLE AND CONNECTORS
16 ☐ General Purpose
17 ☐ Precision or Laboratory

CONTROL COMPONENTS
20 ☐ Switches (Mechanical)
21 ☐ Switches (Solid State)
22 ☐ Attenuators & Phase Shifters

PASSIVE COMPONENTS
26 ☐ Couplers, Hybrids & Power Dividers
27 ☐ Attenuators & Terminations
28 ☐ Filters
29 ☐ Resistors, Capacitors & Inductors
30 ☐ Isolators & Circulators

INSTRUMENTS
37 ☐ Power Meters
38 ☐ Signal & Sweep Generators
39 ☐ Synthesized Signal Sources
40 ☐ Spectrum Analyzers
41 ☐ Network Analyzers
44 ☐ Wave & Modulation Analyzers
42 ☐ Frequency Counters
43 ☐ Oscilloscopes
45 ☐ BER Testers

MATERIALS
47 ☐ Substrate Materials
48 ☐ Absorbing/Reflecting/Shielding Materials
49 ☐ Printed Circuit Boards
50 ☐ Component Hybrid Packages
46 ☐ LTCC

51 ☐ MIXERS AND MODULATORS
55 ☐ OPTOELECTRONIC COMPONENTS

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70 ☐ Diodes
71 ☐ Bipolar Transistors
72 ☐ GaAs FETS, HBT, etc.
73 ☐ MMICs
75 ☐ RFICs
76 ☐ ASICs

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84 ☐ DSP
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solely control a specific frequency band in a defined geographic area. At 70, 80 and 90 GHz, however, any applicant — large service providers such as Sprint or Verizon, end-users such as enterprises, government and military entities, or even individual hardware providers — simply completes an on-line link registration defining the end points of the requested links and pays a small fee. Once coordinated and approved, the successful applicant is permitted to operate along with any other coordinated and approved users in the same frequency and location. FCC chairman Michael Powell has hailed this new concept as revolutionary as increasing competition and reducing bureaucratic slowdown, and suggested a similar approach be adopted in all future rulemakings.

Still in its infancy, only a handful of license applications have been sought and granted, so it is too early to tell whether the new scheme has been successful. However, the promise of this new procedure is very compelling.

SYSTEM PROVIDERS

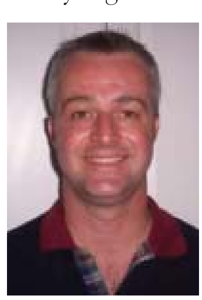
The two leading proponents of the 70 and 80 GHz bands are Loea Corp. and Gigabeam Corp. Based in Hawaii, Loea led the push for the release of the E-band frequencies, and has a growing installed base of commercial products. Loea's most public installation was back in 2003, when millions of Super Bowl XXXVII viewers watched live action shots transmitted through a Loea 70/80 GHz Virtual Fiber link. Traditional elevated shots from a blimp were not permitted due to security restrictions in the airspace above San Diego's Qualcomm Stadium. Loea's wireless Super Bowl link operated at full 720P HDTV output speed, equivalent to 1.485 Gbps, over a 0.5 mile distance.

A second company starting to receive a lot of focus is GigaBeam. Based in Virginia, GigaBeam has a rich wireless pedigree, with the founders being the driving force behind the original FCC approval. Lou Slaughter, CEO and co-founder, commented, "In less than a year since its founding, GigaBeam underwent an innovative Venture Public Offering taking the company public without requiring a round of venture capital funding." GigaBeam recently received a purchase order to install 20 links across New York City. "The network includes links to Trump properties to provide the triple play of high speed voice, data and video to residents," Slaughter added. As yet, no high data rate 94 GHz wireless products have hit the marketplace.

THE FUTURE?

In little more than three years, a whole new industry has been born. The prospects of 10 Gbps data rate, low cost wireless communication systems over distances of a mile or more, are now a reality. Systems will become cheap and quick to license and inexpensive to install and maintain. "70/80 GHz systems are now a serious alternative to fiber," says Loea's CEO, Dan Scharre. "With volume shipments and dropping price points, applications beyond LAN extensions will be realized, opening up such new applications as high definition video-on-demand and wide-area data storage."

Despite this promise, there are still only a few players in this area. The market is restricted in that the rules apply only to the US. No similar bands are yet available internationally. Currently, the FCC rules are being rewritten to tweak some antenna size and output power restrictions that are holding back the realization of low cost architectures. Once this is complete, watch out for the exciting and rapid advance of this fascinating industry segment. ■



Jonathan Wells *received his MBA degree from Massey University, New Zealand, where he specialized in strategic R&D management, and his PhD degree from Bath University, UK, for his work on 94 GHz systems. He is a wireless technology consultant based in San Jose, CA, specializing in strategic marketing and business development of advanced wireless products. He has held a number of business development, marketing and technology management roles, including director of RF engineering for Stratex Networks and director of wideband products for adaptive broadband. He is a senior member of the IEEE, a charter engineer in Europe and is active on the WCA 60+ GHz spectrum development committee. He can be reached at (925) 200 5124 or via e-mail at jonathan@jonathan-wells.com.*

A SELF-EXTINGUISHING GAS CAPSULE PROTECTOR

In modern society, electronic systems impact significantly on everyday life, for individuals, commerce, industry and the community as a whole. Their safe and reliable operation is generally taken for granted, as is the humble surge protector that plays such a vital role in maintaining transceiver structures and ensuring the continued functioning of systems. However, the surge protector need be humble no longer as its development enters a new dimension with the introduction of Huber + Suhner's self-extinguishing protector concept SEMPER to its comprehensive range of lightning gas capsule and surge protectors.

GAS CAPSULE PRINCIPLE

To fully understand the unique importance of this new development consider the gas capsule lightning protector based on the spark gap principle. This method is probably the most widely used in the protection of electronic circuitry against the effects of surge energy that can damage components by exposing them to overvoltage or excessive heating. For many years they have exhibited a high level of reliability when used as overvoltage protective devices.

The main benefits of the standard gas capsule lightning protector — which acts as a low capacitance switch — is its broadband performance (typically from DC to 2.5 GHz), enabling the device to operate at HF, VHF, UHF and cellular frequencies. In addition, as the units make no electrical contact between the inner and outer conductor of the coaxial line, systems using line power for masthead or remote electronics may be accommodated. The level of residual pulse found with these devices plus the ability to withstand multiple strikes at 20 kA (30 kA single strike) makes them an ideal coarse protection device. They can be selected to match specific system requirements and therefore provide versatility to designers.

As with all engineering solutions, however, the ideal solution rarely exists in practice and the drawback with gas capsule lightning protectors is that when an energy surge reaches a gas capsule device, it arcs over once the appropriate spark-over voltage is reached. The arc initiates a short circuit path from the inner

HUBER + SUHNER
Herisau, Switzerland

to the outer conductor (earth) and the energy within the surge pulse is diverted to ground. During this time the Tx/Rx system will be inoperative and will only come back on line when the surge pulse has passed and the capsule returns to its non-activated state.

However, while the capsule is activated the short circuit arc can be sustained by relatively low levels of voltage or current as may be found in line power situations or certain RF transmit power scenarios such as CW power or high pulse power with a very high pulse repetition rate. These characteristics can lead to the gas capsule being 'held on' in its active state rendering the transceiver system inoperative and leading to equipment damage and destruction of the gas capsule due to overheating.

The SEMPER self-extinguishing protector concept, shown in ***Figure 1***, addresses these problems and drives forward the development of gas capsule protectors. Its self-extinguishing operation enables automatic recovery and extinguishes under any coaxial line condition like malfunction of electronic fused DC supplies and malfunction of RF line monitoring. The new capsule unit, shown in ***Figure 2*** alongside a previous version, is available in a range of configurations, including both complete coaxial protectors and a capsule plus holder subassembly, which can be employed for retrofitting for any of the company's gas capsule protectors with exchangeable gas capsule. Cost saving is another important feature as the facility for field replacement enables cost-effective system upgrades, while broadband operation, negligible system downtime and higher safety underscore the benefits.

Fig. 1 The SEMPER self-extinguishing protector.

Fig. 2 The new self-extinguishing gas capsule (gold) shown alongside a previous version.

