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October 2005

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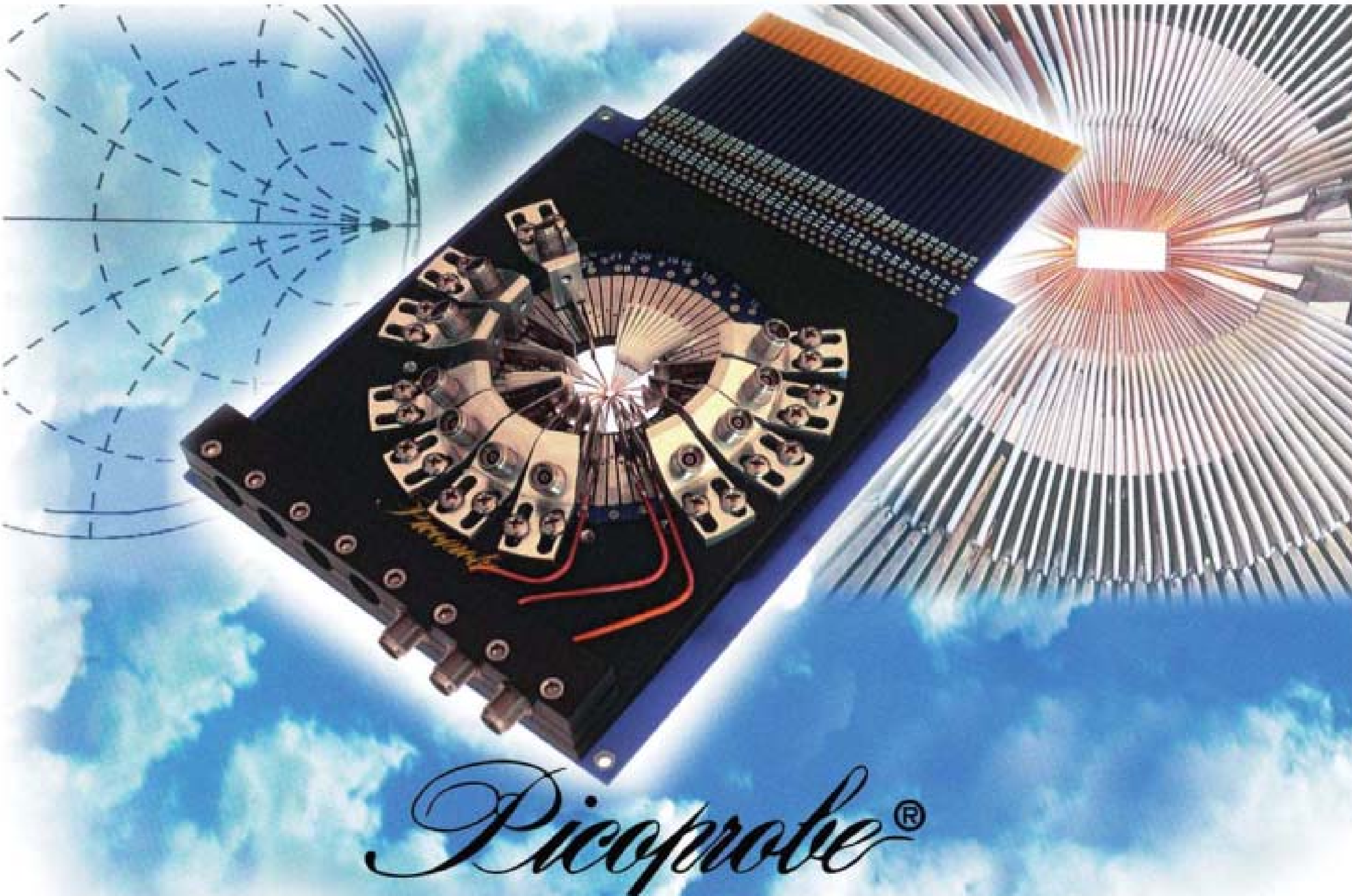

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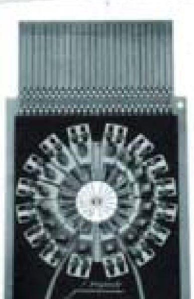

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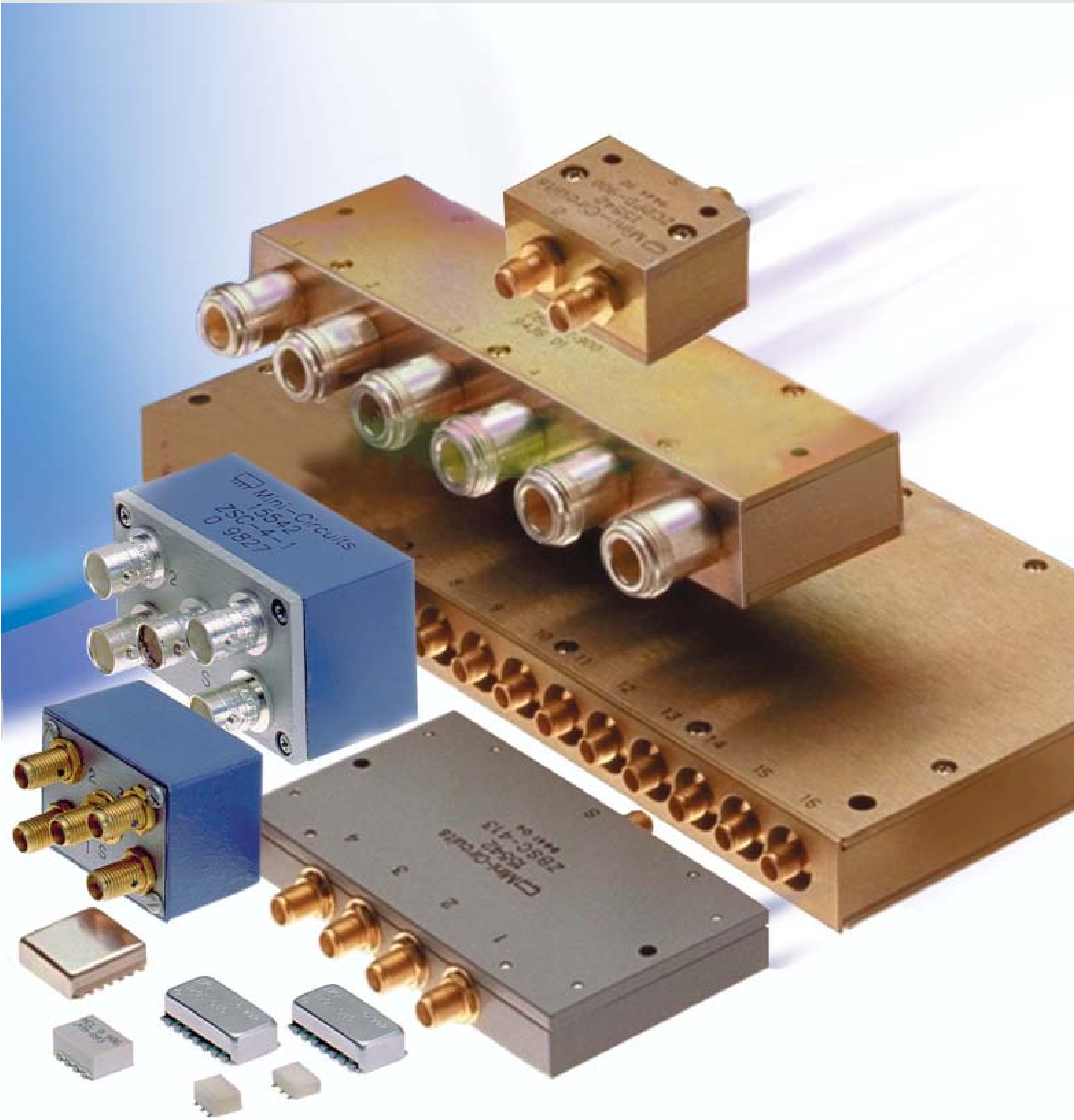

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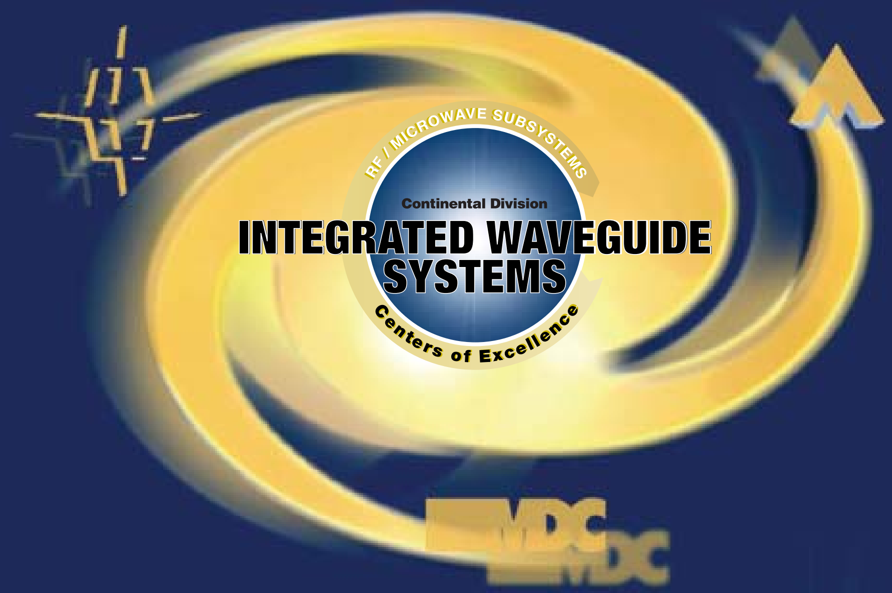

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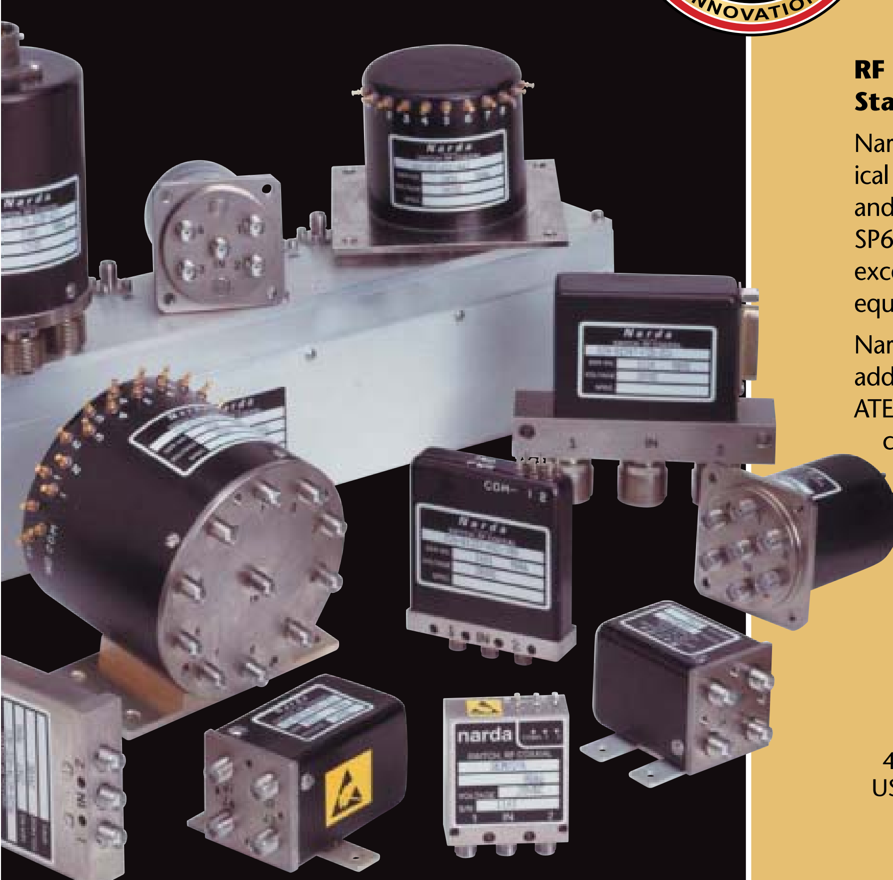

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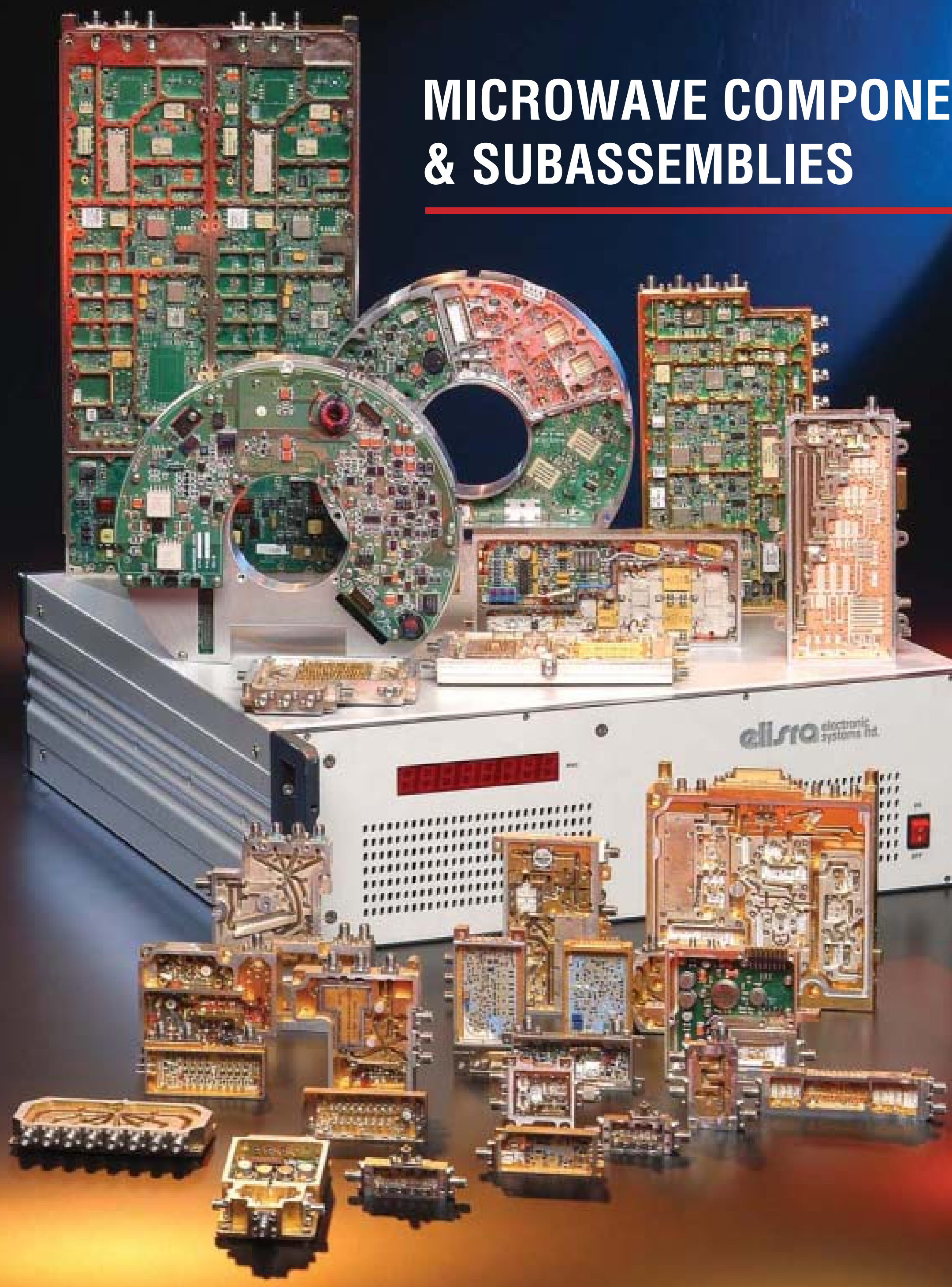

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COMING EVENTS

RadioTecC 2005
October 26–27, 2005
Berlin, Germany

Radio Techniques and Technologies for commercial communication and sensing applications is organized by Gerotron Communication GmbH. The exhibition will highlight GSM, UMTS, 4G, WLAN, UWB, GPS/Galileo, radio over fiber, wireless positioning, sensing and radar, smart antennas and base stations, RF measurement issues, software-defined radio, and sensing and EMC. During the workshop, the EEEfCOM Innovation Award, which is sponsored by Ansoft, Agilent Technologies and Rohde & Schwarz, will be presented. For more information, visit www.gerotron.com or e-mail: EEEfCOM@gerotron.com.

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. An exhibition of products from various vendors of materials, IC products, processing equipment, CAD tools and foundry services specifically addressing the compound semiconductor industry will also be featured. For more information, visit www.csics.org.

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

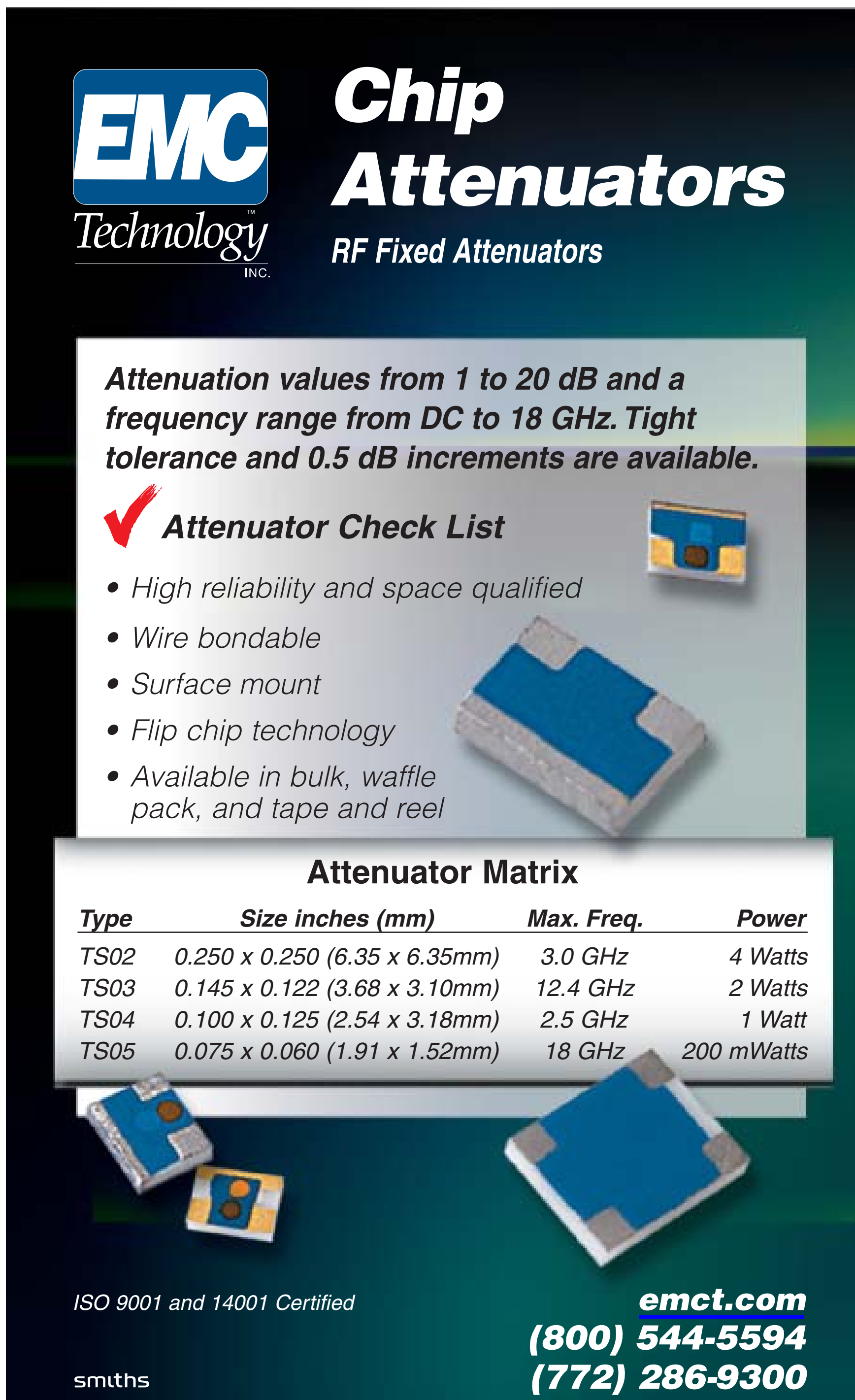
The Antenna Measurement Techniques Association (AMTA) is the international organization dedicated to the development, application and dissemination of advanced antenna, radar signature and related measurement technologies. The annual meeting and symposium consists of a short course, four days of technical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

ARMMS RF & Microwave Society Conference
November 7–8, 2005
Newport Pagnell, UK

The Link Microtek sponsored conference is aimed at engineers involved in RF and microwave, wishing to broaden and enhance their technical knowledge. An exhibition area is available to delegates giving them the opportunity to display and demonstrate new products and ideas. For more information or to book a place at the conference, contact JJ Heath-Caldwell, +44 (0) 845 0950 056 or e-mail: enquiries@armms.org.

Asia-Pacific Microwave Conference
December 4–7, 2005
Suzhou, China

The 17th Asia-Pacific Microwave Conference (APMC 2005) is widely supported by the academia and industries of microwave, wireless and correlative areas. The conference will highlight solid-state device and circuits, low/high noise devices and techniques, monolithic integrated circuits, passive devices and circuits, packaging, interconnects, MCMs, scattering and propagation. In addition to the regularly scheduled sessions for oral and poster presentations, there will be special sessions, workshops and short courses. A large-scale exhibition of commercial products related to the conference topics will be held concurrently. For more information, visit www.apmc2005.org.



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CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
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IEEE Radio and Wireless Symposium
January 17–19, 2006
San Diego, CA

The IEEE Radio and Wireless Symposium (RWS 2006) is a major expansion 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 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.

WCA 2006 International Symposium and Business Expo
January 18–20, 2006
San Jose, CA

This 12th annual symposium gathers technically-oriented wireless broadband carriers and their leading vendors. The event complements WCA's larger annual summer show held in Washington, DC, focusing more on regulatory matters. Investment and business planning issues are common to both shows. The symposium attracts strong attendance from leading international carriers, often at the CEO and CTO levels. For more information, visit www.wcai.com.

AMTA Europe Symposium
May 1–4, 2006
Munich, Germany

The first European Antenna Measurement Techniques Association (AMTA) Symposium aims to build a strong European foundation in the domain of leading edge technologies for antenna and RCS measurements. Topics will address measurement methods relating to theory and application of antennas and radar scattering, advances in near-field, compact range and RCS measurements, phased array and adaptive antenna testing, automation in RF measurements, diagnostic methods and characterizing smart antennas. For more information, visit www.amta.org/europe or e-mail the technical coordinator at tech-coord-europe@amta.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. **Call for Papers**: technical papers for this symposium must be submitted via the IMS2006 Web site (www.ims2006.org). Complete information on how to submit a paper or register for the conference, as well as other information can be found on this site. **Deadline for paper submission: December 2, 2005.** 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 e-mail: kdednah@mwjournal.com.

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Workshops & Courses

Converge Applications Workshop for High Performance Design

■ **Topics:** Converge 2005 is an applications workshop for high performance integrated circuit, microwave, signal integrity and electromechanical design. Attendees will learn new design methods relating to RFIC, MMIC, antenna, radio, signal integrity, high speed serial, packaging, SSO, EMI/EMC, automotive, defense, VHDL-AMS, aerospace and power.
■ **Site:** For location information, please visit url.
■ **Dates:** For date information, please visit url.
■ **Contact:** For more information, visit www.ansoft.com/converge.

Sonnet Training Class

■ **Topics:** This ½ day course is an introduction to the use of Sonnet's 3D planar electromagnetic simulation software. It will offer a hands-on technical training that is designed to bring new users up to speed and highlight new features to experienced users in the area of high frequency design. For more information, visit www.sonnetsoftware.com/support/training.asp.
■ **Site:** For location information, please visit url.
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■ **Contact:** Yun Chase, Sonnet Software Inc., 100 Elwood Davis Road, North Syracuse, NY 13212 (315) 453-3096 or e-mail: chase@sonnetsoftware.com.

Microwave Measurements for High Performance Devices and Applications

■ **Topics:** This 1½ day course covers microwave measurement fundamentals, including vector network analysis, scattering parameters, power and thermal noise. Practical issues such as cables, fixtures, probes and on-wafer measurements are covered. For more information, visit www.arftg.org.
■ **Site:** Washington, DC
■ **Dates:** November 29–30, 2005
■ **Contact:** David Walker, NIST, M.S. 818.01, 325 Broadway, Boulder, CO 80305 (303) 497-5490 or e-mail: dwalker@boulder.nist.gov.

IEEE WirelessMAN 802.16 Broadband Wireless Technical Review

■ **Topics:** This course provides a comprehensive overview of the modes, features and options supported by the IEEE 802.16 both in PHY and MAC layers. It also describes how different modes can be effectively used to target different applications, usage models and wireless network deployment scenarios. The most popular modes of operation are discussed in detail. For more information, visit www.unex.berkeley.edu.
■ **Site:** Redwood City, CA
■ **Date:** November 30, 2005
■ **Contact:** UC Berkeley Extension, 1995 University Avenue, Berkeley, CA 94720 (510) 642-4151 or e-mail: course@unex.berkeley.edu.

Far-field, Anechoic Chamber, Compact and Near-field Antenna Measurements

■ **Topics:** This course presents the state-of-the-art in antenna measurements, including far-field, anechoic chamber, compact and near-field measurements. The course also includes range evaluation and compensation techniques and microwave holography. For more information, visit www.pe.gatech.edu.
■ **Site:** Atlanta, GA
■ **Dates:** December 5–9, 2005
■ **Contact:** Georgia Institute of Technology, Professional Education, PO Box 93686, Atlanta, GA 30377 (404) 385-3500.

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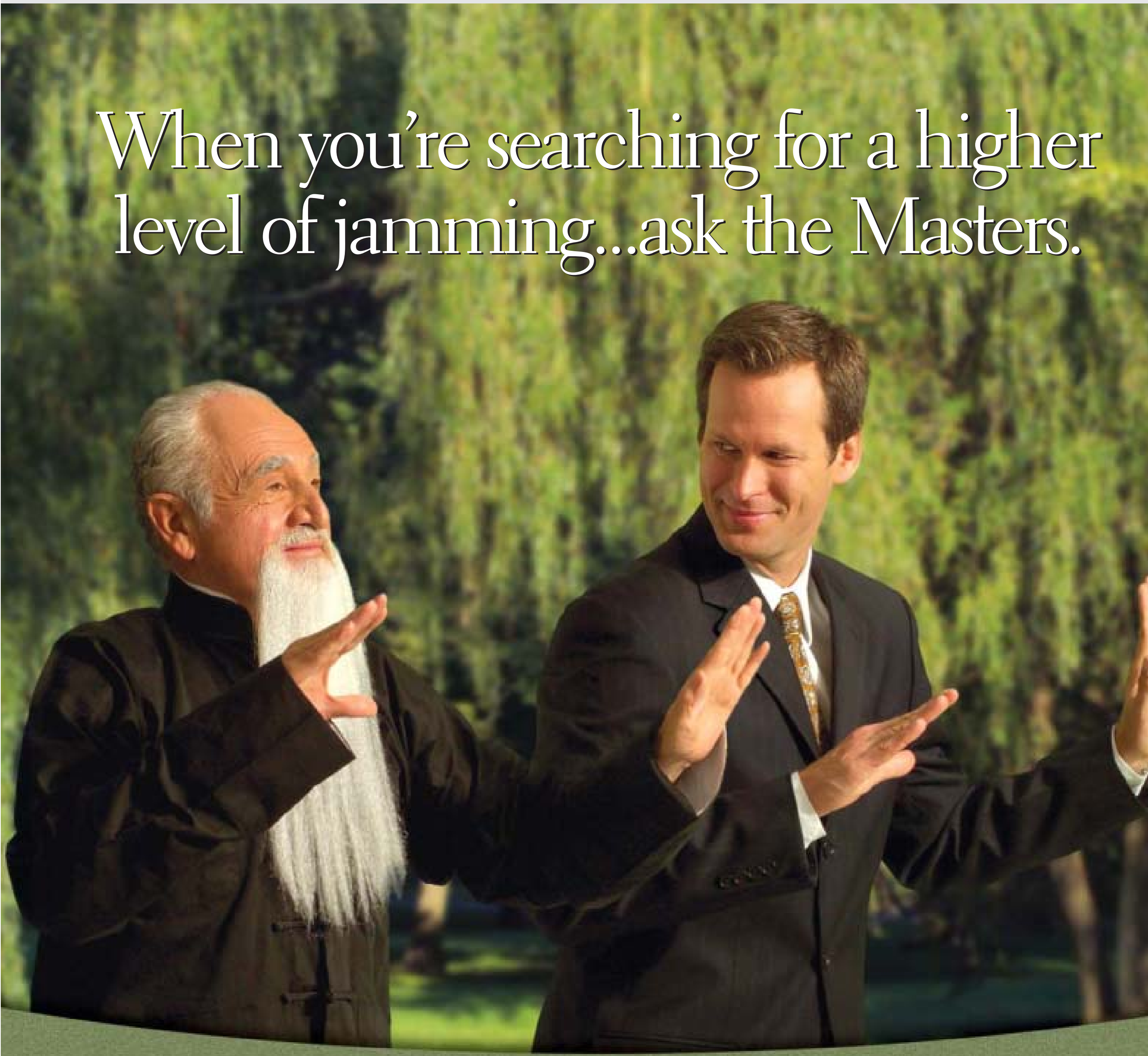

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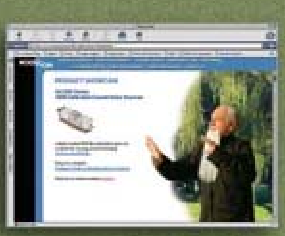

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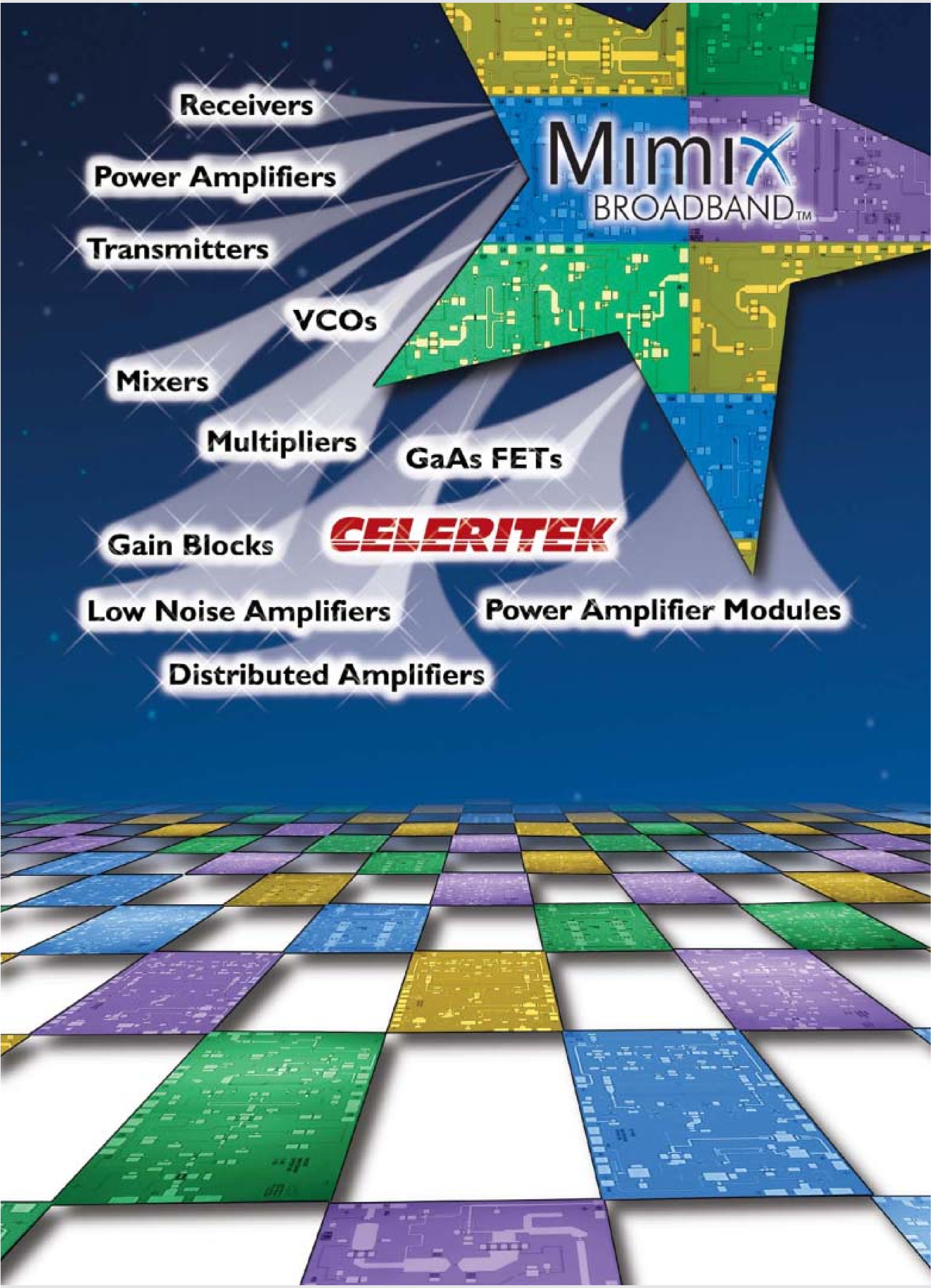
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INVITED PAPER

COVER FEATURE

COMMERCIAL SOFTWARE MARCHES TO BATTLE

The US military seeks to benefit from commercial off-the-shelf communications software.