TECHNICAL SPECIFICATIONS

The SEMPER concept exhibits impressive operating characteristics

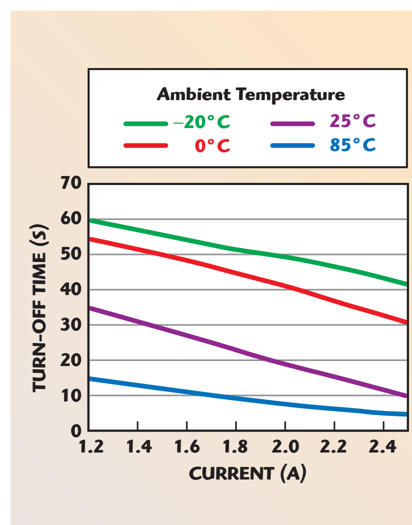


Fig. 3 SEMPER turn-off time performance.

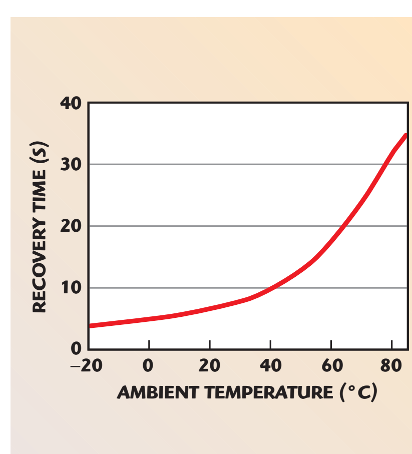


Fig. 4 SEMPER recovery performance.

too, such as a typical turn-off extinguishing time of 20 seconds at 25°C ambient temperature and 2.0 A DC supply current (see ***Figure 3***) as well as a typical recovery time of seven seconds at 25°C ambient temperature (see ***Figure 4***).

SEMPER works under RF and DC conditions in broad and single band units in the frequency range of DC to 2.5 GHz and is also available as a low intermodulation product, typically –150 dBc with a high RF – CW/average and peak power. It has been developed for voltages up to 48 V and power supply short circuit currents up to 2.5 A, as well as for working temperatures from –40° to +85°C (lightning protection functionality) or from –20° to +85°C (SEMPER functionality). Also, the retrofitting of existing Huber + Suhner protectors with the new capsule unit is possible.

WIDE-RANGING APPLICATIONS

With complete unit device and replaceable capsule unit self-extinguishing protector options, lightning protection solutions are available for a very wide range of both civil and military applications and system upgrades. In addition, whereas many applications generally benefit from the enhanced safety and reliability that the SEMPER concept offers, those using DC line power for remote signal amplification and processing and those using high RF power are particularly suitable. Specific applications of note include:

- Feeding DC over coax
- Transmitting high RF power
- Tower mount amplifiers/repeaters
- GPS timing receivers
- Point to point/multi-point radios
- Defense/security radios
- Remote installations

CONCLUSION

Driven by the strategic, safety and commercial pressures applied by system users on the system providers, demand dictates that efficient, cost-effective system surge protection solutions are available to all design engineers/decision makers working with RF transceiver structures. SEMPER, the world's first self-extinguishing gas capsule protector and available as a complete device or as a replaceable capsule unit, meets these requirements. It offers a cost-effective and versatile solution for a wide range of civil and military applications, along with system upgrades.

Huber + Suhner,
Herisau, Switzerland,
+41 71 353 4111,
www.hubersuhner.com.

RS No. 301

Distributed Coupled Voltage-controlled Oscillators

CRO/SAW (coupled-resonator oscillator/surface acoustic wave) resonator-based oscillators are widely used as reference sources in phase-locked loop (PLL) applications, since the technology features very low phase noise at fixed frequencies to beyond 3 GHz. CRO/SAW oscillators are also known for high quality factor (Q) and low phase-noise performance. Unfortunately, CRO/SAW oscillators have several disadvantages, including a limited tuning range (which limits the amount of correction that can be made to compensate for the tolerances of other components in the oscillator circuit), and sensitivity to microphonics and phase hits.

Phase hits are infrequent but cause signal degradation in high performance communication systems, and therefore affect data rate increases and can unlock many communication links if they cannot be absorbed. These phase hits are caused by sudden changes of the crystal structure due to temperature and mechanical stress. As a result, phase hits have become a prime target for elimination. While phase hits have plagued communication equipment for years, today's higher transmission speeds accentuate the problem because of the greater amounts of data affected in a given time period.

Therefore, due diligence must be done upfront by the designer considering using a digitally implemented CRO/SAW oscillator to overcome these problems. In addition, since the design of a new CRO/SAW oscillator is much like that of an integrated circuit (IC), development of an oscillator with a nonstandard frequency requires non-recurring engineering (NRE) costs, in addition to the cost of the oscillators. To counter this problem, the engineering team at Synergy Microwave has developed a low cost oscillator technology based on distributed coupled resonators and novel circuit techniques.

Design Features

Phase hits can be defined as sudden, uncontrolled changes in the phase of the signal source that occurs randomly, and generally lasts for fractions of a second. It can be caused by temperature changes from dissimilar metals expanding and contracting at different rates, as well as from vibration or impact. Microphonics, which are acoustic vibrations that

Synergy Microwave Corp.
Paterson, NJ

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TABLE I

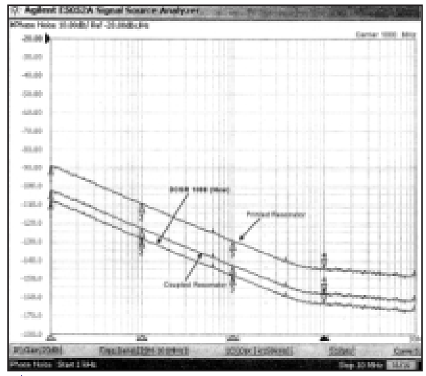
DCSO 1000 OPERATING CHARACTERISTICS

Oscillator frequency (MHz)	1000
Tuning voltage (V DC)	0 to 5
Bias voltage at 30 mA (nom) (V DC)	+10
Output power (dBm)	+5 (typ)
Harmonic suppression (dBc)	20 (typ)
Phase noise at 10 kHz offset (dBc/Hz)	128 (typ)
Operating temperature (°C)	–40 to 85
Size (inches)	0.75 × 0.75

traverse an oscillator package and its circuits, and cause changes in phase and frequency, are dealt with in the DCSOs series VCOs through innovative design topology.[1–3]

DCSOs, which are depicted much like a high Q planar resonator in an equivalent circuit, can achieve the phase-noise performance of CRO/SAW oscillators but over a wide tuning and operating temperature range at low cost. They can be made quite small compared to CRO/SAWs, especially at frequencies of 1000 MHz and less, and can be readily designed at standard and custom frequencies up to approximately 5 GHz without expensive NRE costs.

Fortunately, the new DCSOs series of VCOs break with tradition and



▲ *Fig. 1 The DCSO 1000 VCO's measured phase noise for a carrier frequency of 1000 MHz.*

overcome the long-time hurdle of achieving low phase hits, while also reducing phase noise over the tuning range. The low cost, surface-mountable DCSOs are currently available at frequencies of 1000 and 2488 MHz. In addition, the new DCSOs can be delivered at standard and custom frequencies without the non-recurring-engineering standard costs associated with custom CRO/SAW resonator-based oscillator development.

The traditional disadvantages of printed resonator oscillators such as low Q and large PCB area have been overcome by means of a novel topology, which acts as a Q-multiplier, using mode coupling and a regenerative noise filtering approach.[1,4] The patent-pending approach includes a methodology for DCSOs to enhance the dynamic loaded Q, and to reduce or eliminate phase hits, while reducing the susceptibility to microphonics to an extremely low level, and retaining low phase noise and broadband tunability.[4]

Table 1 lists the performance characteristics model of a DCSO 1000 VCO. ***Figure 1*** shows the phase-noise plot of the DCSO 1000 VCO. The measured phase noise is typically –128 dBc/Hz at 10 kHz offset from the carrier. The DCSOs are supplied in surface-mount packages similar to those used for the company's voltage-controlled CRO/SAW oscillator (VCXO) line. Additional information may be obtained via e-mail at sales@synergymwave.com or from the company's Web site at www.synergymwave.com.

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1. U.L. Rohde, "Ceramic Resonator Oscillators Challenges SAW," *Microwaves & RF*, September 2003, pp. 100–105.
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3. U.L. Rohde, A.K. Poddar, J. Schoepf, R. Rebel and P. Patel, "Low Noise Low Cost Wideband N-Push VCO," IEEE IMS Symposium 2005, Long Beach, CA.
4. U.L. Rohde, A.K. Poddar and G. Boeck, *Modern Microwave Oscillators for Wireless Applications*, John Wiley & Sons Inc., 2005.