A few decades ago, military laboratories were the source of much of the technology that emerged in the consumer world, the most famous example being the Internet, which began as a communications network designed to function in the event of a nuclear strike. Today, some in the military believe the opposite is true, at least in terms of communications and data networking. Commercial off-the-shelf (COTS) software, with some modifications, could provide what the military is, in some cases, trying to develop on its own.

Telecommunications have transformed modern society. Many carry mobile phones, use Internet connections and play sophisticated video games. Go to any military conference today, and many attendees can be seen tapping into their Blackberry e-mail devices during speeches. Military commanders, though, covet all these technologies that are taken for granted by teenagers. Officers discussing battlefield operations often mention their wish for a kind of military personal digital assistant that permits individual soldiers to easily access information about the position of friendly forces, intelligence on the enemy and more. These are in fact being introduced into the field, and not coincidentally, are COTS solutions. The general populace may not be buying rocket launchers, tanks, or fighter aircraft, but it certainly drives demand for new applications like voice over Internet and instant messaging.

UK forces in Iraq must be alert to explosive devices which are often detonated by cell phones and garage door openers. (UK Ministry of Defence photo)

The US military is notorious for having rigid practices for acquiring new technology. There are some efforts to change this, through programs like the US Army's Rapid Equipping Force, but observers wonder to what extent the military overall is willing or able to capitalize on commercial innovation because of long-standing practices.

Why would the military be interested in COTS software for voice and data networking? The US Defense Department and other countries as well, including the UK, Australia and Germany, see the concept of "network-centric warfare" as central to making fighting forces more quickly deployable and maneuverable, and network-centric operations are already widely in use by many commercial businesses, from IBM to Wal-Mart. Their form of command-and-control may be stocking shelves with toilet paper rather than directing the position of army squadrons or fighter aircraft, but the principle is the same: move assets about efficiently and as quickly as possible.

Network-centric operations lie at the heart of modern warfare. If military operations are more likely to be civil wars in poor countries like Liberia or Haiti, military intervention requires extreme care not to injure or kill innocent people and destroy civilian property. Even if larger, more uncontrolled warfare should erupt against a major power, precise weaponry and better coordination among deployed forces should compensate for more lightly armored tanks and other assets. All of this depends on greater speed and more accurate targeting of forces, which themselves depend on fast transmission of information. The sooner military

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forces can receive intelligence, the faster they can act on it. In the 1991 Persian Gulf War, for instance, the US would look for Scuds, find them, send an asset out to bomb them, but often too late — they would be gone. Better data networking will permit quicker reaction, so targeting becomes a matter of seconds rather than hours, and forces can capitalize on enemy weaknesses and coordinate the movements of forces and their missions.

TEAM EFFORT

The problem with existing military communications is that they often do not permit very convenient joint communications — that is, between different services like the Air Force and Army, or different components of the same services, such as aircraft and ground forces. For instance, the radios of many countries' ground forces lack compatibility with the aircraft that put troops into the field and — they hope — will take them out again. Moshe Markowitz, a retired brigadier general and former chief signals and electronics officer for the Israeli Defense Forces, who is now vice president of business development for Tadiran Communications (Holon, Israel), said that to establish ground-to-air communications, Israel and the armies of other countries usually just give ground forces UHF equipment. "They have extra radios for officers if they need to talk to the air force. It's usually for voice only and does not enable a higher rate of data communications, and cross-band or cross-network transmission are not permitted," Markowitz said. "It is what we call a very poor communication."

▲ Military exercises focus on sharing data among different locations. The best data networking technology comes from the commercial sector. (US Army photo)

Aircraft have similar problems. A bomber flying from the US to somewhere overseas on a mission may along the way have to use a number of different radios and frequencies to keep in touch with air-traffic and command control. Say the plane leaves from a base in Missouri; to communicate with air-traffic control in the United States, it uses various UHF or VHF frequencies, with frequency changes based on the controller's location. As it passes over the ocean and loses line-of-sight with ground antennas, it switches to HF for air-traffic control and either HF or satellite communications for command and control. Once in Europe, the plane must switch to different frequencies again and again as it passes over individual countries that may each employ different parts of the spectrum for different civil and military uses. To handle each of these modes, a plane on such a mission today typically carries a number of radios on-board: VHF, UHF, SATCOM and perhaps more besides. To communicate with aircraft from other nations or with army forces on the ground, whether they be those of the same country or another, more radios might need to be

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installed, or upgrades made to existing radios, before the plane takes off. It would be far better to have one radio that works on many frequencies and can be up-dated to handle different types of waveforms, so that, among other things, communications can be encrypted in different ways, preventing enemies from listening in.

The key to this approach is the software within the radios. Software-programmable radios are flexible and can store different modes. For example, if German ground forces know they are going on a mission with US ground forces and the Germans have the FEM93 mode of EPM, they can develop a software program for Single Channel Ground and Airborne Radio System (SINCGARS), load this into their radio and, in their combined mission, are able to talk to their partners. Nations might continue to use special waveforms among their own forces — some Far East countries use the Rohde & Schwarz-developed SECOS waveform, for example — but software-programmable radios would allow them to easily add Have Quick II or SATURN on their radios as well, diplomatic treaties permitting. Among the countries that have begun acquiring such radios is the Brazilian Air Force, which has been taking delivery of the software-programmable M3AR from Rohde & Schwarz.

A soldier programs radio frequencies into the communication systems of an Abrams tank prior to a mission in Iraq. (US Army photo)

Radios that combine different frequency ranges have actually been around for 10 years or so — the SINCGARS radios in the US, for example — so that one radio is able to operate in both the UHF and VHF bands and can bridge the gap between ground and air, allowing the soldier to lighten his load. But given the frequency limitations inherent in SINCGARs, as well as the system's inability to easily switch among different waveforms — used, among other things, to encrypt communications so that enemies cannot easily listen in — the US is now in the midst of an effort to develop the software-programmable Joint Tactical Radio System (JTRS) program, which will permit different services to communicate with one another, using the same radios, whether they be on land, at sea, or in the air.

But the JTRS program has run into a lot of problems. Developing the technology is proving far more complex than some planners expected, and the result has been program delays. Department of Defense officials, disappointed at the pace at which the JTRS program is advancing, actually issued a "partial stop-work order" for the program early this year. The program is divided into various "clusters," each focused on groups such as Special Forces and Army aviation, and none of the JTRS-

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based radios in development are expected to enter limited production until 2007 at the earliest, which for troops already deployed and fighting on the field, seems far away indeed.

Besides the problem of interoperable radios, the US military must deal with other types of networking problems. For instance, a general lack of networking capabilities leads to problems in situational awareness. The Air Force may not be aware that a coalition partner is operating on the ground within the battle theater and drop munitions that put the coalition member's troops in harm's way. "Overall, the US is spending some $6 B on developing network-centric operations," said US Army Major General Dave Bryan (ret.), an executive at Northrop Grumman Information Technology, "yet people continue to have to sort through mountains of information to get what they want."

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WASTED EFFORT

Mainly, the US military has set in motion programs to develop new communications and networking programs that, while they could have employed COTS software, essentially are technology programs begun from scratch.

▲ *Commercial software is being used in military space applications such as the European Galileo Satellite Navigation System. (European Space Agency image)*

As it does in the area of communications, the tendency by the US government to build from the ground up instead of buying commercially available products also prevails in the area of mission-planning software, said Gene Colabatistto, CEO and president of Xvionics (Vienna, VA), which provides mission-planning software for the Israeli and Hellenic Air Forces and is trying to crack the US market as well. Things have changed over the years, Colabatistto noted. The US Army now buys Fords and other commercially produced vehicles, when they used to have their own special types of vehicles built (Jeeps, for example). Even 15 years ago, the government awarded contracts for computers specially designed for the military, rather than buying commercially available personal computers, as it does today.

"People are saying the right things, but it takes a while for organizations to change," said Colabatistto. "You can buy something for $1 M that provides 80 percent of what you are looking for, or you can buy something for $100 M that provides 100 percent. Consumers make this choice all the time, and they choose the option that makes sense economically."

Whether or not the military does decide to purchase COTS software and do some modifications of it instead of develop its own software, they may well find themselves faced with adversaries who do buy products on the commercial market, and given

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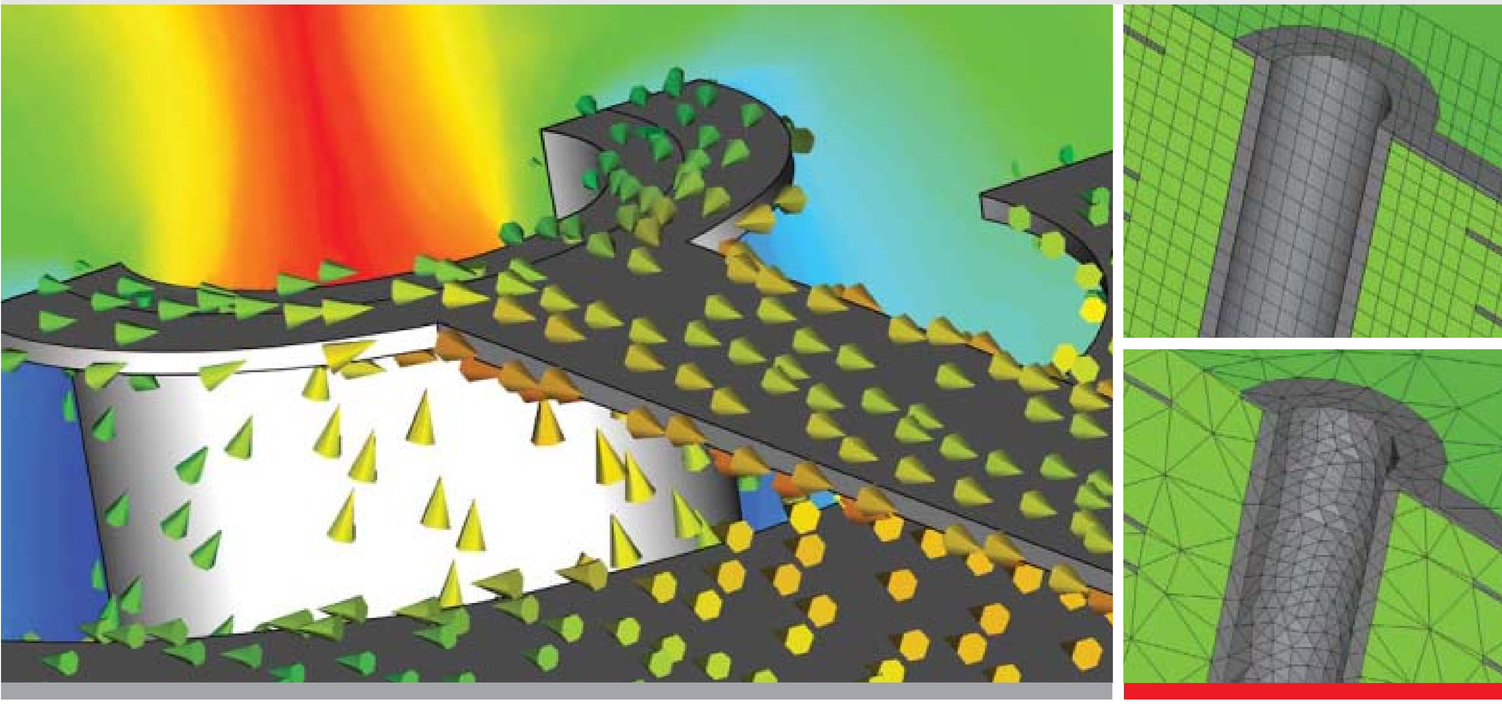

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the type of computer and networking equipment available commercially, that can be quite a threat. Take, for example, cryptographic products. Dr. Michael Kurdziel, chief cryptographer at Harris' RF Communications Division (Rochester, NY), said that the spread of cryptography is difficult to stop. University professors write papers on how to compromise algorithms, and that information becomes publicly available. Dealing with this security problem, including the difficulties it could create in intercepting enemy communications, probably will entail the military turning to the commercial world as commercial providers say it might, given that corporations like banks and other keepers of sensitive data need to be on the cutting edge of network security, if only because failing to do so could lead to major financial losses and legal problems.

Judging by a number of presentations at the TechNet International trade show, held May 17–19 in Washington, DC, military officers generally agree that the nature of warfare revolves around new forms of technology that are pervasive in the consumer world, from mobile telecommunications networks to video games that can serve as excellent training platforms.

▲ *Commercial software is being adapted to train soldiers to fight in various situations. (Meta VR image)*

Often, it is the young enlisted members of the forces that know the most about the benefits of technologies, as opposed to the older, old-fashioned officers. "The 38 year-old majors may not be so used to using these things, but the people who have just joined certainly are, and they expect to have them," said US Marine Corps Col. John Toolan, currently director of the Marine Corps University Command and Staff College.

In addition, corporate approaches to managing organizations — and by extension, training organizations to use new technology — seem to be seeping into the military ranks. For example, Gen. Benjamin Griffin, commanding general of US Army Materiel Command, during a presentation at the conference, repeatedly mentioned the use of Six Sigma methodology, which General Electric and other corporations have popularized, making their workforce more efficient. Indicating the interest that the military has in corporate practices, one panel of speakers at the TechNet show consisted of executives at a number of large corporations, including IBM Federal, Bank of America and Ryder, who discussed how their organizations had implemented better "network-centric operations," which is precisely what the US and other militaries are aiming to adopt to make their fighting forces faster and more precise.

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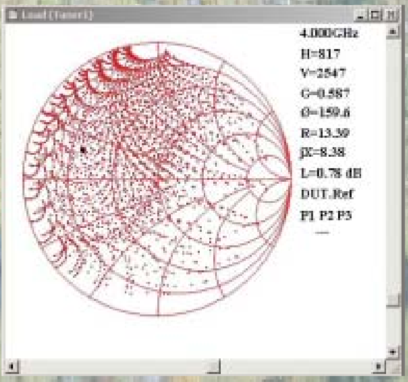

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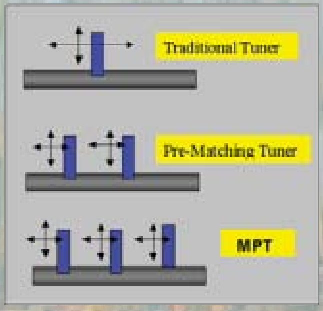

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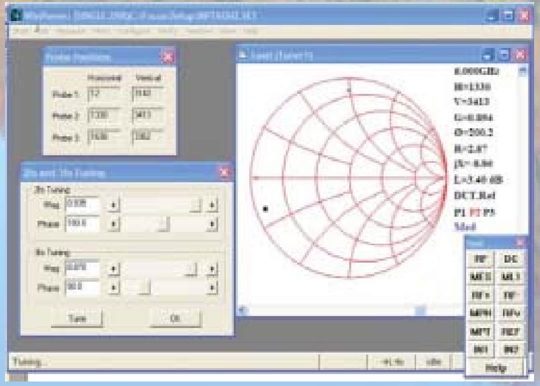

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But talk about "network-centric warfare" is one thing. Getting the US military to acquire the technology for it fast enough is quite another, whether it is COTS software or something developed by the military on its own. "Not wanting to wait for new kinds of communications, in some cases during Operation Iraqi Freedom, US servicemen, prior to deployment, were known to buy equipment off the shelf at places like Radio Shack, because the acquisition process is not working fast enough," said US Marine Corps Col. Eric Rolaf. Could part of the problem be that the government still feels it can develop its own communications systems, such as JTRS, from scratch? An executive at one major commercial manufacturer of telecommunications infrastructure equipment, Ericsson, said that much of what the US military aims to construct with its JTRS program already exists in the commercial world, yet it has basically chosen to build a network anew, with proprietary radios, as opposed to simply adapting something from the commercial world.

US Air Force Maj. Gen. Timothy A. Pepper (ret.), currently president of the Greater Hampton Roads Chapter of the National Defense Industrial Association, said that in the case of the US Joint Forces Command (JFCOM), based in Suffolk, VA, commercial businesses interested in proposing new ideas for the military frequently run into dead ends. "JFCOM needs to tell the industry where to go, and I do not believe that has happened in the past," General Pepper said.

Representatives of JFCOM said they are working hard to address such complaints, and General Pepper noted exceptions like the US Marine Corps which, he said, in the last nine months has developed some 170 new technological capabilities because of the service's willingness to acquire technologies commercially "off the shelf" as opposed to requiring modifications that may make the technology a bit more suited to its own use but significantly slow down the acquisition process. But overall, while military planners seem to know the benefits of COTS software, the reality seems to be a sluggish DoD that — because of official technology requirements prior to the process of acquisition, various rules about ensuring sufficient competition for contracts and other rules — often unintentionally stifles acquisition of technology that its services need to improve their effectiveness.

"The laws the US DoD must follow regarding competition serve as a kind of barrier to innovation," said US Air Force Maj. Gen. Donald F. Hoffman, director of requirements for Air Combat Command Headquarters at Langley AFB, VA. Such laws may have helped address problems notorious in the 1980s, but are not without their drawbacks. "I do not know how many times we have reformed the acquisition process since then, but at this point, it ought to be damn near perfect," said Maj. Gen. Hoffman, who described the Defense Department as seeming like a monolithic structure to commercial businesses, intimidating because of its Byzantine acquisition practices. "If I were on the outside looking in, I do not know if I would want to get involved with the government, to be honest. A

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TC+ Models

MODEL	Ω Ratio	Elec. Config.	Freq. (MHz)	Ins. Loss• 1dB (MHz)	Price $ea. (qty. 100)
TC1-1T+	1	A	0.4-500	1-100	1.19
TC1-1+	1	C	1.5-500	5-350	1.19
TC1-15+	1	C	800-1500	800-1500	1.29
TC1.5-1+	1.5	D	.5-2200	2-1100	1.59
TC1-1-13M+	1	G	4.5-3000	4.5-1000	.99
TC2-1T+	2	A	3-300	3-300	1.29
TC3-1T+	3	A	5-300	5-300	1.29
TC4-1T+	4	A	.5-300	1.5-100	1.19
TC4-1W+	4	A	3-800	10-100	1.19
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

TCM+ Models

MODEL	Ω Ratio	Elec. Config.	Freq. (MHz)	Ins. Loss• 1dB (MHz)	Price $ea. (qty. 100)
TCM1-1+	1	C	1.5-500	5-350	.99
TCML1-11+	1	G	600-1100	700-1000	1.09
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
TCM8-1+	8	A	2-500	10-100	.99
TCM9-1+	9	A	2-280	5-100	1.19

*Step down transformer. TC+ and TCM+ Dimensions (LxW): 0.15" x 0.16" •Referenced to midband loss.

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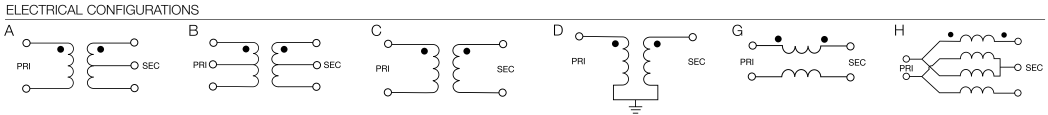

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small company, with a good idea, has a very hard time flourishing in an environment like this."

PRACTICE TESTS

Progress is being made in introducing new technologies and practices to the military, of course, as many officials recognize the benefits of commercial technology and want to take advantage of it as much as possible. Exercises that test new technologies in various military situations occur regularly. For example, looking to solve communications networking problems, as well as improve other aspects of coordinating combined operations, whether among different military services, other countries, or domestic law enforcement and other civil agencies, the US Department of Defense on June 13-23 held its latest annual Coalition Warrior Interoperability Demonstration (CWID), hosted this year by US Northern Command in Colorado Springs, CO, and managed by US Joint Forces Command in Suffolk, VA. Two basic types of scenarios formed the basis for this exercise: one focused on multi-party responses to fictional domestic crises — the derailment, near Washington, DC, of a train carrying chlorine gas was one of the situations — and the other testing the international response to a crisis involving the fictional, oil-rich, African country of Lumbia, where two civil factions were attempting to destabilize the government.

In all, CWID 2005 connected five US and 11 international sites for the purpose of testing 41 different types of systems or software for sharing information or communications, with sites including Hanscom AFB, MA, the Naval Surface Warfare Center in Dahlgren, VA and sites in New Zealand, Norway and the UK, among other countries. One of those 41 applications was a commercially developed, homeland-defense-type system called the Incident Commanders' Radio Interface (ICRI), designed to serve as a go-between for incompatible radio and communications equipment. Following the crash of commercial aircraft into the World Trade Center, thousands of fire fighters, police officers, and other New York City law-enforcement and emergency personnel rushed to help, but the response was chaotic. Effective command and control was absent, radio communications among different departments was often ineffective, and more people than expected may have died as a result. It is exactly this type of situation that the ICRI is designed to aid, said participants at the Dahlgren, VA, Navy site of the exercise. What will be the result of this and other trials of technology that took place during CWID and other similar exercises? They may or may not be developed into larger programs and put in the field, organizers said. Such is the point of such trials: to determine whether the technology shows promise, and to provide an opportunity for testing new technological solutions, whatever their origins, commercial or government. ■

Ted McKenna *lives in Washington, DC, and is senior editor for the defense publications eDefense Online and the* Journal of Electronic Defense. *Previously, he was staff editor of* Telecommunications, *Norwood, MA, and news editor for the Internet dotcom publication TelekomNet, Boston, MA.*

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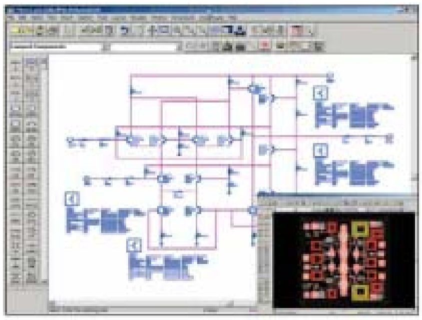

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LOW NOISE OCTAVE BAND AMPLIFIERS

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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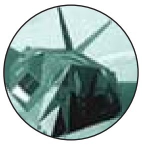


DRS Technologies Receives $44 M for Advanced Intelligence Equipment

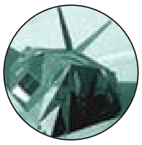
DRS Technologies announced that it has received orders with a combined value of approximately $44 M to provide advanced intelligence equipment supporting all installation types used in the collection of communications intelligence (COMINT) and signal intelligence (SIGINT) data. These products will be used in man-portable, fixed-site and mobile applications supporting the intelligence community. The contracts were awarded to DRS by various intelligence agencies and US government organizations, as well as domestic and international defense prime contractors. For these orders, the company's DRS Signal Solutions unit in Gaithersburg, MD, will provide various high performance tuners, receivers, demodulators and direction finding equipment. Product deliveries are expected to be completed in approximately six months. DRS's receivers, tuners, demodulators and signal analyzers perform signal intercept, including cellular intercept, identification, direction finding, location and analyzing functions within the 5 kHz to 40 GHz spectrum. The equipment can be deployed on board surveillance aircraft, helicopters, surface and sub-surface vessels and vehicles, as well as at fixed sites. The company product lines range from miniature, single-function components to integrated assemblies and systems, and are supported by DRS's custom software development. DRS Signal Solutions provides advanced military and space communications technologies to achieve information superiority on the 21st century battlefield. It offers a wide range of solutions for gathering, exploiting and protecting critical Command, Control, Communications and Intelligence (C3I) information, including microwave products with unmatched signal purity for increased surveillance and compact satellite communications (SATCOM) converters at half the physical size of any other available, with low phase noise and low distortion.

Harris Corp. Selected for Phase One of Quint Networking Technology

Harris Corp. announced that it is one of two companies to receive a nine-month, $3.5 M contract for the Quint Networking Technology (QNT) program. QNT is a Defense Advanced Research Projects Agency-led (DARPA) technology program to produce a very small and modular digital communications system for a variety of ground and airborne applications. The program is being funded by DARPA, the US Navy and the US Air Force. "We are very pleased that Harris has been selected to participate in the QNT program," said Dan Pearson, president of the Department of Defense unit of Harris Corp.'s Government Communications Systems Division (GCSD). "Harris has a compelling and successful track record in the development of communications networks and weapon data links for munitions such as the US Navy Standoff Land Attack Missile (SLAM)." Harris is leading a team composed of ViaSat, L-3 Communications, The Boeing Co., Lockheed Martin, BBN, Cybernet Systems, Innovative Concepts and Vanu. The team's solution leverages its advanced capabilities in communications technologies to provide QNT network and terminal solutions. The combined team's capabilities include software-defined radios, mobile and ad hoc networks, the Joint Tactical Radio System (JTRS), the Multi-functional Information Distribution System (MIDS) and the Common Data Link (CDL) to provide QNT network and terminal solutions.

Raytheon Receives $10 M for New Radar Warning Receiver Technology

Raytheon Co. has been awarded a $10 M contract for an advanced concept technology demonstration of Advanced Tactical Targeting Technology (AT3). The technology will be demonstrated in 2007 on three F-16 Block 30 aircraft using Raytheon's digital radar warning receiver, the ALR-69A (V). The award was received from the Warner Robins Air Logistics Center, Robins Air Force Base, GA. The phase one contract calls for the demonstration of rapid and accurate location of radio frequency emitters associated with enemy air defenses. Three F-16 aircraft will be networked to share precise signal measurements in a timely manner, providing 360-degree coverage to rapidly and accurately locate RF emitters from any angle of arrival without use of external hardware. This demonstration will build upon the success of a US Air Force Research Labs/Defense Advanced Research Agency (DARPA) AT3 advanced technical demonstration completed in 2003 by Raytheon Missile Systems. The contract also contains $11 M in options for additional test phases of the program. "This program is a giant step toward providing network-enabled defeat of enemy air defenses," stated Pat Hurley, vice president and general manager of Raytheon Electronic Warfare Systems. "Our ALR-69A (V) is a highly advanced radar warning receiver, and this technology enhancement is just one example of its extraordinary capabilities." The ALR-69A (V) receiver system used for the AT3 demonstration is an upgrade of the ALR-69 (V), which is currently installed on US Air Force C-130, F-16, A-10 and MH-53 aircraft. Raytheon was awarded the ALT-69A (V) program in August 2001. Flight tests of the new digital radar-warning receiver are expected to begin later in 2005, followed by a low rate initial production decision in 2006. Work on the radar warning system is being done at Raytheon's Space and Airborne Systems business by its Electronic Warfare Systems organization, located in Goleta, CA.



Lockheed Martin JCM Seeker and Software Pass Key Design Reviews

The tri-mode seeker and guidance software that represent the "eyes and brains" of the Lockheed Martin Joint Common Missile (JCM) reached a significant milestone in passing subsystem Preliminary Design Reviews (PDR) recently. "The tri-mode seeker is really what distinguishes JCM from the eight missiles it will be replacing," said Rick Edwards, director for tactical missiles at Lockheed Martin Missiles and Fire Control. "It gives JCM the ability to zero in on and destroy threat targets even in close proximity to vital urban structures, friendly forces and non-combatants who must be protected. The tri-mode seeker and multi-purpose warhead were identified by the customer as crucial risk areas for the JCM program because of their advanced technologies and because their capabilities had never been achieved before. Now that both the seeker and the warhead have been demonstrated against the full range of required targets, this risk has been substantially reduced." JCM's multi-purpose warhead, which previously passed its subsystem PDR, includes both a tandem-shaped charge for armored targets and a blast fragmentation capability for other targets, such as reinforced structures in urban areas. The JCM seeker includes a semi-active laser (SAL), for precision strike and limited collateral damage; an imaging-infrared (I2R) sensor for passive fire-and-forget and robustness against countermeasures; and a millimeter-wave (MMW) radar for active fire-and-forget and operation in adverse weather and battlefields obscurants. The sophisticated seeker — the first of its kind — gives JCM both line-of-sight and beyond-line-of-sight targeting capability, as well as the ability to acquire, track and destroy a wide range of stationary and moving land and maritime targets. The subsystem PDR for JCM's guidance group covered both the seeker and the micro-miniaturized high speed electronics that process the data the sensors acquire. The subsystem PDR for JCM software and simulations covered the software in the on-board computer that interprets the seeker data, selects a target, sets the warhead mode and generates the electronic commands that guide the missile to its destination. Data presented in the PDRs summarized the results of tower and captive-carry tests of two prototype tri-mode seekers, tracking land and littoral (coastal) targets, as well as extensive computer simulations that have been conducted since 2003. Passage of the two subsystem PDRs completes the series required in the preparation for the system-level PDR, which will determine whether the program has demonstrated the level of maturity for exit from Phase 1 of its System Design and Development (SDD) contract. ■

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INTERNATIONAL REPORT

Richard Mumford, European Editor

Infineon Transfers RFID Software Solutions to RF-iT Solutions

As part of a management buy out, Infineon Technologies has transferred its activities in the area of RFID software solutions to RF-iT Solutions GmbH. This means that patents, trademarks, licenses, development hardware and software, as well as current customer projects and RFID demonstration applications have been transferred to RF-iT Solutions, which has its registered office in Graz, Austria.

Infineon focuses its RFID activities in the area of object identification on logistics applications and other intelligent label applications on the further development, production and marketing of RFID chips and inlays, which comprise chips, antennae, and the connection between chip and antenna.

The newly formed RF-iT Solutions will take over all activities related to RFID system solutions, including the You-R®OPEN software, which Infineon developed to market readiness, as well as readers and service components. The company will continue to develop its range of services and You-R OPEN. In addition, RF-iT Solutions will continue to operate the RFID Solution Excellence Centre in Graz. The Centre acts as a showcase for different RFID applications, a development laboratory for sector-specific RFID solutions, a verification laboratory to carry out technology research and a customer training centre.

Chinese R&D Centre to Focus on NGN and Microwave Transmission

Alcatel has announced that it will inaugurate a new Research & Development Centre in Chengdu, the capital city of Sichuan Province in Western China, by the end of 2005. Located inside the Chengdu High-Tech Park, an area dedicated to advanced IT and telecom technology development, the Centre will be managed by Alcatel Shanghai Bell, the company's Chinese flagship company.

The Centre will undertake the development of world-class technologies and product concepts covering fixed and mobile communication areas. Initially, it will focus on advanced mobile technologies and solutions in the area of mobile Next Generation Networks and microwave transmission. Around 300 R&D engineers will be employed in this new facility.

In close collaboration with the existing Research and Innovation Centre at Alcatel Shanghai Bell's headquarters in Shanghai, the Chengdu R&D centre will bring to market promising new technologies coming out of the company's research and, in time, house the activities currently being carried out in the Optical Communication R&D Centre in the city.

Gerard Dega, president of Alcatel Shanghai Bell, commented, "With the new Centre, Alcatel Shanghai Bell will be able to quickly respond to changing market needs in China and deliver the most advanced technologies to our customers' doorstep. The ready availability and abundance of research and engineering talent in China enables us to bring cutting-edge, cost-effective telecom technologies and solutions to our customers."

NEC and Siemens Supply W-CDMA/UMTS 3G Network in Ireland

NEC Corp. and its 3G partner Siemens Communications are assisting Hutchison 3G Ireland (trading as 3 Ireland) in deploying its W-CDMA/UMTS 3G network. As the supplier of 3 Ireland's W-CDMA/UMTS radio access network (UTRAN), the contract includes the delivery of a full complement of Node-B radio base stations and radio network controllers with the aim of providing ubiquitous 3G network coverage for customers around the country.

A key part of the contract will be the delivery by NEC of a large number of units of its PASOLINK point-to-point wireless access system, which is a PDH/SDH microwave system. Due to the rapid expansion of mobile networks globally, operators are deploying this system to connect radio base stations in order to facilitate the reliable and speedy installation of the 3G mobile infrastructure.

According to Katsuhiro Nakagawa, associate senior vice president of NEC Mobile Solutions Operations Unit, "This latest contract is a clear testimony to the continuing success of the highly effective 3G network provided by NEC and Siemens for Hutchison."

VDD Makes Space for QinetiQ Share Acquisition

QinetiQ and the Verhaert Group of Belgium have announced the acquisition by QinetiQ of a 90 percent share of Verhaert Design and Development NV (VDD), the leading Belgian space systems integrator, with the option to purchase the remaining 10 percent of shares at a later date. The company will be renamed Verhaert Space NV.

Announcing the deal, Andrew Rogoyski, managing director of QinetiQ's Space Division, said: "With this deal QinetiQ and Verhaert have created a company that is well placed to bridge the gap that currently exists in the European space industry between the two biggest players and a multitude of smaller suppliers. By combining QinetiQ's expertise in space missions and technology with Verhaert's complementary capabilities in small satellites, spacecraft system integration, payloads and instrumentation we believe we can establish ourselves as the leading European mid-tier space company."

"The deal with QinetiQ represents a huge opportunity for our customers, our employees and our company," said Paul Verhaert, Verhaert's CEO. "By partnering with QinetiQ we can better exploit the market trend towards the provision of smaller, low cost, fast-to-launch satellites for government and commercial customers. Through QinetiQ we can also gain access to leading edge technologies that can deliver product innovations to Verhaert's client base."