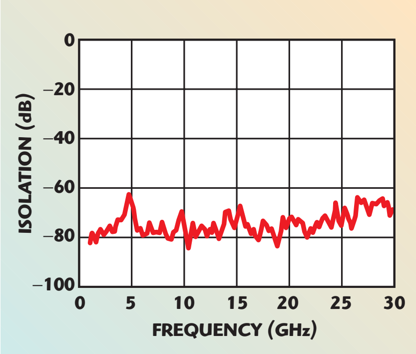
Synergy Microwave Corp., Paterson, NJ 973-881-8800.

RS No. 300

A Coaxial High Frequency Relay for 26.5 GHz Applications

A series of high frequency relays has recently been developed that feature very small size and low power consumption. The most recent relay in this series is the model G9YA, a 26.5 GHz coaxial relay designed primarily for mobile communications base station and antenna applications. The new single-pole, double-throw (SPDT) relay is available in a failsafe/non-latching configuration and a latching configuration, and features high isolation (55 dB minimum at 26.5 GHz) and low insertion loss (0.8 dB maximum at 26.5 GHz). ***Figures 1*** and ***2*** show the isolation and insertion loss versus frequency characteristics, respectively.

Fig. 1 The G9YA relay's isolation vs. frequency characteristics.



One of the more significant properties of this relay and the others in the HF family is its low power consumption, a mere 700 mW for the failsafe/non-latching type and 500 mW for the latching configuration. Note, the latching G9YA model saves power by requiring only a set or reset pulse to change operating states. In addition, the switch is capable of handling 120 W of power. Its HF characteristics include a 1.7 max VSWR and a maximum switching time of 15 ms at 20°C. The new relay operates over a

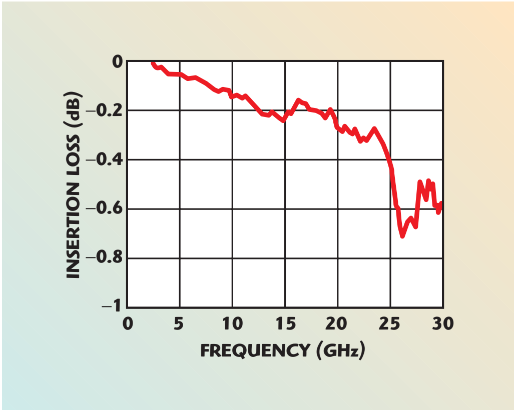


Fig. 2 The G9YA relay's insertion loss vs. frequency.

Omron Electronic Components LLC
Schaumburg, IL

temperature range of –55°C to +85°C and a relative humidity range of 5 to 85 percent, and is housed in a 34 × 13.2 × 37.8 mm (L × W × H) package with SMA connectors.

Applications for the G9YA 26.5 GHz relay include mobile communications base station antenna switching, power amplifier switching, band pass filter switching and tower-mounted amplifier switching, as well as transmitter and receiver, power amplifier and low noise amplifier redundancy switching.

This new 26.5 GHz coaxial HF relay joins a growing family of similar HF relays from Omron. The models G6K-RF, G6Z, G6Y and G6W HF relays (see ***Figure 3***) all feature small size and low power consumption. The G6Z is a 2.6 GHz SPDT surface-mount relay that features 50 Ω and 75 Ω impedance models and measures 20 × 8.6 × 8.9 mm (L × W × H) with E-shaped or Y-shaped terminal structures. E and Y input and output terminal arrangements give designers the ability to layout a PC board without the need for extra tracings and patterns. The G6W relay is a 5 GHz surface-mountable SPDT relay with Y-shaped terminals that measures 20 × 9.4 × 8.9 mm. The G6K-RF is a compact HF DPDT relay with 2 Form C contacts that measures 5.4 × 6.9 × 10.3 mm; the G6Y 900 MHz SPDT relay is based on microstrip line technology and is 20.7 × 11.7 × 9.2 mm. The G6Z and G6W relays are available in SMT and PCB through-hole packaging. The G6Y is PCB through-hole mountable and the G6K-RF is available in SMT.

In addition to the wireless infrastructure applications of all of the described switches, the G6Z and G6Y relays are applicable to digital TV tuners, test equipment, security systems and satellite communications equipment.

Consult the company for pricing and availability for the G9YA coaxial HF relay. The G6K-RF, G6Z, G6Y and G6W are all available from stock. The G6Y and G6Z relays are $1.50 for 10,000 pieces. The G6K-RF is $10.00 for 10,000 and the G6W is $50.00 for 10,000. Additional information may be obtained from the company's Web site at www.info.omron.com.

Omron Electronic Components LLC, Schaumburg, IL (847) 882-2288, www.components.omron.com.

RS No. 302

▲ *Fig. 3 Models G6W, G6K-RF, G6Z and G6Y, from left to right.*

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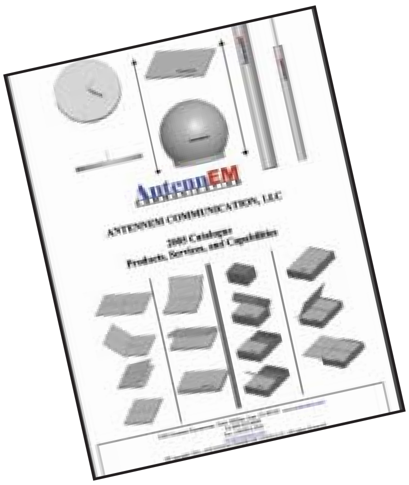

▲ Product Catalog

This product catalog features the company's advanced antenna systems. It highlights new products including the Phased Beamer,™ modular phased array panels, Edge-of-Space Gateway,™ SatCom antenna system with orbital down conversion and UniScan Direct,™ and a real time airport security RF imaging scanner, all based on the company's patent-pending technologies.
AntennEM Communication LLC,
San Jose, CA (408) 927-6880,
www.antennem.com.

RS No. 310

▲ Product Catalog/CD-ROM

This catalog showcases the range of products and services offered through the company, including OEM consulting and manufacturing, custom antenna design, low profile disc antennas, microcell hemi antennas, omnidirectional antennas, Yagi antennas, Enviro-Sealed Protected (ESP) Yagi antennas, PCD subscriber series antennas, and dual-band and tri-band antennas.
Astron Wireless Technologies Inc.,
Sterling, VA (703) 450-5517,
www.astronwireless.com.

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▲ Shortform Catalog

This shortform catalog (No. 14S) details over 500 standard models of general purpose pulse generators (5 to 100 V), high speed and high voltage pulse generators (rise times as low as 50 ps), high voltage amplifiers and function generators (to 1000 V peak-to-peak), high frequency amplifiers (to 4 GHz), pulsed laser diode drivers and current pulsers (1A to 200A), and delay generators.
Avtech Electrosystems Ltd.,
Ogdensburg, NY (800) 265-6681,
www.avtechpulse.com.

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▲ High Performance Solutions

This 600-page catalog features over 425 products that include components and integrated assemblies in frequencies ranging from 100 kHz to 20 GHz. Components include: TO-8 cascadable amplifiers, VCOs, mixers, switches, detectors, limiters, limiting amplifiers, attenuators and voltage-controlled amplifiers. Custom integrated assemblies, available in a variety of custom packages, including IQ demodulators, switch limiting amps and down converters, are also highlighted.
Cougar Components,
Sunnyvale, CA (408) 522-3838,
www.cougarcorp.com.

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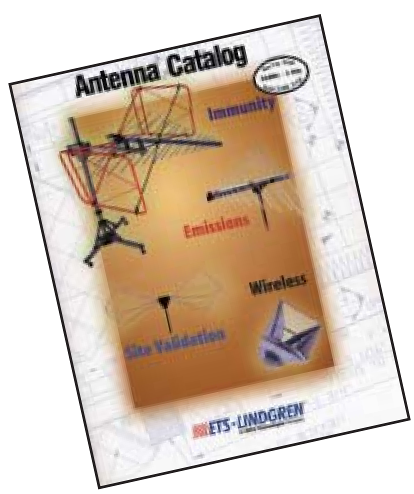

▲ Antenna Catalog

This product catalog features the company's antenna products including BiConiLog,™ Biconical, log periodic, double-ridged waveguide horn, diagonal dual polarized horn, tuned dipole, loop and magnetic field coil, rod, and conical log spiral. A quick find chart, antenna calculations, and antenna selection charts by test type and frequency are provided to help locate specific products.
ETS-Lindgren,
Cedar Park, TX (512) 531-6400,
www.ets-lindgren.com.

RS No. 314

▲ Product Catalog

This catalog highlights the company's miniature semi-rigid coaxial cable including MIL-C-17 QPL, low loss EZ Form*AL* Aluminum, EZ Flex cable assemblies, delay lines and RF connectors. The catalog features its line of RF coaxial connectors, in standard series such as SMA, SMB, SMC, BNC, TNC, N and MCX, in-and-between series adapters and its EZ Quick Snap push-on connector system.
EZ Form Cable Corp.,
Hamden, CT (203) 785-8215,
www.ezform.com.

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ZRL-700	250-700	29.0	2.0	46	24.8	12	550	119.95
ZRL-1150LN	500-1400	31.0	0.8	40	24.0	12	500	119.95
ZRL-1200	650-1200	27.5	2.0	46	24.3	12	550	119.95
ZRL-2150	950-2150	25.0	1.5	33	22.0	12	300	119.95
ZRL-2300	1400-2300	23.5	2.5	46	24.6	12	550	119.95
ZRL-2400LN	1000-2400	27.0	1.0	45	24.0	12	550	139.95
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▲ RFI/EMI/Tempest Components

This six-panel brochure features RFI/EMI/Tempest components and subsystems used for military, industrial and commercial applications. The brochure includes key features and specifications for EMI/RFI/Tempest line filter and surge protector product lines, as well as an overview of the company and its capabilities. The company's products serve the worldwide aviation/aerospace industry and industrial markets.
Filter Networks Inc.,
Salisbury, MD (410) 341-4200,
www.filternetworks.com.

RS No. 316

▲ Switch Catalog

This space-qualified microwave switch catalog features information about the company's high reliability electromechanical devices. This complete line of space-qualified switches is for high power applications in the L-, S-, C-, Ku- and Ka-bands. The product line consists of coaxial switches, waveguide switches, switch matrices and blocks. These products are typically custom-designed and manufactured according to specific performance requirements.
Teledyne Relays,
Hawthorne, CA (800) 284-7007,
www.teledynerelays.com.

RS No. 328

▲ Amplifier and Converter Capabilities

This brochure highlights the company's amplifier and converter design and manufacturing capabilities. Products include low noise amplifiers with noise figures to 0.4 dB, solid-state power amplifiers with output power to 300 W, and converters with variable and fixed local oscillators.
Locus Microwave Inc.,
State College, PA (814) 861-3200,
www.locusmicrowave.com.

RS No. 318

▲ Coaxial Cable Assemblies

This brochure highlights the company's SiO2™ silicon dioxide coaxial cable assemblies that meet the requirements of demanding microwave interconnect applications in aircraft, space, shipboard and ground based systems as well as other hostile environments. SiO2 is ideally suited to applications requiring low loss, unmatched phase stability and low phase hysteresis over extremes of temperature and pressure.
Times Microwave Systems,
Wallingford, CT (203) 949-8433,
www.timesmicrowave.com.

RS No. 329

▲ Millimeter-wave Products

This 90-page catalog features the company's standard millimeter-wave products in the frequency range of 18 to 110 GHz. The products offered include millimeter-wave amplifiers, antennas, control devices, ferrite devices, frequency converters, Gunn oscillators, passive components and subsystems. The catalog also offers product application notes and useful technical references.
WiseWave Technologies Inc.,
Torrance, CA (310) 539-8882,
www.wisewave-inc.com.

RS No. 330

▲ Agile Precision Frequency Sources Catalog

This catalog describes the complete line of precision frequency synthesizers, based on a high stability frequency standard. Easy and fast remote programming is available. These synthesizers are used in advanced measurement and production systems as well as stand alone test equipment and mode locking applications. Options and accessories are available to customize them to a required specification.
Programmed Test Sources Inc.,
Littleton, MA (978) 486-3400,
www.programmedtest.com.

RS No. 321

CATALOG UPDATE

▲ Full Line Catalog

This latest edition includes a number of new products, including both PIN diode and waveguide switches, as well as coaxial switches up to 65 GHz. The filter section now includes a range of Bessel filters, both absorptive and reflective, as well as cable filters. The company's most recent innovation is to integrate a number of products into a single housing creating a "super component" to meet specific requirements.

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

RS No. 322

▲ High Performance Cables

This catalog features the RTK-Flex high performance flexible microwave cables. The entire product line is constructed using a low or ultra low density PTFE dielectric offering good loss characteristics, phase stability and flexibility. The company manufactures a broad line of cable assemblies, ranging from hair-thin configurations for electro-medical applications, to phase stable precision cables, to semi-rigid cables or high flexible braded lines.

Rosenberger of North America LLC,
Lancaster, PA (717) 290-8000,
www.rosenbergerna.com.

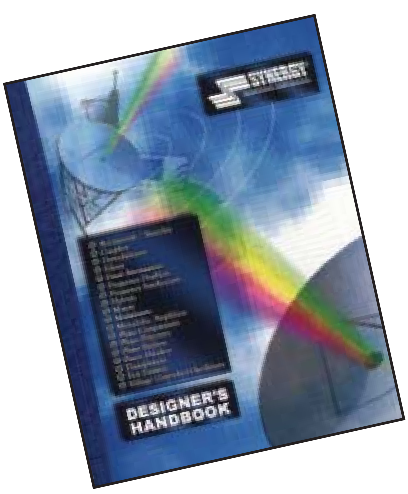
RS No. 323

▲ Product Selection Guide

This guide features the company's analog, mixed signal and digital semiconductors for mobile communications applications. The company's power amplifiers, front-end modules, direct conversion transceivers and complete system solutions are at the heart of many of today's multimedia handsets, cellular base stations and wireless networking platforms.

Skyworks Solutions Inc.,
Woburn, MA (781) 376-3000,
www.skyworksinc.com.

RS No. 324



▲ Designer's Handbook/CD-ROM

This designer's handbook/CD-ROM features the company's signal processing components, including double balanced mixers, image reject mixers, quadrature IF mixers, power dividers, couplers, modulators, filters, frequency doublers, phase shifters, phase detectors, attenuators and transformers. A product index, environmental specifications and quality assurance program details are also provided.

Synergy Microwave Corp.,
Paterson, NJ (973) 881-8800,
www.synergymwave.com.

RS No. 325

▲ Material Guide

This material guide features the company's high performance laminates that include PTFE/woven glass base materials for microwave, RF and high speed digital applications. Applications include LNAs, LNBs, PCS/PCN antennas, GSM and UMTS antennas, power amplifiers, passive components, collision avoidance radar, aerospace guidance telemetry and phased array radar.

Taconic, Advanced Dielectric Division,
Petersburgh, NY (518) 658-3202,
www.taconic-add.com.

RS No. 326

▲ Engineering Capabilities Brochure

This brochure highlights the company's engineering capabilities and their ability to provide unique engineering solutions and custom products for passive RF and microwave signal control components and subsystems.

Technical Research
and Manufacturing Inc.,
Bedford, NH (603) 627-6000,
www.technicalresearch.com.

RS No. 327

Ultra Wideband VCOs

FEATURED MODELS

Model #	Frequency (MHz)	Tuning Voltage (VDC)	Typical Phase Noise @10 kHz (dBc/Hz)	Bias Voltage (VDC)
DCMO SERIES				
DCMO514-5	50 to 140	0.5 to 24	-104	+5
DCMO1129	110 to 290	0.5 to 24	-110	+5 to +12
DCMO-1545	150 to 450	0.5 to 24	-106	+5 to +12
DCMO1857	180 to 570	0.5 to 24	-105	+5 to +12
DCMO2476	240 to 760	0.5 to 24	-104	+5 to +12
DCMO-60170	600 to 1700	0.5 to 24	-99	+5
DCMO100230-12	1000 to 2300	0.5 to 24	-102	+12
DCMO100230-5	1000 to 2300	0.5 to 24	-97	+5
DCMO150318-12	1500 to 3200	0.5 to 20	-95	+12
DCMO150318-5	1500 to 3200	0.5 to 20	-96	+5
DCMO-190410	1900 to 4100	0.5 to 15	-90	+5

Other models are available at our website.