Triumvirate Teams Up to Pursue NATO Project

Defence industry leaders EADS, Indra and Northrop Grumman Corp. have formed an international team to pursue a systems engineering and integration contract that is a key part of the new NATO active-layered theatre ballistic-missile defence programme. This programme will be the first to link the assets of member nations into a multi-layered system that will effectively protect deployed alliance forces against short- and medium-range ballistic-missile attack.

The winning team for the NATO systems engineering and integration (SE&I) contract will design and operate an integration test bed in Europe that will help NATO prepare its member nations' assets for inclusion into this unified system, with the award of the contract due in the second quarter of 2006.

If chosen, the team will use the integration test bed as a platform to integrate, test and verify the proposed architectures; develop and evaluate theatre missile-defence concepts of operation; and test and evaluate the different architectural capabilities as hardware and software become available. In addition, the team will ensure integration and interoperability among the various NATO components of the architecture from both a technical and operational perspective. The test bed will also be used for performance verification, using detailed modeling and simulation tools to ensure that the actual missile defence performance will meet the requirements.

"We are excited about this opportunity to team with Northrop Grumman and Indra, and bring the full capabilities of EADS to the challenge of NATO ballistic missile defence," said Dr. Stefan Zoller, chief executive officer of EADS Defence & Security Systems Division. "We have a strong focus on transatlantic cooperation projects and expect to expand this further within our defence and security strategy." ■

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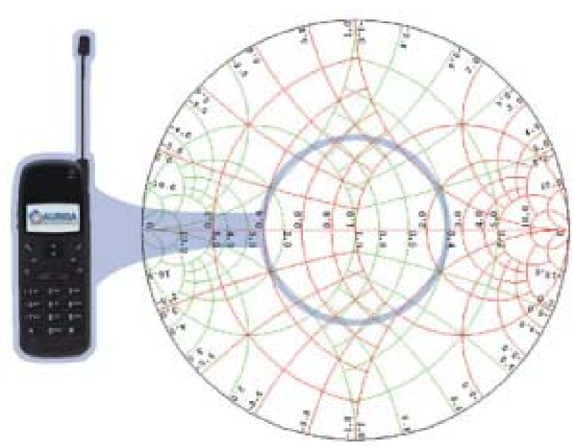

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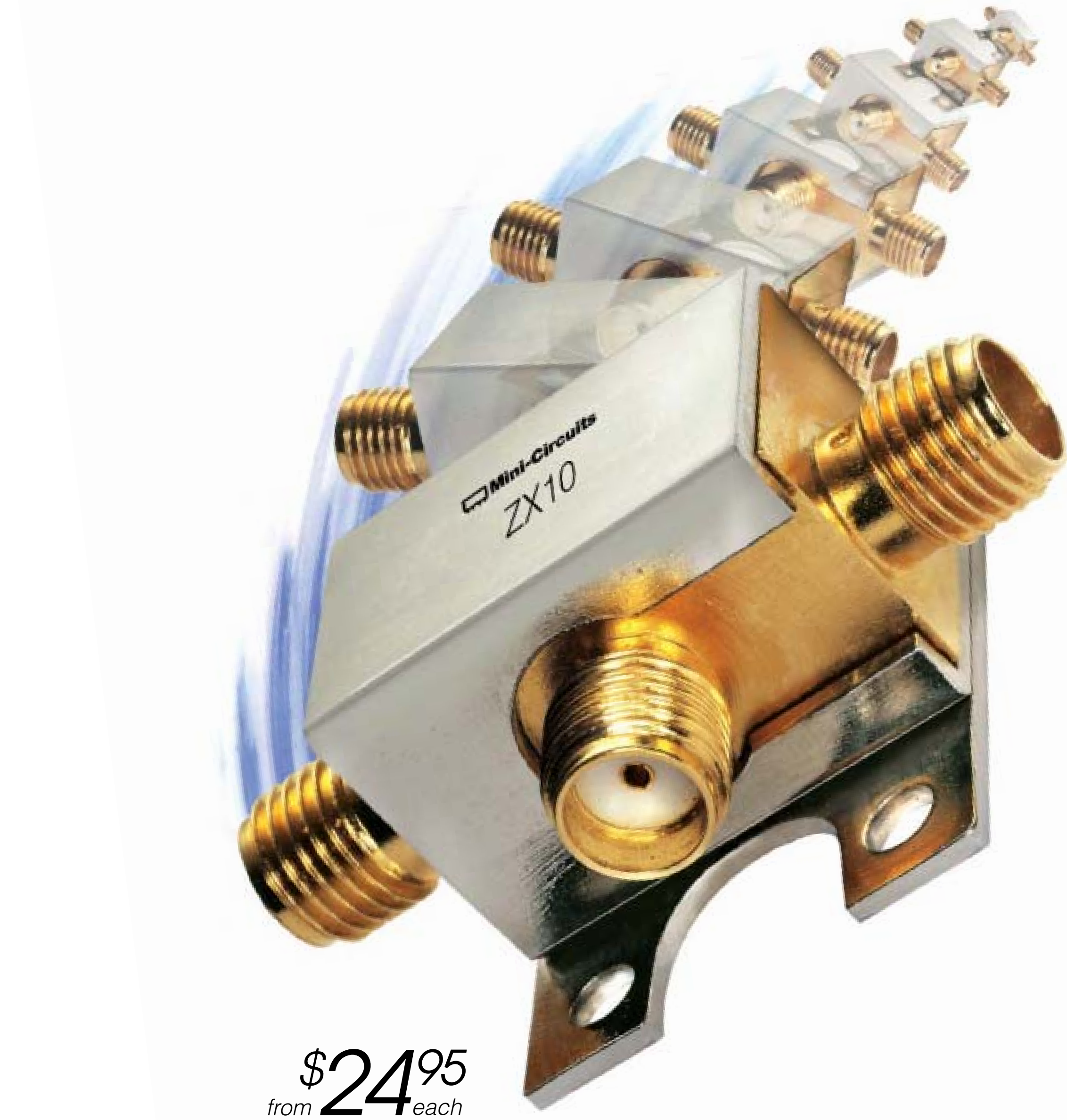

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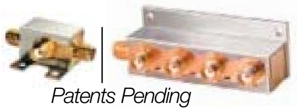
TYPICAL SPECIFICATIONS

2WAY-0° Model	Frequency (GHz)	Isolation (dB)	Insertion Loss (dB) Above 3.0dB	Price $ea. (Qty.1-24)
ZX10-2-12	.002-1.2	21	0.5	24.95
ZX10-2-20	.2-2	20	0.8	24.95
ZX10-2-25	1-2.5	20	1.2	26.95
ZX10-2-42	1.9-4.2	23	0.2	34.95
ZX10-2-71	2.95-7.1	23	0.25	34.95
ZX10-2-98	4.75-9.8	23	0.3	39.95
ZX10-2-126	7.4-12.6	23	0.3	39.95
4WAY-0°			Above 6.0dB	
ZX10-4-11	.8-1.125	20	0.6	38.95
ZX10-4-14	1.1-1.45	20	0.8	38.95
ZX10-4-19	1.425-1.9	20	0.75	38.95
ZX10-4-24	1.675-2.35	20	0.9	38.95
ZX10-4-27	2.225-2.7	20	1.0	38.95



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(L).74"x(W).90"x(H).54"
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DAT SELECTION GUIDE

Specifications Typical at: T_{AMB} = 25°C

Model Series	Interface	Z (Ω)	Freq. MHz	Atten. dB	Steps dB	Bits	Price $ea. (Qty.10)
DAT-15R5-P ▲	Parallel	50	DC-4000	15.5	0.5	5	3.55
DAT-15R5-S ▲	Serial	50	DC-4000	15.5	0.5	5	3.55
DAT-15575-P ▲	Parallel	75	DC-2000	15.5	0.5	5	3.55
DAT-15575-S ▲	Serial	75	DC-2000	15.5	0.5	5	3.55
DAT-31-P ▲	Parallel	50	DC-2400	31.0	1.0	5	3.55
DAT-31-S ▲	Serial	50	DC-2400	31.0	1.0	5	3.55
DAT-3175-P ▲	Parallel	75	DC-2000	31.0	1.0	5	3.55
DAT-3175-S ▲	Serial	75	DC-2000	31.0	1.0	5	3.55
DAT-31R5-P ▲	Parallel	50	DC-2400	31.5	0.5	6	3.80
DAT-31R5-S ▲	Serial	50	DC-2400	31.5	0.5	6	3.80
DAT-31575-P ▲	Parallel	75	DC-2000	31.5	0.5	6	3.80
DAT-31575-S ▲	Serial	75	DC-2000	31.5	0.5	6	3.80

▲To specify Supply Voltage:
Add the letter (P) to model number for positive +3 volts.
Add the letter (N) to model number for Dual ±3 volts.
Example: DAT-15R5-PP or DAT-15R5-PN
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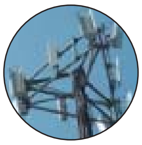

Home Networking Revenue to Top $20 B in 2009

Revenue derived from annual networking hardware shipments and from equipment that incorporates a home networking connection will jump from almost $9 B in 2004 to over $21 B in 2009, reports In-Stat. A push for higher speeds, lower prices and increasing network areas in the home is driving the market, the high tech market research firm says. However, one highly touted use, the storage and streaming of multimedia files, may take years to catch on with the mass consumer. "Our research shows that there is growing interest among US consumers to use home networks to connect their increasing library of digital entertainment, audio and video files, with their traditional entertainment equipment (stereo, TV)," says Joyce Putcher, In-Stat analyst. "As consumers become more comfortable and familiar with the idea of bridging their PCs with their traditional analog equipment, interest will pick-up."

A recent report by In-Stat found the following:

- WLAN has now usurped Ethernet as the desired home network of choice, and is now dominated by multi-band 54 Mbps 802.11g.
- The installed base of home networks worldwide went from about 24 million in 2003 to 37 million in 2004.
- Home networking equipment continues to drop in price, and increasing functionality such as wireless and VoIP is being integrated. Silicon prices, higher volumes and competition have all contributed toward aggressive pricing.

The report, "Digital Domicile 2005: Wireless Overtakes Ethernet," contains analysis using consumer survey data, vendor profiles and detailed forecasting. It examines key world market shares for SOHO routers, residential gateways, networked cameras, 802.11b, 802.11g, 802.a/g, HomePlug and HomePNA equipment. Forecasts are broken down by product segment (NICs/LOM, Routers/Switches, Residential Gateways and Media Network Devices), as well as by type of LAN interface. The worldwide installed base of home network forecast is provided by region and by interface technology category.

RFID Integrators are Looking to the Long Term

When a group of twenty RFID vendors announced the formation of a 'patent pool' consortium intended to simplify and streamline users' access to RFID intellectual property, they signaled yet another step towards maturity for the young RFID industry. RFID is no longer just about hardware — tags and readers — says Erik Michielsen, ABI Research's director of RFID and ubiquitous networks. Many of the companies involved in the announcement have broadened their focus to include full integration of RFID with end-users business' systems. These and many other integrators and their services are the subject of ABI Research's study, "RFID Integration Services Markets," which includes models for RFID verticals and applications with a focus on RFID reader, software (middleware) and systems integration services. "Today, it is no longer a question just of trials and compliance testing," says Michielsen. "Now it is about building scalable, high volume, high value integrated solutions that use RFID to collect information, then putting that information into well-designed enterprise infrastructures where it can be used to drive more agile and informed business decision-making. It is a process of making that core tag information more meaningful." Examples include avoiding theft in the pharmaceutical supply-chain, improving manufacturing productivity through RFID tracking, increasing promotion visibility at retail stores, reducing inventory or building more comprehensive, globally scalable integrated solutions for the homeland security or defense. It is also about companies relocating themselves in a shifting competitive landscape. Companies large and small, coming from different backgrounds in IT, applications development and systems integration are seeking appropriate partners in different markets. Large IT-based firms such as IBM (with its WebSphere RFID Device Infrastructure), Microsoft, SAP and Oracle are actively tying RFID information into enterprise architectures, while smaller fry such as TrueDemand Software, OATSystems, Connecterra and ACSIS try to redefine themselves to complement their bigger neighbors.

MEMS Shipments to Grow 20 Percent per Year Through 2009

Buoyed by a strong, eventful 2004, the MicroElectroMechanical Systems (MEMS) market will grow over the next few years in terms of unit shipments at a compound annual growth rate (CAGR) of 19.87 percent to nearly six billion units in 2009, reports In-Stat. Funding for MEMS companies increased by 43.9 percent in 2004 versus 2003, the high tech market research firm says, as the market continued to rack up strong sales. Year-over-year total MEMS revenues were up 32 percent from 2003 to 2004.

A recent report by In-Stat found the following:

- Microfluidic devices accounted for nearly 69 percent of total unit shipments and 23 percent of total revenues in 2004.
- With more cell phones integrating RF MEMS devices and inertial sensors and the optical networking sector finally embracing MEMS technology, the communications market is forecast to experience the highest CAGR for unit shipments and revenues.
- Despite the fragmented and niche-like nature of the industrial segment, it is the dominant segment in terms of

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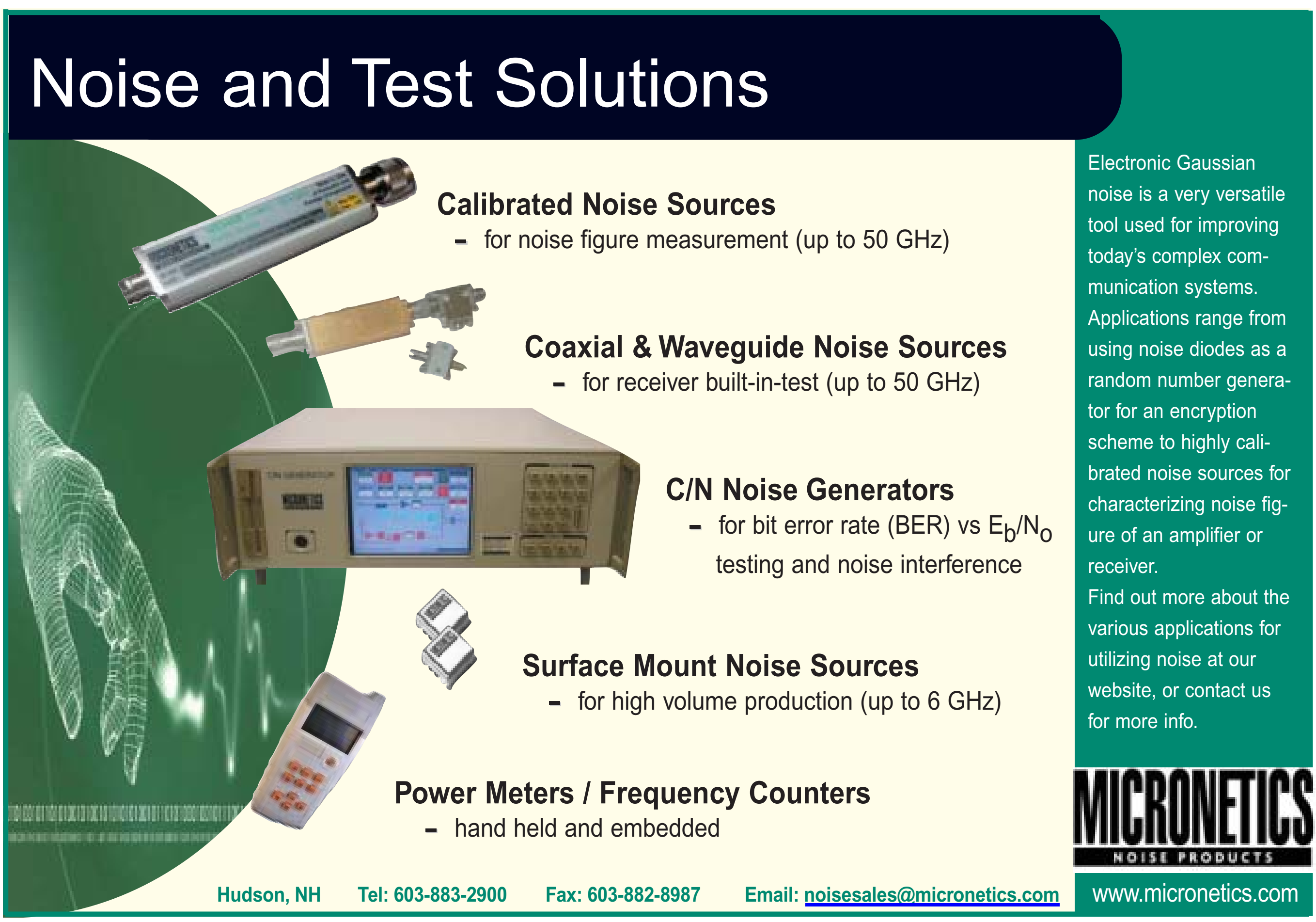
revenue in 2004, and remained so throughout the forecast period.