Features:
- Ultra Wide Bandwidth
- High Immunity to Phase Hits
- Exceptional Phase Noise
- Very Low Post Thermal Drift
- Small Size Surface Mount
- Lead Free - RoHS Compliant
- Patent Pending
- REL-PRO® Technology

RoHS COMPLIANT

For additional information,
contact Synergy's sales and application team.
201 McLean Boulevard, Paterson, NJ 07504
Phone: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com

SYNERGY® MICROWAVE CORPORATION

Visit Our Website At WWW.SYNERGYMWAVE.COM

Visit mwjournal.com/info and enter 114 to request information

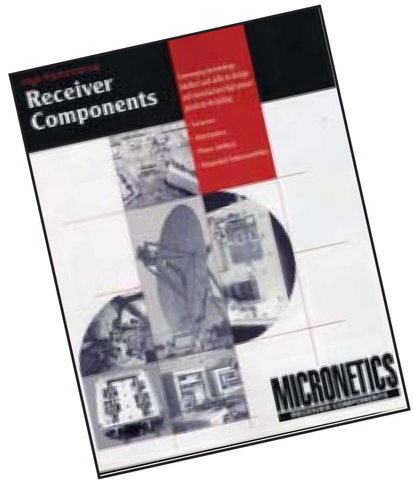
CATALOG UPDATE

▲ Connectors and Components

This catalog details the company's RF connectors, cable assemblies and RF microwave components for wireless mobile communications, aerospace and the industrial market. Product descriptions, photographs, characteristics and outline drawings are provided for each product.

ISOTEC Corp.,
Seoul, Korea (82-2) 3413-2806-8,
www.isoconnector.com.

RS No. 317



▲ Receiver Components Brochure

This product brochure features the company's high performance receiver components that include switches, attenuators, phase shifters and integrated subassemblies. These components and subassemblies offer proven performance in both defense and commercial applications.

Micronetics Receiver Components,
Hudson, NH (603) 883-2900,
www.micronetics.com.

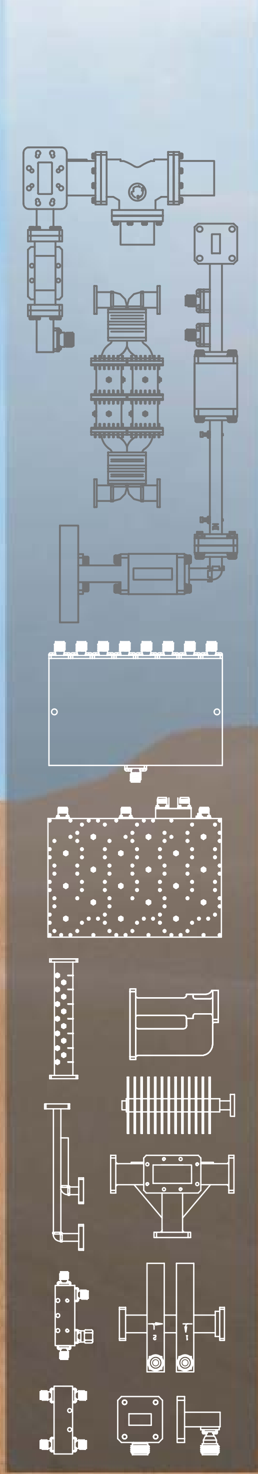
RS No. 319

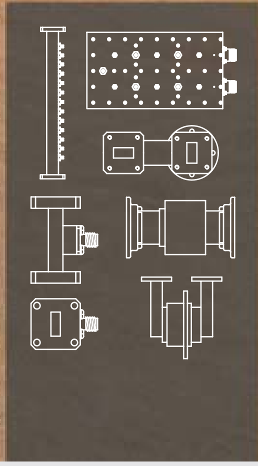
▲ Microwave Components Catalog/CD-ROM

This CD catalog contains over 2000 pages of the company's extensive component product lines including amplifiers, IF signal processing and microwave control products, mixers and low noise receiver front ends, fiber optic products, frequency multipliers, frequency generation products, passive power components, integrated microwave assemblies and communication systems.

MITEQ Inc.,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

RS No. 320





NEW WAVES: Communications/Wireless Applications

Enhanced Wireless Network Simulator Software

This wireless network simulator (WNS) software enhances the functions of the MD8470A signaling tester — a base station simulator for mobile terminal application software development and verification. It establishes interactive operation between the MD8470A and a W-CDMA or GSM/GPRS mobile terminal and simplifies the setting of test conditions for application testing, because it eliminates the need to create scenarios.

Anritsu Ltd., Bedfordshire, UK +44 (0)1582 433 433, www.anritsu.com.

RS No. 216

Multipath Fading Emulator

The PROPSim (FE) fading emulator is an air interface emulator for testing 2/2.5/3/3.5G (GSM, GPRS, EDGE, CDMA, CDMA2000, WCDMA, WLAN) wireless networks, terminals and chipsets.

It introduces an integrated solution for creating test case connections of TS34.121, TS25.141, TS51.010, TS51.021 TIA/EIA and IS-95/97/98/2000, including multipath fading, additive white Gaussian noise (AWGN) generation and faded modulated interfering signals in a single tool. Thus, it can be used as a platform for pre-conformance testing with any available communication tester via an RF analog or digital baseband interface with just two cable connections.

Elektrobit Group, Oulunsalo, Finland +358 40 344 2000, www.elektrobit.com.

RS No. 217

T/R Switch

The model HMC546MS8G is a low loss, high linearity GaAs MMIC 10 W T/R switch housed in an 8-lead MSOP8G surface-mount package.

This switch provides high P1dB compression of +40 dBm, and input IP3 of +65 dBm on the transmit port, making it ideal for use in transmit-receive applications, which require low distortion at high input power levels. On-chip circuitry enables this model to operate with single positive control voltages from 0/+3 V to 0/+8 V, with low DC current consumption. This switch is designed for cellular/3G, mobile radio and automotive telematics applications from 0.2 to 2.2 GHz.

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

RS No. 218

Suspended Substrate Filter

The model WSA-00241 is a dual-band receive-only (half duplex) TTLNA for macro or micro cellular AMPS/DAMPS/PCS1900 communication systems.

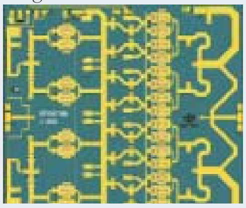
This model offers dual-band receive coverage for 800 MHz AMPS (824 to 849 MHz) and 1900 MHz PCS (1850 to 1910 MHz), with single input from dual-band receive antenna and single multiplexed output to feedline. The WSA-00241 offers 15 dB nominal (±2 dB) gain in each receive path, with high selectivity preselect filters providing –65 dBc rejection in transmit bands. Size: 11" × 8.1" × 4".

K&L Microwave Inc., Salisbury, MD (410) 749-2424, www.klmicrowave.com.

RS No. 219

High Power Amplifier

The model XP1007 is a GaAs MMIC two-stage, single-ended, X-band high power amplifier that integrates an on-chip gate bias circuit to simplify biasing.



Using 0.5 micron gate length GaAs PHEMT device model technology, this device covers the 8.7 to 10.7 GHz frequency bands, delivers 40 dBm output power and offers 32 percent power-added efficiency. This amplifier also has a typical large-signal gain of 17 dB with good input and output match. This high power amplifier is well suited for radar and communications systems, primarily for military applications.

Mimix Broadband Inc., Houston, TX (281) 988-4600, www.mimixbroadband.com.

RS No. 220

High Efficiency Antenna

The model RP2-54-N is a high efficiency 2' diameter antenna that is designed for use in the licensed Public Safety communications band of 4.94 to 4.99 GHz and the unlicensed frequency bands from 5.25 to 5.85 GHz.

The reflector is precision spun aluminum. The mount includes azimuth/elevation fine adjustment capability and is designed to attach to a range of mast pipe sizes from 1.9" to 4.5" in diameter. Mount hardware is galvanized and stainless steel. The input for the feed is a type N female connector.

mWAVE Industries LLC, Gorham, ME (207) 857-3083, www.mwavellc.com.

RS No. 221

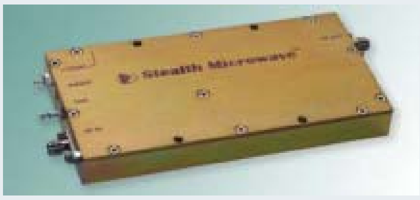
Hardware and Advanced Software Solutions

These system-on-chip (SoC) Bluetooth® products, transceivers and protocol stack software enable handset manufacturers to more easily integrate Bluetooth wireless technology into current and next-generation cellular handsets. UltimateBlue™ solutions are optimized to deliver advanced capabilities such as enhanced data rate and streaming music that cellular service providers are requiring in feature-rich handsets. The UltimateBlue portfolio is comprised of the SiW4000, SiW3500, SiW1722 and embedded protocol stack and profile software.

RF Micro Devices Inc., Greensboro, NC (336) 664-1233, www.rfmd.com.

RS No. 222

Linear Power Amplifier



The model SM0825-36H is a GaAs FET amplifier that is designed for multi-purpose use in military and wireless markets or GSM, DCS1800, PCS, UMTS, ISM, WLL and IMT2000 applications. The unit operates from 800 to 2500 MHz with a P1dB of +35.5 dBm (min) and OIP3 of +48 dBm. Small-signal gain is 35 dB with a flatness of ±0.75 across the band. Size: 5" × 2.5" × 0.6".

Stealth Microwave Inc., Trenton, NJ (888) 772-7791, www.stealthmicrowave.com.

RS No. 223

Test Cable

This heavy-duty armored SilverLine™ Tuff-Grip™ test cable is designed for wireless infrastructure and wireless Internet cell site RF field testing applications.

These test cables employ a robust hand grip at the system test end enabling the user to apply as much hand resistance as necessary to make or break heavily weatherproofed RF connections quickly and easily without the use of wrenches and without damaging the test cable, important considerations for technicians working in harsh conditions under time constraints.

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

RS No. 224

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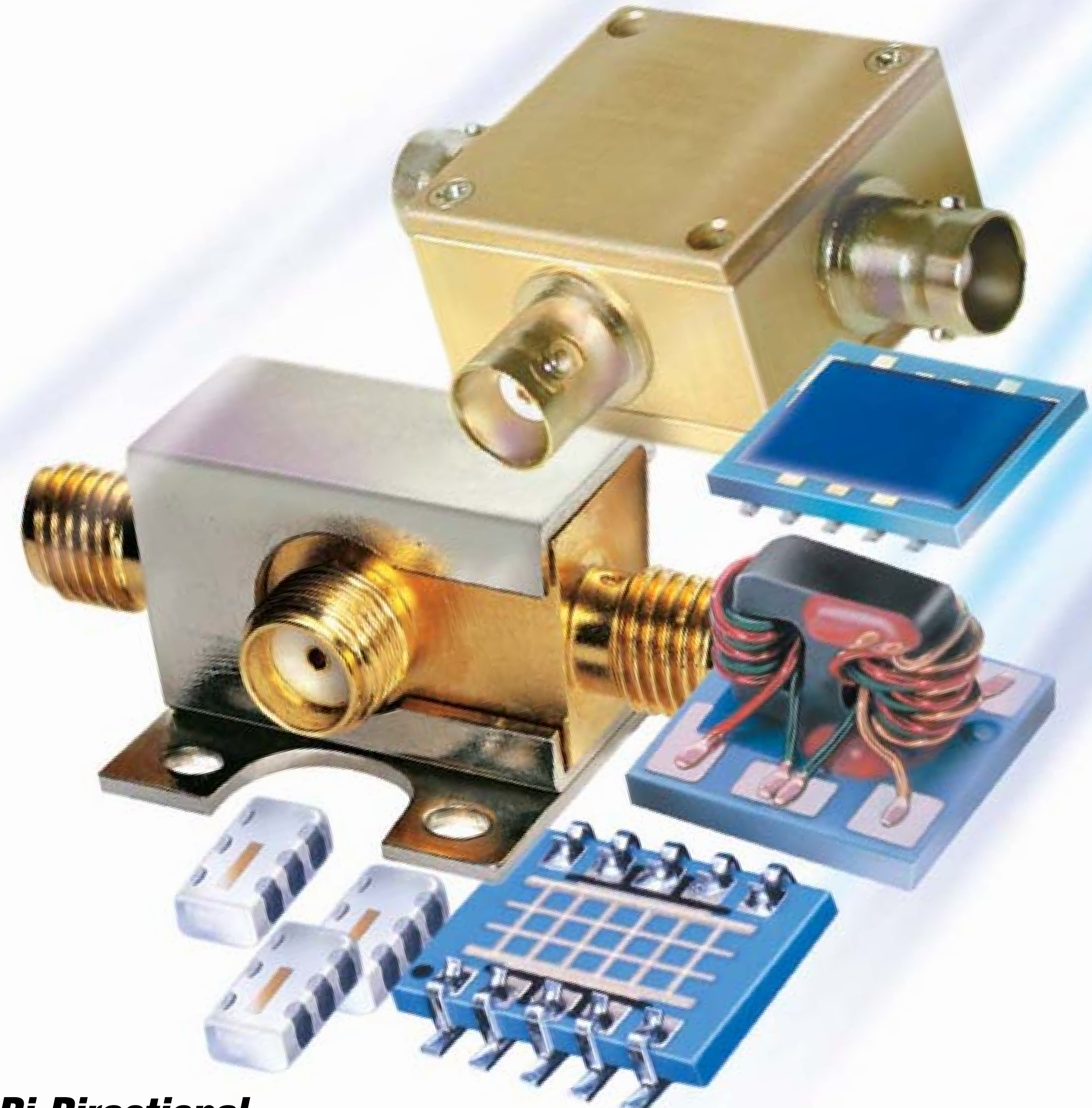

Directional/Bi-Directional

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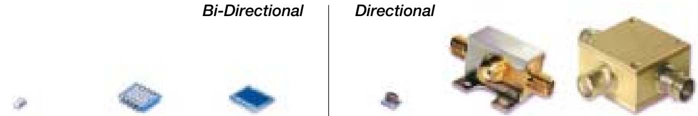

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U.S. Patent 6140887. Add'l Patents Pending.

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See our 244 page RF/IF Designer's Guide in EEM (Electronic Engineers Master)

NEW PRODUCTS

COMPONENTS

High Power Termination

The model 551-101-250 is a small footprint 50 Ω termination that handles 250 W average power and covers the DC to 3 GHz frequency range. Maximum VSWR is 1.35 maximum and the operating temperature is –40° to +85°C. Connector type is SMA male or SMA female. Size: 1.950" × 0.875" × 0.560" not including the SMA connector.

BroadWave Technologies Inc.,
Franklin, IN (317) 346-6101,
www.broadwavetech.com.

RS No. 225

Bi-directional High Pass Filter

The model 3HPD-1600-SR is a bi-directional high pass filter that features a 3 dB typical cut off of 1600 MHz. The insertion loss is 1 dB maximum from 1800 MHz to 15 GHz. The VSWR is 2.0 from 1800 to 15 GHz. Size: 0.750" × 0.750" × 0.500" excluding SMA female removable connectors.

Lorch Microwave,
Salisbury, MD (800) 780-2169,
www.lorch.com.

RS No. 226

16-way Power Divider

The part number PM16-40-75/BF19 is a customized 16-way power divider specifically designed for rack placement. At 19" long, the brackets can be placed on the input side or output side based on customer preference. It covers a frequency range of 0.95 to 1.45 GHz and offers an impedance at 75 Ω with BNC female connectors. Delivery: upon receipt.

Microwave Communications Laboratories Inc. (MCLI),
Saint Petersburg, FL (727) 344-6254,
www.mcli.com.

RS No. 227

Mixers

These patent-pending ADEX level 4, 7 and 17 (LO) mixers are designed to give high isolation of greater than 50 dB typical with flat conversion loss of ±0.2 dB typical over the entire 10 to 1000 MHz band. LO and RF have good matching, typically 15 to 20 dB return loss, and the low profile 0.112" package is ideal for high density designs. Price: $2.95 each (10).

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

RS No. 228

4.4 to 8.5 GHz Diplexer

The part number 2DP-4.69/7.8-11 is a diplexer with passbands of 4.4 to 4.9 GHz and 7.125 to 8.5 GHz. Passband insertion loss comes in at less than 0.5 dB, with a passband VSWR of less than 1.5, minimum channel-to-channel isolation of 80 dB, and is rated for input power of up to 5 W. This unit can come with most any RF connector and is sized at only 1" high × 2.5" wide × 6.6" long.

Reactel Inc.,
Gaithersburg, MD (301) 519-3660,
www.reactel.com.

RS No. 230

Coaxial Terminations

The VLC series of off-the-shelf, rugged coaxial terminations is designed for broadband applications in commercial and defense frequency bands. These 50 Ω coaxial terminations operate from DC to 20 GHz, typical VSWR of 1.10, power handling to 5 W CW and are offered in economical brass or stainless steel construction for durability.

Vista RF Inc.,
Santa Clara, CA (408) 943-8114,
www.vistarf.com.

RS No. 235

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RF Coaxial Relay

The RML series is a multi-position high power relay in a low profile package. This device provides greater layout and packaging density with good RF performance to 6 GHz. The product is available with up to six output positions in either failsafe or latching configurations. Option for a DC header is available. Size: 2.50" × 2.50".

RelComm Technologies Inc., Salisbury, MD (410) 749-4488, www.relcommtech.com.