- The top twenty suppliers of MEMS devices accounted for 62.2 percent of revenues in 2004.

The report, "2005 MEMS Industry Overview and Forecast," covers the worldwide MEMS industry. It contains forecasts in unit shipments and revenues by product category and by industry through 2009. It also includes a ranking of the top twenty MEMS suppliers and a detailed review of new products and developments.

Power Amplifier Modules Emerge as Wi-Fi Growth Continues

New applications, competition and technology developments are expected to propel the Wi-Fi chip market from $900 M in 2004 to $2.1 B in 2009, according to "Wi-Fi Component Forecast and Vendor Share," from Strategy Analytics. The continuing reduction in Wi-Fi radio chip prices, increasing integration and adoption of front-end PA modules, will help drive Wi-Fi into an ever-increasing number of platforms. Although demand from notebook computers currently accounts for the majority of chip shipments, by 2009 Wi-Fi enabled cell phones will dominate. The power amplifier market is experiencing one of the most heated technology races in Wi-Fi. GaAs, with its low power consumption and ability to provide good performance at 5 GHz, leads this segment. With SiGe's potential integration and cost advantages, SiGe vendors have made inroads against GaAs at 2.4 GHz, and will continue to push this technology over the next five years in crucial, high value power amplifier and front-end module markets. "Several SiGe and GaAs power amplifier vendors made dramatic inroads against better established Wi-Fi power amplifier vendors in 2004 with the introduction of front-end modules incorporating filters, switches and power amplifier chips. We believe that the simplicity of modules for system makers means that this trend will continue," says Asif Anwar, director of the Strategy Analytics GaAs Program. Despite the opportunities for the Wi-Fi chip makers, this report makes sobering reading for vendors. "Broadcom, Atheros and Intel presently control over half of the Wi-Fi chip market," states Chris Taylor, director, Strategic Analytics' RF and Wireless Component service. "The number of vendors has fallen dramatically over the past two years, but we count at least 58 players still in the market, which is still far too many. We only expect around 20 to survive the next five years." The report contains an analysis of Wi-Fi volume by application, forecasts by technology and vendor market share for Wi-Fi chipsets and PAs. ■



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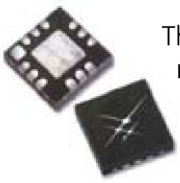
GaAs T/R Diversity Switch DC–6 GHz



The SKY13267-321 is a monolithic DPDT switch fabricated using Skyworks Solutions proprietary GaAs PHEMTs as the switching elements. This wideband switch offers very low insertion loss 0.8 dB type @ 5.2 GHz. The P_1dB is +30 dBm type @ 3V and RF signal paths within the SKY13267-321 are fully bilateral.

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CMOS Switch DBS 4 x 2 Switch Matrix 250 MHz–2.15 GHz

The SKY13264-340LF is a 4-input to 2-output switch in a low cost QFN-20 4 x 4 mm package. The SKY13264-340LF enables 16 states, directing any of the four inputs to either of the two outputs. States are selected by four positive voltage control inputs. The switch can operate over the temperature range of -40 °C to 85 °C.

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250–2700 MHz Linear Power Amplifier Driver

The SKY65009 is a high performance, ultra-wideband amplifier with superior output power, linearity, and efficiency. The device uses low-cost, Surface-Mount Technology in the form of a 4-pin SOT package (-11 option) or lead (Pb)-free, 3-pin MCM package (-21 option, pin-compatible with the -11). The high linearity and superior ACPR/ACLR performance of the SKY65004 make it ideal for use in the driver stage of infrastructure transmit chains.

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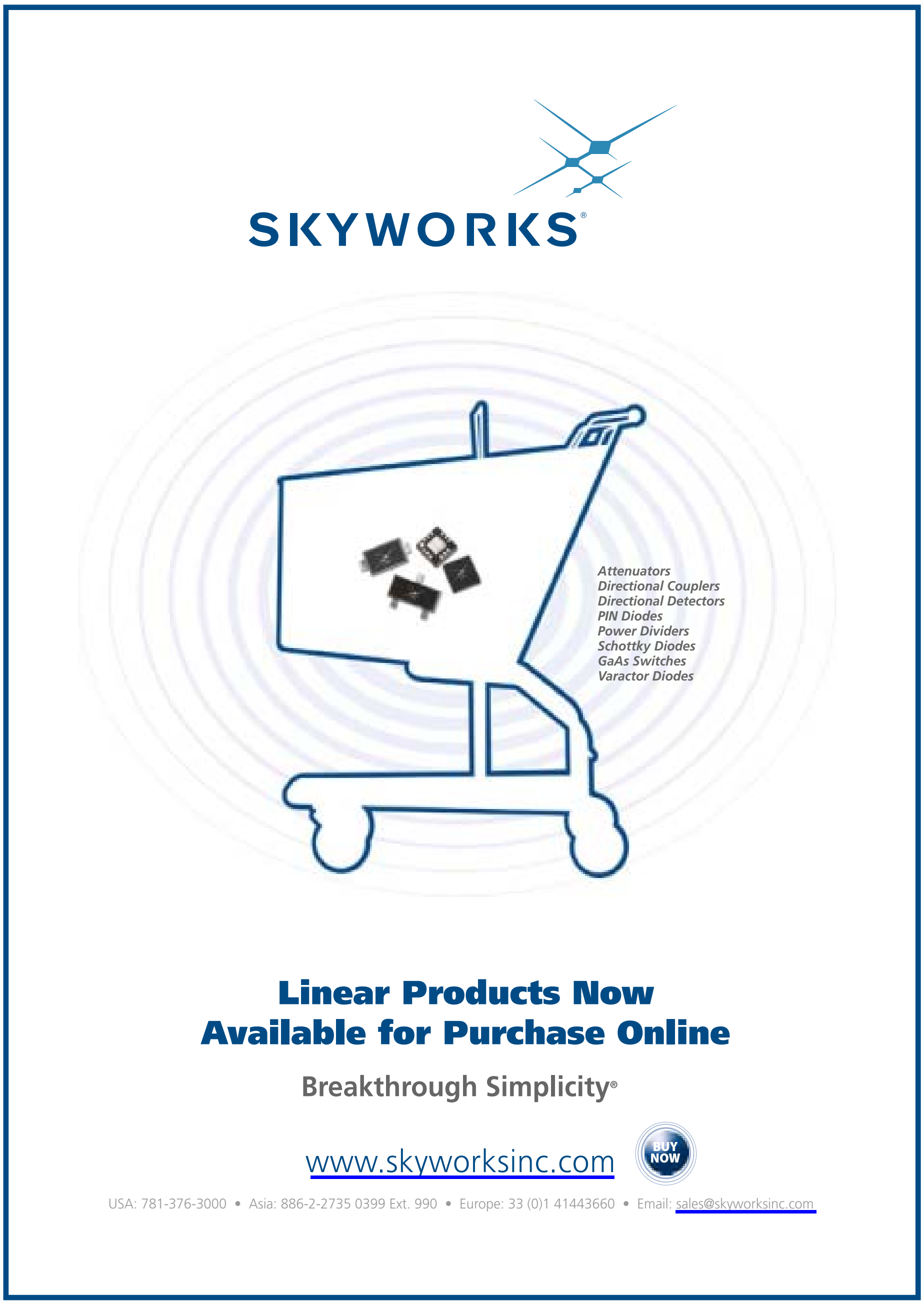

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Model Number	RF/LO Frequency (GHz)	IF Frequency (GHz)	LO Power (dBm)	Conversion Loss (dB) Typ./Max.	LO-to-RF Isolation (dB) (Min.)
DOUBLE-BALANCED VERSIONS					
DM0052LA2	0.5 – 2	DC – 0.5	7 – 13	6.5/8.5	30
DM0104LA1	1 – 4	DC – 1	7 – 13	5.5/7.0	30
DM0208LW2	2 – 8	DC – 2	7 – 13	7.0/8.0	30
DM0416LW2	4 – 16	DC – 4	7 – 13	7.0/8.0	30
DB0218LW2	2 – 18	DC – 0.75	7 – 13	6.5/8.5	22
DB1826LW1	18 – 26	DC – 2	7 – 13	7.5/9.5	20
DB0226LA1	2 – 26	DC – 2	7 – 13	6.5/8.5	20
DB0440LW1	4 – 40	DC – 2	10 – 15	9.0/10	20
M1826W1	18 – 26	DC – 8	10 – 13	9.0/11	20
M2640W1	26 – 40	DC – 10	10 – 13	10/12.5	20
TRIPLE-BALANCED VERSIONS					
TB0218LW2	2 – 18	0.5 – 8	10 – 15	7.5/9.5	20
TB0426LW1	4 – 26	0.5 – 8	10 – 15	10/12	20
TB0440LW1	4 – 40	0.5 – 20	10 – 15	10/12	18

PASSIVE DOUBLERS

Model Number	Input Frequency (GHz)	Input Power (dBm)	Output Frequency (GHz)	Conversion Loss (dB) Typ./Max.	Rejection (dBc) Fund.	Rejection (dBc) Odd Harm.
DROP-IN VERSIONS						
SXS01M	0.5 – 3	8 – 12	1 – 6	13/16	-20	-25
SXS04M	2 – 9	8 – 12	4 – 18	13/15	-20	-25
SXS07M	3 – 13	8 – 12	6 – 26	13/17	-18	-25
CONNECTORIZED VERSIONS						
SXS2M010060	0.5 – 3	8 – 12	1 – 6	13/16	-20	-25
SXS2M040180	2 – 9	8 – 12	4 – 18	13/15	-20	-25
SXS2M060260	3 – 13	8 – 12	6 – 26	13/17	-18	-25

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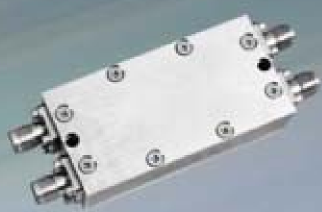
IMAGE REJECTION MIXERS



Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Image Rejection (dB) Min.	LO-to-RF Isolation (dB) Min.
IMAGE REJECTION MIXERS				
IRM0204(*)C2(**)	2 – 4	7.5	18	20
IRM0408(*)C2(**)	4 – 8	8	18	20
IRM0812(*)C2(**)	8 – 12	8	18	20
IRM1218(*)C2(**)	12 – 18	10	18	20
IRM0208(*)C2(**)	2 – 8	9	18	20
IRM0618(*)C2(**)	6 – 18	10	18	18
IR1826NI7(**)	18 – 26	12	18	23
IR2640NI7(**)	26 – 40	13	18	20

Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Balance Phase (±Deg.) Typ./Max.	LO-to-RF Amplitude (±dB) Typ./Max.	Isolation (dB) Min.
I/Q DEMODULATORS					
IRM0204(*)C2Q	2 – 4	10.5	7.5/10	1.0/1.5	20
IRM0408(*)C2Q	4 – 8	11	7.5/10	1.0/1.5	20
IRM0812(*)C2Q	8 – 12	11	7.5/10	1.0/1.5	20
IRM1218(*)C2Q	12 – 18	13	10/15	1.0/1.5	20
IRM0208(*)C2Q	2 – 8	12	7.5/10	1.0/1.5	20
IRM0618(*)C2Q	6 – 18	13	10/15	1.0/1.5	18
IR1826NW1Q	18 – 26	15	10/15	1.0/1.5	23
IR2640NW1Q	26 – 40	16	10/15	1.0/1.5	20

SSB UPCONVERTERS OR I/Q MODULATORS

Model Number	RF Frequency (GHz)	Conversion Loss (dB) Max.	Carrier Suppression (dBc) Min.	Carrier Suppression Carrier - Fundamental IF (dBc) Min.
IF DRIVEN MODULATORS				
SSM0204(*)C2MD(**)	2 – 4	9	20	20
SSM0408(*)C2MD(**)	4 – 8	9	20	20
SSM0812(*)C2MD(**)	8 – 12	9	20	20
SSM1218(*)C2MD(**)	12 – 18	10	20	18
SSM0208(*)C2MD(**)	2 – 8	9	20	20
SSM0618(*)C2MD(**)	6 – 18	10	20	18

For full data sheets on the products shown, please visit www.miteq.com/adinfo

For Carrier Driven Modulators, please contact MITEQ.

MODEL NUMBER OPTION TABLE

(*) Add Letter	LO/IF Power Range	P1 dB C.P. (dBm) (Typ.)
L	10 – 13 dBm	+6
M	13 – 16 dBm	+10
H	17 – 20 dBm	+15

(**) Add Letter	IF FREQUENCY OPTION (MHz)
A	20 – 40
B	40 – 80
C	100 – 200
Q	DC – 500 (I/Q)

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AROUND THE CIRCUIT

INDUSTRY NEWS

■ **Hittite Microwave Corp.** acquired substantially all of the assets of **Q-Dot Inc.**, a research and development organization advancing mixed-signal silicon integrated circuit technology in data acquisition, signal processing, imaging and communications, from **SIMTEK Corp.** The acquisition, for $2.2 M in cash, includes Q-Dot's intellectual property and its business, consisting primarily of research and development contracts with US Government defense agencies. The employees of Q-Dot have joined Hittite and will continue to work at the Colorado Springs, CO facility.

■ **Applied Wave Research Inc.** (AWR®) and **APLAC Solutions Oy** announced that AWR has acquired APLAC, which develops and markets simulation and analysis software for analog and radio frequency design. The merger of the two electronic design automation software developers was driven by key customer demand for APLAC's high performance, foundry-approved circuit simulation strength combined with the open, integrated AWR Design Environment™ technology.

■ **Peak Devices Inc.**, a manufacturer of radio frequency transistors, has announced the acquisition of certain assets related to **Agere Systems**' RF power LDMOS portfolio, including the production wafers, die, packages, lids and select specialized assembly equipment for the manufacture and support of transistors that produce more than 10 W of RF power. In related news, Peak announced the acquisition of wafers, die, packages, lids and specialized assembly equipment needed to continue to manufacture and support the **Infineon** PTB series of bipolar RF transistors.

■ **Agilent Technologies Inc.** announced it has completed the acquisition of privately held **Eagleware Corp.**, which does business as Eagleware-Elanix. Agilent and Eagleware-Elanix, a provider of system and circuit design software for the communications industry, had announced an acquisition agreement July 28. Financial details were not disclosed. Eagleware-Elanix employees have joined Agilent's EEsof division.

■ **Littelfuse Inc.** is now able to integrate the **WICKMANN Group** and its Wickmann, Efen and Pudenz brand of circuit protection products from Heinrich Industrie, Essen, Germany, into the global organization. The addition of the WICKMANN Group greatly increases the breadth and depth of Littelfuse's portfolio with new additions to its electronic, automotive and electrical business units.

■ **Skyworks Solutions Inc.** has signed an agreement with **BFi OPTiLAS**, a wholly owned subsidiary of the Avent Corp. and technical distributor focused on selling high performance analog/RF devices and modules, to distribute solutions focusing on its linear products portfolio throughout Europe. Effective immediately, Skyworks' customers may place orders with BFi who will offer a number of products including Skyworks' amplifiers, attenuators, diodes, direct conversion products, mixers and switches.

■ **EMS Technologies Inc.** announced that it is providing assistance to Katrina relief efforts in the Gulf area by supplying key communications hardware to support restoring communications. Three of the company's divisions, **EMS SATCOM**, **EMS Satellite Networks** and **EMS *Wireless***, have responded with either mobile satellite communications equipment or with wireless infrastructure equipment to restore cell phone coverage in the stricken areas.

■ **Sonnet Software Inc.** announced that **Rockwell Collins** has selected Sonnet Suites Professional™ Release 10 as part of its complete set of EDA design tools. In addition, Rockwell Collins has implemented Sonnet's new emCluster™ computing support, providing fast EM analysis through parallel processing on the company's grid network. Sonnet Professional will help the designers at Rockwell Collins in their development of advanced packaging technology for government applications.

■ **Taconic** announced that the company has begun manufacturing its copper-clad base materials for RF and microwave printed circuit boards in Cheonan, Korea. This new manufacturing capability will enable the company to quickly respond to the growing Asian market as well as enhancing service to existing customers in the Far East.

■ **Andrew Corp.** has reached an agreement to sell its 104 acre property at 10500 W. 153rd Street in Orland Park, IL, to developer Kimball Hill Homes for $28.5 M. The sale, contingent on completion of due diligence and other factors, is expected to close in two phases over the next 18 months. The company will relocate its global corporate headquarters and manufacturing operations to separate suburban Chicago locations that will provide improved operational effectiveness and state-of-the-artfacilities.

■ **EiC Corp.** announced the creation of a separate company for application, test and design engineering. The company, **Innocomm**, is located in Hsinchu Science Park in Taiwan. CC Shiue will head the new operation that will provide engineering support for EiC Corp. The company also announced that Jerry Curtis has stepped down as EiC president to pursue another career opportunity. Curtis has directed EiC's product expansion and growth since 2000, when he took the position of president. EiC sold off its wireless infrastructure business to WJ Communications in June 2004.

■ **Rohde & Schwarz** announced that its North American Calibration Laboratory has received A2LA accreditation for ISO/IEC 17025 and ANSI/NCL Z540 laboratory standards. ISO 17025 is an international standard that is used to assess the technical competency of calibration laboratories.

■ **Sabritec**, a custom connector manufacturer, announced that it has received certification to AS9100 Rev B. RWTUV USA Inc. certified that Sabritec has established and applies a management system for design and manufacture of connectors, cable assemblies, integrated electro-mechanical assemblies and custom interconnect solutions that fulfill the requirements of ISO 9001:2000/AS9100 Rev B. Sabritec's certificate is valid through July 2008.

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FEATURED MODELS

Model #	Frequency (MHz)	Typical Phase Noise (dBc/Hz) @10 kHz	Typical Phase Noise (dBc/Hz) @100 kHz
FSW Series [Dual supply voltage +5 & +15 VDC]			
FSW511-50	50 to 115	-103	-120
FSW1125-50	110 to 250	-100	-122
FSW1536-50	150 to 360	-100	-120
FSW1847-50	180 to 470	-95	-120
FSW1847-100	180 to 470	-98	-120
FSW2462-50	230 to 620	-95	-119
FSW60160-50	600 to 1600	-90	-117
FSW150290-50	1500 to 2900	-85	-107
FSW190410-50	1900 to 4100	-82	-107
FSW Series [Dual supply voltage +5 & +24 VDC]			
FSW514-50	50 to 140	-103	-120
FSW1129-50	110 to 290	-100	-122
FSW1545-50	150 to 450	-100	-120
FSW1857-50	180 to 570	-95	-120
FSW1857-100	180 to 570	-98	-120
FSW2476-50	240 to 760	-95	-119
FSW60170-50	600 to 1700	-90	-117
FSW150320-50	1500 to 3200	-85	-107
FSH196225-50	1960 to 2250	-94	-119
LFSW Series [Single Supply voltage +5 VDC]			
LFSW514-50	50 to 140	-102	-120
LFSW1129-50	110 to 290	-99	-122
LFSW1545-50	150 to 450	-98	-120
LFSW1857-50	180 to 570	-94	-120
LFSW1857-100	180 to 570	-98	-120
LFSW2476-50	240 to 760	-94	-119
LFSW35105-50	350 to 1050	-108	-130
LFSW60170-50	600 to 1700	-90	-117
LFSW150320-50	1500 to 3200	-85	-107
LFSW190410-50	1900 to 4100	-82	-107
LFSH196225-50	1960 to 2250	-93	[illegible]

FEATURES:

- Exceptional Phase Noise Performance
- Interactive Communication
- Selectable Interface
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- Single or Dual Supply Options
- Small Size, Surface Mount
- Lead Free - RoHS Compliant
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AROUND THE CIRCUIT

■ **FreeWave Technologies**, a designer and manufacturer of premium quality spread spectrum radios and wireless solutions for industrial, scientific, military and commercial applications, announced its FGRIO radios for wireless I/O are now UL approved for Class 1/Division 2 areas, enabling the use of the FGRIO system in hazardous areas.

■ **Radio Waves Inc.** announced that all antennas shipped into the EU marketplace are now compliant with the WEEE directive. As part of the company's commitment to the environment all antennas now utilize the compliant WEEE labeling.

■ TT electronics **IRC Advanced Film Division** has developed lead-free versions of all of its products as a response to increasing customer demands for compliance with governmental and industry RoHS directives.

■ **TestMart**, a sales, marketing and service provider for the test and measurement industry, is the top seller of FSC66 test equipment on the Government Services Administration procurement Web site, www.GSAadvantage.gov, for the year to date. TestMart has generated twice the number of orders as the number two vendor.

■ **Kyocera** was presented with the "Supplier of the Year Award" and the "Gold" Performance Excellence Award by **Freescale Semiconductor Inc.** at its annual Supplier Day.

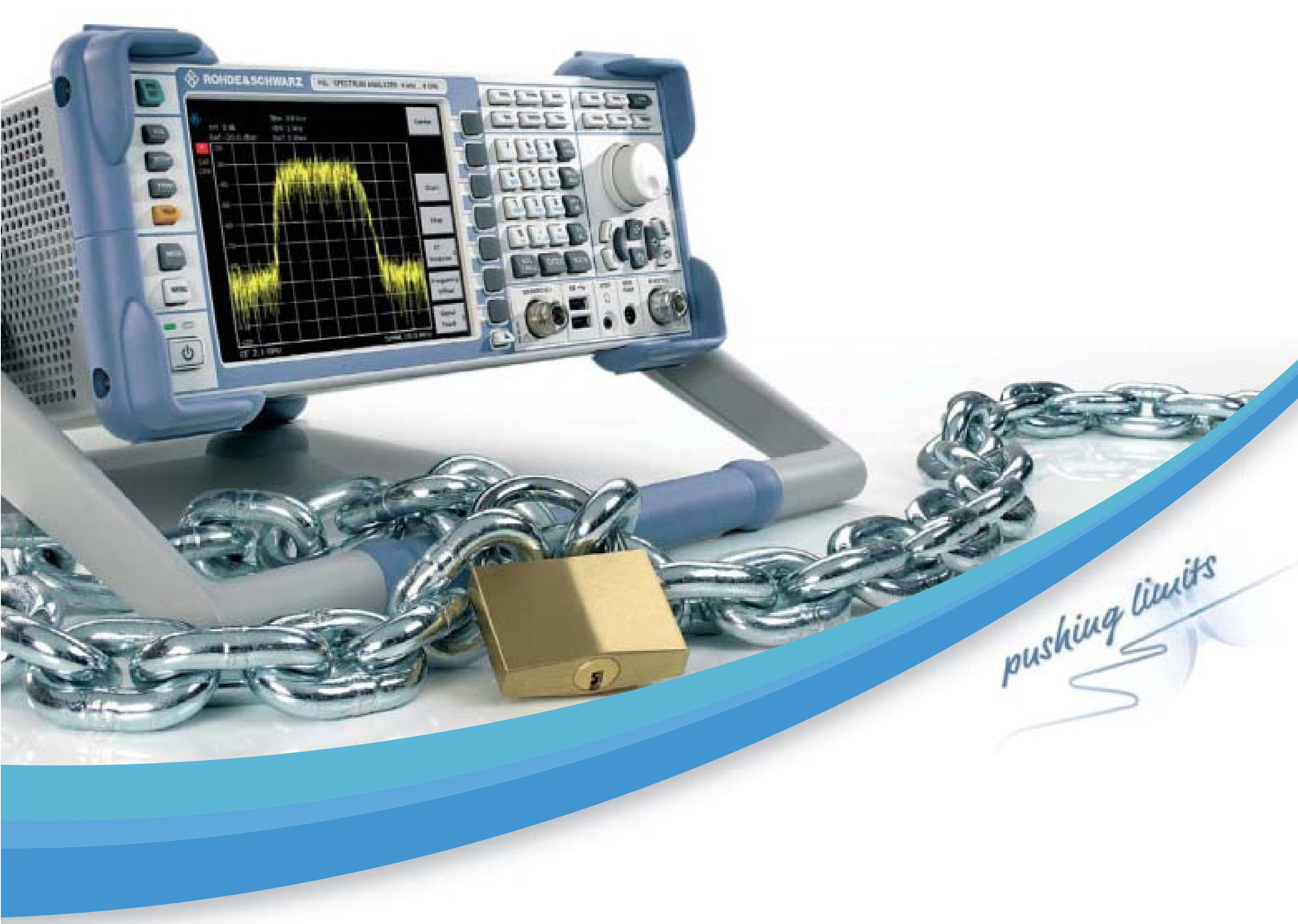
CONTRACTS

■ **ORBIT/FR Inc.**, a producer of automated microwave test and measurement systems, announced the award of a $10 M contract by a major European aerospace contractor. The contract calls for the company to deliver a state-of-the-art anechoic shielded chamber for an electromagnetic and antenna measurement testing facility. The contract represents the implementation phase of the system, which is scheduled to be delivered to the customer's site in 2007.

■ **Symmetricom Inc.** announced that it has been awarded funding for Phase-III of the **Defense Advanced Research Projects Agency** (DARPA) Chip Scale Atomic Clock (CSAC) program. The CSAC development will produce miniature, low power atomic clocks for precision timing applications in handheld battery-powered instrumentation for use by military personnel. Under the award, valued at $3.4 M, Symmetricom will develop miniature low power atomic clocks based on its proprietary coherent population trapping atomic interrogation technology and microelectromechanical systems fabrication techniques.

■ **Merrimac Industries Inc.** announced that it has finalized a contract for an additional $2.1 M for Multi-Mix® integrated modules, following receipt of the related $1 M advance contract for product documentation and materials procurement, as previously announced. These Multi-Mix Microtechnology® subassemblies provide an enabling and unique solution for use in a multi-year military program.

■ **Phasebridge Inc.**, specializing in advanced photonic integration technologies, has been awarded a contract for



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- LAN interface and USB host adapter
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the development and manufacture of integrated fiber optic transmitters and receivers for the AN/ALR-95 system on the P-3C Maritime Patrol Aircraft. The contract was awarded by **EDO Corp.**, which is providing the AN/ALR-95 system to the Naval Air Systems Command Maritime Patrol Aircraft program.

FINANCIAL NEWS

■ **Rogers Corp.** reports sales of $83.4 M for the second quarter of fiscal 2005 ended July 3, 2005, compared to $93.3 M for the same period in 2004. Net loss for the quarter was $8.8 M ($0.54/per diluted share), compared to a net income of $11.8 M ($0.68/per diluted share) for the second quarter of last year.

■ **Ansoft Corp.** reports sales of $14.8 M for the first quarter of fiscal 2006 ended July 31, 2005, compared to $12.7 M for the same period in 2005. Net income for the quarter was $1.4 M ($0.11/per diluted share), compared to a net income of $0.3 M ($0.02/per diluted share) for the first quarter of last year.

■ **Superconductor Technologies Inc.** (STI) reports sales of $8.6 M for the second quarter ended July 2, 2005, compared to $6.3 M for the same period in 2004. Net loss for the quarter was $2 M ($0.02/per diluted share), compared to a net loss of $8.9 M ($0.11/per diluted share) for the second quarter of last year. In related news, Superconductor announced that it has closed the sale of $12.5 M of common stock and warrants in a registered direct offering. Under the terms of the transaction, STI sold 17,123,288 shares of common stock and 3,424,658 warrants to purchase common stock to a select group of institutional investors. The offering generated net proceeds of $11.4 M. SG Cowen & Co. LLC acted as exclusive placement agent for the offering.

■ **EMS *Wireless***, a division of EMS Technologies Inc., announced that it has achieved an all-time high for annual orders, as of the end of the third week of August. Orders for the division's antennas and repeaters now exceed $58 M, breaking its previous annual orders record in 2000, which resulted in sales of $57.7 M.

NEW MARKET ENTRY

■ Frank Arams, co-founder and former vice president of LNR Communications, with 30 years experience in high tech electronics, has established a patent expert and technical/management/marketing consulting practice. He is a Fellow of the IEEE. His background spans RF/microwave, telecom, broadband, satellite, optics and video technology, applications, and physics. Arams has successfully provided technical expertise to patent attorneys and electronics firms, consulting in high technology, business development and technical management. He can be contacted via e-mail at tangle1345@ieee.org or call (516) 466-8597.

PERSONNEL

■ WJ Communications Inc. announced that **Ephraim Kwok**, senior vice president and chief financial officer,

Narda-West Amplifiers

for your mission-critical programs

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Millimeter Wave Amplifiers

Features:

- P-1 dB >30 dBm
- Noise figure <4 dB
- Various gain & P-1 dB options
- Single bias from 8V to 15V
- Internal voltage regulation
- Custom configurations
- Small hermetic packages

27–59 GHz Power Amplifiers

(Gain = 34 dB typical)

Frequency (GHz) Min.	Frequency (GHz) Max.	P-1 dB (dBm) Min.	Model Number
27.0	29.0	33	DBM-2729N333
27.0	31.0	30	DBM-2731N330
29.0	31.0	31	DBM-2931N331
33.0	36.0	29	DBM-3336N329
37.0	39.0	32	DBM-3739N332
37.0	40.0	30	DBM-3740N330
39.0	42.5	29	DBM-3942N329
58.0	59.0	13	DBP-5859N613

20–44 GHz Low Noise Amplifiers

(Gain = 33 dB typical)

Frequency (GHz) Min.	Frequency (GHz) Max.	Noise Figure Max.	Model Number
20.2	21.2	3.5	DBS-2021N620
23.0	24.0	2.5	DBS-2324N410
26.5	40.0	5	DBL-2640N610
34.0	35.0	3	DBS-3435N410
40.5	42.5	4	DBS-4042N510
44.0	45.0	4	DBS-4445N510

Low-Cost RF & Microwave Amplifiers from Narda's Offshore Facility

Features:

- Single supply operation
- Wide & narrow band applications
- Low noise figure
- High output power
- Gain equalization
- Gain & phase matching/tracking
- Temperature compensation
- External gain control
- Hermetically sealed

Delivery 4 weeks ARO!

(RF & Microwave Amplifiers only)

0.5–26.5 GHz Power Amplifiers

(Gain = 33 dB typical)

Frequency (GHz) Min.	Frequency (GHz) Max.	P-1 dB (dBm) Min.	Model Number
0.5	2.0	30	DBS-0102N430
2.0	2.5	27	DBS-2520N427
2.1	8.0	33	DBP-0208N533
2.2	18.0	27	DBM-0218N427
2.8	3.3	30	DBS-3328N530
3.0	3.5	27	DBS-3530N427
4.4	5.0	30	DBS-5044N530
5.9	6.4	30	DBS-6459N530
6.0	18.0	27	DBS-0618N627
18.0	26.5	30	DBM-1826N330

1.0–26.5 GHz Low Noise Amplifiers

(Gain = 28–34 dB typical)

Frequency (GHz) Min.	Frequency (GHz) Max.	Noise Figure Max.	Model Number
1.0	19.0	5.5	DBS-0119N510
2.0	4.0	2	DBL-0204N310
2.0	8.0	2.3	DBS-0208N315
2.0	18.0	3.5	DBL-0218N308
4.0	8.0	2	DBL-0408N410
4.0	8.0	2.5	DBS-0408N318
4.0	11.0	2.5	DBS-0411N313
5.0	13.0	2.5	DBS-0513N415
6.0	12.0	2.5	DBS-0612N315
6.0	18.0	2.5	DBL-0618N420
9.0	10.0	1.7	DBS-0910N420
18.0	26.5	5	DBS-1826N515

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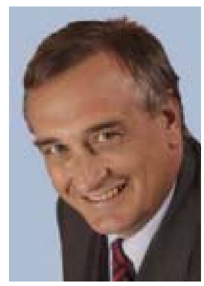
has resigned from the company to join a pre-IPO technology company. The company has begun a search for his replacement and has named **Rainer Growitz**, vice president of finance and board secretary, as its interim chief financial officer. Growitz joined the company in 1978 and has held a variety of finance, contracts and managerial positions at the company.


▲ Hervé Guillou

■ **Hervé Guillou** has taken up the position of chief executive officer of the EADS Business Unit Defence and Communications Systems, the EADS Systems House. Guillou transfers from the position of CEO EADS Space Transportation, and consequently will contribute experience gained previously within the defense activities of the EADS Group. At the same time it is intended that he will take over the responsibility for EADS Defence & Security Systems S.A., becoming président directeur général of the French entity.

■ Micronetics Inc. announced that **Diane L. Bourque** has joined the company as chief financial officer. Bourque brings with her over 20 years of financial experience to Micronetics. As CFO, Bourque will be responsible for leading the company's corporate finance, regulatory compliance, corporate governance, accounting, strategic planning and analysis, treasury, tax, audit and investor relations. Most recently, Bourque served as vice president and controller at Presstek Inc., a $270 M NASDAQ listed digital imaging company.

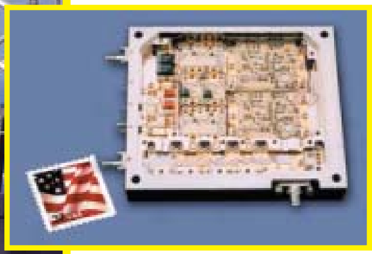
■ Aeroflex Inc. announced the appointment of **Jimmy Tan** as vice president, APAC for its test and measurement group. In this position, Tan will be responsible for all of Aeroflex's sales activities in Asia and the Pacific Rim, including the solicitation of orders, maintaining customer relations, and coordination of sales representatives and distributors. He will also coordinate the company's product installations, customer training and support. Tan comes to Aeroflex with more than 20 years experience in the test and measurement industry.