RS No. 231

Surface-mount Isolators/Circulators

The SLE series of low power surface-mount isolators/circulators operate in the frequency band of 380 to 2200 MHz. These isolators are good for low power applications. This device is low cost and miniaturized in size making it a good fit for tomorrow's telecom applications. The device is also available in a circulator version. Both are available in tape and reel format for high speed automated assembly. Models available in typical bandwidths of 5 percent with isolation > 17 dB and insertion loss < 0.8 dB.

Renaissance Electronics Corp., Harvard, MA (978) 772-7774, www.rec-usa.com.

RS No. 232

W-band Biased Mixer

The model MW-UB is a DC biased mixer that down or upconverts signals in W-band. The LO input power is only 0 to +4 dBm, which can easily be generated with a multiplier. The frequency range covered by both the RF and LO port is 75 to 110 GHz. The IF can be from 0.01 to 3 GHz. Conversion loss is 7 dB typical, 10.5 dB maximum. DC bias is +15 V.

Spacek Labs, Santa Barbara, CA (805) 564-4404, www.spaceklabs.com.

RS No. 233

Hermetic Connectors

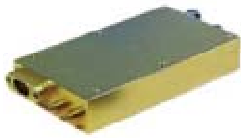
The EZpinMini™ series of hermetic connectors is available in Micro-D and Nano form factors. These connectors provide affordable, robust hermetic connectors, robust ceramic seals and stable pins for reliable wire bonding. The connectors are available in Al, Ti, SST and other materials. This series also offers COTS mating connectors.

SRI Hermetics Inc., Melbourne, FL (321) 254-4067, www.srihermetics.com.

RS No. 234

Down Converter

The 2 Gs/s sampling down converter is intended for use in high end digital radar receivers. These modules have high dynamic range, wide bandwidth and large LO tuning range. Key performance parameters include RF bandwidth of 25 GHz minimum, sample rate of 10 Msps to 2 Gsps, SFDR of –50 dBc maximum, and power dissipation of 5 W maximum. The intended environment for these down converters is MIL-STD airborne and naval requirements.



Picosecond Pulse Labs Inc., Boulder, CO (303) 443-1249, www.picosecond.com.

RS No. 229

AMPLIFIER

Miniature RF Amplifiers

The model A402277 is a miniature RF amplifier that operates in the 26 to 40 GHz frequency band. This amplifier offers a gain of 30 dB, gain variation of ±2 dB, maximum noise figure of 6 dB and VSWR of 2.3. P_{out} at 1 dB compression is +16 dBm. Nominal DC current at 12 V is 400 mA. It is available with removable connectors.

Herotek Inc., San Jose, CA (408) 941-8399, www.herotek.com.

RS No. 236

ANTENNA

High Performance Spiral Antenna

These high performance spiral antennas are designed for electronic warfare, radar warning and other broadband applications. Part number 092-00637 operates over the 18 to 40 GHz frequency range with a maximum VSWR of 2.5, and provides nominal gain of 0 dBiL. This antenna is only 0.75 inch in diameter and includes an integral protective radome. The antenna is available in amplitude matched sets and is ideal for interferometer applications. Its lightweight and small size make it ideal for fulfilling requirements of airborne applications, including tactical aircraft, strategic aircraft and UAVs.

Chelton Microwave – Sensor & Antenna Systems, Baltimore, MD (410) 542-1700, www.cheltonmicrowave.com.

RS No. 237

SOFTWARE

Dielectric Resonator Library Software

The version 5.5 is a new dielectric resonator library that has been added to the EM-software

tool of µWave Wizard. It offers state-of-the-art solutions for almost any microwave waveguide circuit or antenna design problem. The existing Boundary Contour Mode Matching (BCMM) method for the computation of integrated waveguide cavity structures with inherent milling radii has been extended. It now also includes an arbitrarily located partial height dielectric post inside the cavities. This enables a universal approach for rapid development and low cost production of dielectric resonator filters.
Mician GbR,
Bremen, Germany +49 (421) 168 993 51, www.mician.com.
RS No. 238

SOURCES

Low Noise Oscillator

This low noise oscillator operates in the full frequency band of 18 to 40 GHz and over –40° to + 85°C. Phase noise is –95 dBc/Hz at 100 kHz offset. This oscillator offers a power output of +15 dBm minimum, phase noise of –95 dBc/Hz at 100 kHz offset, harmonics of –12 dBc and spurious output of –60 dBc. Delivery: six weeks ARO.

Micro Lambda Wireless Inc.,
Fremont, CA
(510) 770-9221,
www.microlambdawireless.com.
RS No. 239

Harmonic Multiplier

This harmonic multiplier provides a low phase noise signal for system designers with reference oscillator multiplication applications. This multiplier uses a linear amplifier to multiply an input frequency of 100 MHz, generating an output signal at 2.6 GHz. The multiplier then filters the input signal, amplifies it and filters it again to provide a power-leveled low noise output to a connector. Output filtering then cleans up the signal to remove all the unwanted fragments. This system multiplies the signal to the selected output frequency, while only degrading the input phase noise by 30 dB.

Spectrum Microwave Inc.,
Delmar, DE (302) 846-2750, www.specwave.com.
RS No. 240

Voltage-controlled Oscillator

The model V602ME26 is a low noise, high performance voltage-controlled oscillator (VCO) designed for the terrestrial radio market. This model generates frequencies between 1500 and 1800 MHz within 0.25 to 4.75 VDC of control voltage, making it attractive for quick implementation into PLLs where the error voltage can be taken directly from the ICs charge pump circuitry. This VCO exhibits a clean spectral signal of –100 dBc/Hz, typically at 10 kHz from the carrier, and is ideal for terrestrial applications operating from a 5 VDC source while drawing a mere 13 mA. Size: 0.5" × 0.5" × 0.22". Delivery: stock to four weeks.

Z-Communications Inc.,
San Diego, CA (858) 621-2700, www.zcomm.com.
RS No. 241

SYSTEM

Data Link System

This data link transponder is a military flight-qualified microwave data link system for command and control of unmanned aerial vehicles. The transponder provides TDMA command and telemetry with burst data rates up to 256 kbps. GMSK modulation provides narrowband (1 MHz at –60 dBc) operation at operating ranges up to 250 NM with the systems ground parabolic antenna system. Specialized DSP techniques provide FEC and 24-bit CRC to ensure high data integrity and reliability over long distances. Options include frequency agility to overcome interference and/or multipathing effects in difficult operating conditions.

Micro Systems Inc., a Herley company,
Fort Walton Beach, FL (850) 244-2332, www.gomicrosystems.com.
RS No. 242

TEST EQUIPMENT

Time and Frequency Generator

The XLi SAASM time and frequency generator is an ultra precision instrument with a secure, selective availability anti-spoofing module (SAASM)-based GPS receiver. This generator meets the global positioning system security requirements of the US Department of Defense. It is available in three configurations and provides a number of high performance features, including plug and play architecture, redundant time sources, including dual SAASM GPS receivers, network-based remote management, field upgradeable software, redundant power supplies and a wide variety of high performance hardware and software options.
Symmetricom Inc.,
San Jose, CA (978) 927-8220, www.symmetricom.com.
RS No. 243

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www.astswitch.com

RS 2

ENGINEERING MANAGER

SyChip

Sychip.com in Plano, TX is looking for an Engineering Manager: responsible for leading the efforts in research and development of radio frequency technology. Support base band component and system research and development. Provide leadership on technical and product design and development projects. Required minimum of Bachelor degree in EE with 5 years related experience.

Contact Ken Sun at 972-202-8833 or sun@sychip.com

RS 111

Laboratory (RF)MicroProbe Station

Extremely Low Cost
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DC/RF/Microwave Test

A ultra compact, manually operated probe station for engineers, scientists and students. Measure Microwave, RF and IV parameters of Semiconductor Devices. Characterize MEMS, wireless, photonic and nanoelectronic components and assemblies.

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•10X/30X Stereo Zoom Trinocular Microscope • Flourescent Illuminator •
•Compatible with additional Magnetic Mount Positioners(optional)•
•Compatible with industry standard microwave probes(optional)•

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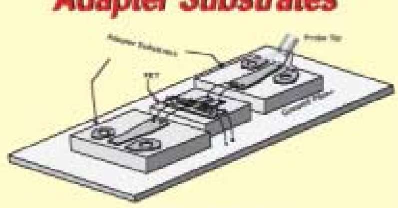

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Erratum

In "A Novel Frequency Doubler Using a Feedforward Structure and DGS Microstrip for Fundamental and High Order Components Suppression," a technical feature by Yong-Chae Jeong, Do-Kyeong Hwang and Jong-Sik Lim that appeared in the May issue of *Microwave Journal*, the affiliations of the authors were listed incorrectly. The correct byline should read: Yong-Chae Jeong, Chonbuk National University, Chonju, Korea, Do-Kyeong Hwang, ACE Technology, Incheon, Korea and Jong-Sik Lim, Soonchunhyang University, Chungnam, Korea.

We regret any inconvenience this error may have caused.

New Literature

Selection Guide

This basic instruments selection guide includes product comparison tables for oscilloscopes, function generators, power supplies, counters, digital multimeters and basic RF products for easy evaluation and selection. Agilent Direct lets a user build side-by-side product comparisons, and Quick Quote, a Web-based 24/7 order quote system.

Agilent Technologies Inc.,
Palo Alto, CA (800) 829-4444,
www.agilent.com.

RS No. 200

White Paper

This white paper details the company's OneBase Macroshelf solution for original equipment manufacturers (OEM). This is a new approach to purchasing and deploying base station RF systems. To view a copy, visit www.andrew.com/isol/onebase-wp-kenington.pdf.

Andrew Corp.,
Orland Park, IL (800) 255-1479,
www.andrew.com.

RS No. 201

Power Products Brochure

This 12-page, four-color literature offers photographs, and specifications relating to the company's broad range of non-isolated and isolated DC-DC converters. The brochure features converters that operate from 2.5, 3.3, 5 or 12 V rails and provide output voltages from less than 1 to 5 V.

Bel Fuse Inc.,
Jersey City, NJ (800) 235-3873,
www.belfuse.com.

RS No. 202

RF Probe Selection Guide

This selection guide provides readers with the company's line of RF probes. There are 10 series of RF probes highlighted within this product line. Each of the series contains a product overview, photograph, performance charts and outline drawings.

Cascade Microtech Inc.,
Beaverton, OR (800) 550-3279,
www.cascademicrotech.com.

RS No. 203

RF Test Cell Brochure

This brochure presents detailed information, including construction and capabilities, on a variety of standard and custom benchtop systems for RF isolated measurement. Full specifications and shielding data for each test cell are also provided.

ETS-Lindgren,
Cedar Park, TX (630) 307-7200,
www.ets-lindgren.com.

RS No. 204

Product Brochure

This product brochure provides an overview of the company's product line, which includes power dividers, directional couplers, quadrature hybrids, phase shifters, phase detectors, phase modulators, attenuators, multi-couplers, distribution amplifiers, mixers, up/down converters, power insertion systems and switching devices. Descriptions, photographs and a frequency table are also provided.

I.F. Engineering Corp.,
Fabyan, CT (860) 935-0280,
www.ifengineering.com.

RS No. 205

Product Catalog

This CD-ROM product catalog includes the company's off-the-shelf solutions and demonstrates its wide range of RF design capabilities. The guide provides an in-depth look at the company's line of specialized RF test systems.

JFW Industries Inc.,
Indianapolis, IN (317) 887-1340,
www.jfwindustries.com.

RS No. 206

Coaxial Cable-Assembly Catalogs

These five catalogs highlight the company's range of coaxial cable assemblies for military, telecom, automotive and space applications. A general catalog introduces all the RG, ECO-friendly, hand formable and semi-rigid cables and associated connectors.

Radiall,
Cedex, France +33 1 49 35 35 35,
www.radiall.com.

RS No. 207

Power Dividers/Combiners Catalog

This catalog showcases the company's most recent power divider and combiner products within the 400 MHz to 26.5 GHz frequency range. The catalog features a new look and easy-to-read specifications and details on its complete product line.

Renaissance Electronics Corp.,
Harvard, MA (978) 772-7774,
www.rec-usa.com.

RS No. 208

Product Brochure

This brochure features the company's microwave ferrite devices including drop-in isolators and circulators. The brochure provides product overviews, specification charts and performance graphs for the products highlighted.

SDP Components Inc.,
Quebec, Canada (514) 421-5959,
www.sdp.ca.

RS No. 209

Short Form Brochure

This short form brochure highlights the company's SMA connectors that include DC to 18 GHz, VSWR 1.10 maximum and 18 to 27 GHz, VSWR 1.15 maximum. Product photographs, performance graphs and features are also included.

Sources East,
Campbell, CA (408) 374-1031,
www.sourceseast.com.

RS No. 210

Product Digest

The 96-page digest provides data sheets for RF electromechanical relays, microwave coaxial switches, military and aerospace solid-state relays. It also incorporates supplemental information such as performance curves, product selection guides and application notes.

Teledyne Relays,
Hawthorne, CA (800) 284-7007,
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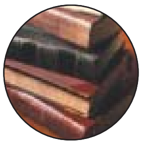
RS No. 211



THE BOOK END

Digital Communication Over Fading Channels, Second Edition

Marvin K. Simon and Mohamed-Slim Alouini

Wiley-Interscience
934 pages; $195
ISBN: 0-471-64953-8

Like its predecessor, this second edition discusses in detail, coherent and non-coherent communication systems as well as a large variety of fading channel models typical of communication links found in the real world. Its coverage includes single- and multi-channel reception and, in the case of the latter, a large variety of diversity types. The moment generating function (MGF)-based approach for performance analysis, introduced by the authors in the first edition and referred to in literally hundreds of publications, still represents the backbone of the book's presentation. Since the publication of the first edition, a great deal of additional significant work on the subject has been performed and reported on in the literature. Perhaps the most significant of these new developments is the explosion of interest and research that has taken place in the area of transmit diversity and space-time coding and the associated multiple-input/multiple-output (MIMO) channel, a subject that was briefly alluded to but not discussed in any detail in the first edition. Aside from these developments, many new and exciting results have been developed that have led to new and improved diversity schemes and allow for the performance analysis of previously known schemes operating in new and different fading scenarios not discussed in the first edition. The book is composed of five parts, each with its own express purpose. The first part contains an introduction to the subject of communication system performance. Part 2 starts by introducing the alternative forms of the classic functions and shows how these forms can be used. Part 3 derives the optimum receiver structures corresponding to a variety of combinations concerning the knowledge or lack thereof of the fading parameters. Part 4 deals with multiuser communications and Part 5 extends the theory developed previously for uncoded communication to error-correction-coded systems.

> ***"Since the publication of the first edition, a great deal of additional significant work on the subject has been performed..."***

To order this book, contact: John Wiley & Sons Inc., One Wiley Drive, Somerset, NJ 08875 (800) 225-5945.

Multi-antenna Wireless Communication Systems

Sergio Barbarossa

Artech House
463 pages; $109, £73
ISBN: 1-58053-634-4

Most current communication systems implicitly assume that the information is carried by a physical support (information signal) that is defined over a one-dimensional independent variable: time. Adding space to time creates a high number of additional degrees of freedom that can be exploited to increase the spectral efficiency. To incorporate space as an additional domain where the information flows, beside time, it is necessary to transmit from different points in space and to gather information from different points. This is achieved through multi-antenna systems. The scope of this book is to provide the basic theoretical tools for designing and analyzing multi-antenna communication systems. Space-time coding plays a fundamental role in this book, as the way to achieve most of the promised benefits. Three chapters are entirely devoted to space-time coding and one more chapter addresses the relatively novel strategy of distributed space-time coding, as a novel paradigm to design cooperative communication systems. However, this is not a book on space-time coding. There are many other tools which are not, typically, part of a book on multi-antenna systems. These include: game theory, as a tool to devise the optimal transmission strategies in a multi-user scenario where different user terminals (players) compete with each other for the use of the available resources; convex optimization and majorization theory, as the basic tool for optimizing the transmission scheme when the transmitter has some knowledge about the channel; random geometric graphs, as the basic tool for studying the connectivity of wireless networks; and eigendecomposition of weakly inhomogeneous operators, as a way to analyze the optimal transmission strategies over time-varying channels. The hope is to provide the reader with a series of tools, borrowed from different disciplines but presented in a single context, whose combination may give rise to a strong synergism and cross fertilization.

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To order this book, contact: Artech House, 685 Canton St., Norwood, MA 02062 (781) 769-9750 ext. 4030; or 46 Gillingham St., London SW1V 1HH UK +44 (0) 207-8750.

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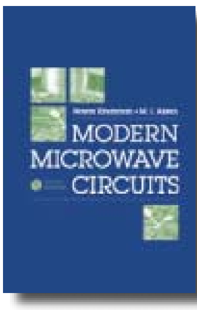

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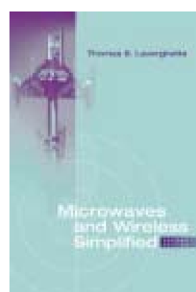

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