■ Xpedion Design Systems Inc. announced the addition of **Ken Kundert** and **Henry Chang** to its technical advisory board. Both Kundert, who is the chairman of the board, and Chang bring a deep knowledge of RF circuit design and simulation technology as well as industry insight to Xpedion.


▲ Veniamin Stakhin

■ HTC-e announced the appointment of **Veniamin Stakhin** to the position of general manager of HTC Russia Ltd., a newly formed organization with the purpose of managing operation and design activities for HTC-e Corp.'s contract design services business. HTC Russia is located in Zelenograd, near Moscow. Stakhin is experienced in technology development, design and strategic planning with both start up and growth electronic companies.

Frequency Generation, Conversion and Control



STC Microwave Systems, part of Crane Aerospace & Electronics, provides development through production of components, sub-systems, and systems. Our products, backed by over 30 years of innovation, experience and reliability, are used in military/defense, aerospace, industrial and space ground applications.

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REP APPOINTMENTS

■ **Reactel Inc.**, a manufacturer of RF and microwave filters, multiplexers, switched filter banks and subassemblies to the commercial, military, industrial and medical industries, announced the appointment of **Hi-Peak Technical Sales** as the company's representative in New England. For more information about Hi-Peak, visit www.hi-peak.com

■ **Trilithic**'s RF and Microwave Components division welcomed new companies to its representative team. These appointments will have exclusive technical representation in several strategic Asian countries. **Evergo Instruments Co. Ltd.** will represent Taiwan, **K-Tech Korea Inc.** will be responsible for Korea and **Everjet Science and Technology Co. Ltd.** will expand sales in China.

■ **International Manufacturing Services Inc.** announced the appointment of **RF Spectrum** as the company's representative in Canada. RF Spectrum's offices are located at 7750 Birchmount Road, Unit 18, Markham, Ontario, Canada L3ROB4 (905) 415-1854 phone or (905) 415-0665 fax. Zully Alidina, owner/sales engineer, can be contacted via e-mail at zully@rf-spectrum.com.

■ **Presidio Components Inc.**, a manufacturer of high reliability ceramic capacitors, announced the appointment of **Texel Ltd.**, Los Alamitos, CA, as its authorized sales representative for southern California. Texel Ltd. can be reached at (562) 596-9411 or visit www.texelltd.com.

■ **IMS Connector Systems**, which is headquartered in Germany, has increased its worldwide sales and distribution network by contracting **Antes Sales Oy** to be its new sales partner in Estonia. As a specialist in the sales of antennas, antenna systems, connectors and cables, the company will add the complete IMS product range of RF coaxial connectors and cable assemblies to its portfolio.

■ **StratEdge** announced the selection of **McDermott Technical Sales Inc.**, West Caldwell, NJ, as its representative in the Mid-Atlantic US. McDermott will handle sales and support for StratEdge's complete line of DC to 50+ GHz packages, stripline filters, and assembly and test services. McDermott will cover the states of Virginia, Maryland, Delaware, Pennsylvania, New Jersey and southern New York including Long Island. Bill McDermott can be reached by phone at (973) 618-0759 or e-mail: wjmcdermott@comcast.net.

WEB SITE

■ **Rosenberger** has completely restructured and redesigned its Web site (www.rosenberger.de). As a global supplier of high frequency connectors, components and cable assemblies, the company's new site provides the latest information about RF products and technology including the company's manufacturing and assembly locations around the world, the international sales network, quality and environmental policies, and company news.

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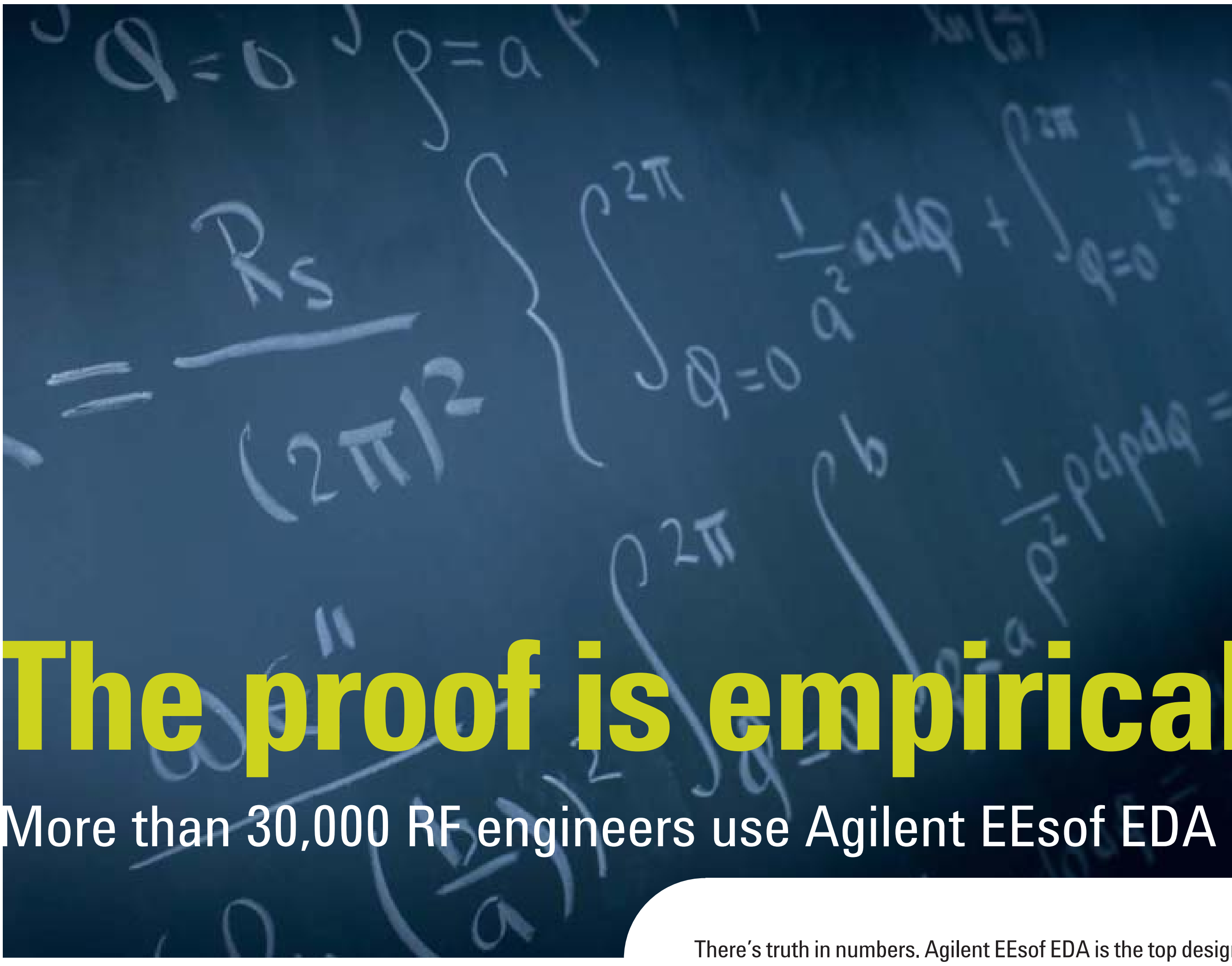
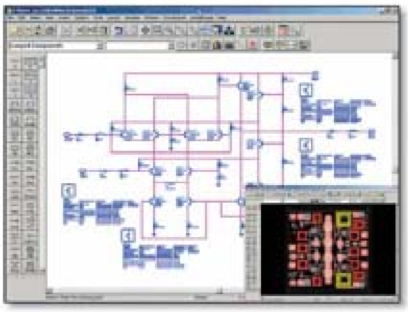


The proof is empirical

More than 30,000 RF engineers use Agilent EEsof EDA



Eagleware-Elanix is now part of Agilent EEsof EDA.

There's truth in numbers. Agilent EEsof EDA is the top design software choice among engineers for the vast the majority of the world's wireless devices.

The fact is derived from software products with undisputed breadth of functionality. Agilent EEsof EDA applications were created for RF engineers by RF engineers. They have the capabilities you need the most. And now with the addition of Eagleware-Elanix you have further ease of use, new synthesis technology, and additional pricing options other products can't touch. Agilent's team of EDA experts releases multiple improvement updates each year. And Agilent has the largest number of technology partners, application examples, and technical articles in the industry.

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Agilent Technologies

Transistor LC Oscillators for Wireless Applications: Theory and Design Aspects, Part I

The transistor LC oscillator is at the heart of any wireless communications system. Due to their low cost, design simplicity and ease in practical implementation, for example, MOSFET-based oscillators are widely used in modern wireless handset applications. This three-part tutorial highlights the basics of the oscillator circuit design, setting the relationships between the start-up and steady-state operating modes and the device equivalent circuit parameters. The basic DC and RF device operation regions are explained and analyzed in Part I. It is very important for the oscillator noise model to express a clear relationship between the oscillator spectral noise power density and resonant circuit, and active device parameters. Several approaches, including the simple linear Leeson feedback oscillator model, the linear negative resistance oscillator model and the nonlinear Kurokawa model, will be described and analyzed in Part II. A new impulse response model, based on a phase plane approach, which has become very popular recently, will be the subject of Part III.

In the first part of this tutorial article, the active device regions and modes of DC and RF operations are discussed with emphasis on CMOS devices, resulting in very simple analytical large-signal voltage-current relationships.

OPERATION AND DESIGN PRINCIPLES

In the first part of this tutorial article, the active device regions and modes of DC and RF operations are discussed with emphasis on CMOS devices, resulting in very simple analytical large-signal voltage-current relationships. An analysis of the start-up and steady-state oscillation conditions, based on a matrix technique showing an explicit analytical dependence between the device and feedback parameters, is given for a widely used single-ended oscillator with a parallel resonant circuit based on a simplified device equivalent model. The basic operation principle of a differential cross-coupled tail-biased oscillator is explained in the time domain.

Device Operation Modes

To better understand the oscillator operation and design principles, it is necessary to first start with the basic physics and electrical behavior of the MOS transistor as a main

ANDREI GREBENNIKOV
M/A-COM Eurotec Operations
Cork, Ireland

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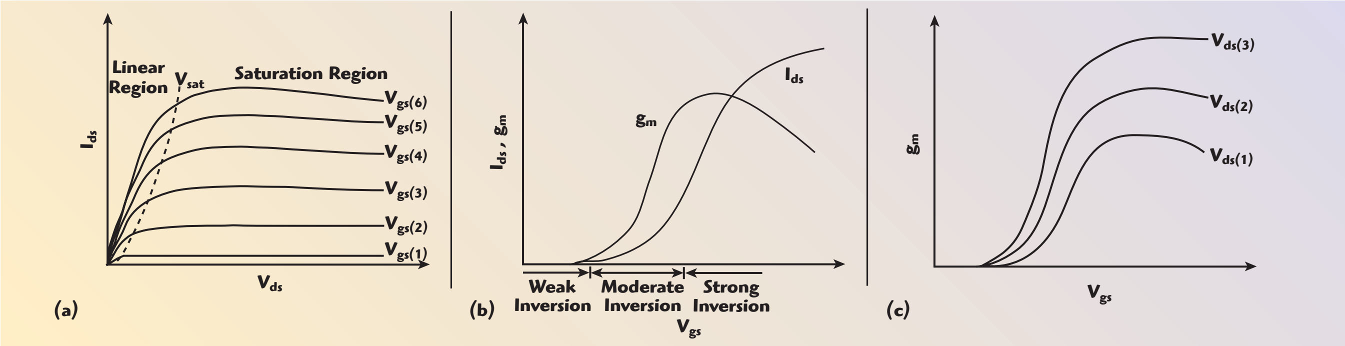

Fig. 1 *Drain current and device transconductance versus gate voltage.*

element of the oscillator, whose typical current-voltage (I-V) characteristics are shown in ***Figure 1***. Initially, consider the situation for a fixed gate bias V_{gs} and an increasing drain-source voltage V_{ds}. As seen for low drain bias voltages V_{ds}, the drain current I_d increases almost linearly. This region of the device output DC characteristic is therefore called the linear region. In this case, there is an inversion layer connecting the source and drain, which behaves as an ideal ohmic resistor. Then, at larger drain bias voltages, the dependence of the drain current on the drain bias voltage decreases. Finally, at some voltage, known as the saturation voltage V_{sat}, the drain current no longer increases with increasing drain-source voltage. This region is called the saturation region, due to the effect of the DC drain current saturation at high drain bias voltages for a certain gate-source bias voltage V_{gs}. At $V_{ds} = V_{sat}$, the channel is pinched off and the inversion layer is no longer affected by the drain voltages. At drain-source voltages below V_{sat}, the current continues to flow because there is no barrier to transfer carriers traveling down the channel toward the drain. As they arrive at the edge of the pinched-off region, they are pulled across it by the field directed from the drain toward the source. If the drain bias is increased further, any additional voltage is dropped across the depleted, high field region near the drain electrode, and the point at which the channel is entirely depleted moves slightly toward the source.[1] Note that at very high gate bias voltages (voltages $V_{gs(5)}$ and $V_{gs(6)}$), due to a self-heating effect in the high dissipated power region, the slope of the output I-V curve will be negative, which means a degradation of the device transconductance.[2]

The transfer characteristics of the MOS transistor behave differently in different regions of the device operation. For example, the drain current in a weak-inversion region is mainly dominated by the diffusion component that increases exponentially with the gate voltage.[3] On the other hand, in the strong-inversion region when the gate-source voltage V_{gs} is greater than the threshold voltage V_{th}, the drain current is proportional to the square of $(V_{gs}–V_{th})$. However, with a further increase of V_{gs}, the sensitivity of the drain current to the gate-source voltage increase becomes smaller. Therefore, to link all regions of the device operation with analytically derived closed-form expressions, it is necessary to use transcendental functions.[2,4] As seen, the transconductance g_m, derived by differentiating I_{ds}, reaches a maximum and then decreases with increasing V_{gs} due to the influence of V_{gs} on the effective carrier mobility and the increasing effect of the series parasitic resistances with increasing I_{ds}. For lower drain-sources voltages, $V_{ds(1)} < V_{ds(2)} < V_{ds(3)}$, the maximum value of the transconductance g_m is reduced, with the corresponding significant degradation of the transconductance at large gate bias voltages.[5] This means that the closer the drain bias voltage is to the saturation region, the faster the reduction in ΔI_{ds} for the same ΔV_{gs} at large gate-source bias voltages V_{gs}.

It is necessary, however, to distinguish the device DC operation regions from its operation regions under the the RF signal. Generally, the large-signal transistor behavior is divided into three operation regions, as shown in ***Figure 2***.[6] The region where the input driving voltage v_{gs} is less than the threshold voltage V_{th}, that is $v_{gs} \le V_{th}$, is called the pinch-off or cut-off region. The term pinch-off is normally used for FET devices. The operation region, where $v_{gs} > V_{th}$, is called the active or linear region, where the transistor can be considered as a voltage-controlled current source responding linearly to the gate voltage drive. Finally, the transistor is roughly equivalent to a resistance R_{sat}, operating in the saturation region. Unlike a DC current saturation region, the RF saturation region corresponds to a voltage saturation, since there is a particular saturation voltage V_{sat} corresponding to a fixed load resistance and defined by the intersection point between the load line and linear part of the I-V curves. The saturation or on-resistance R_{sat} is defined as the slope of the linear part of the I-V curves, that is $R_{sat} = dv_{ds}/di_{ds}$.

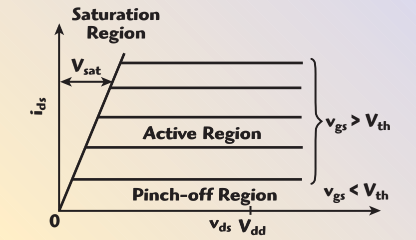

Fig. 2 *Idealized transistor I-V characteristics showing the regions of RF operation.*

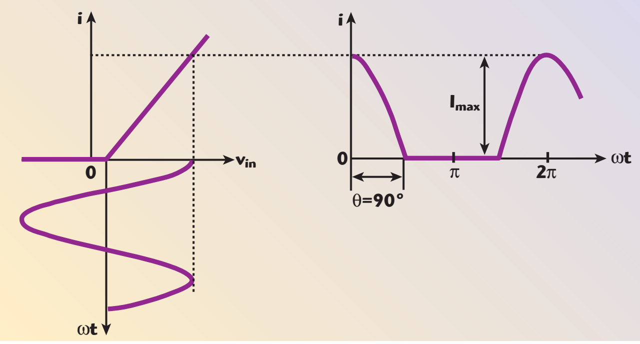

Fig. 3 *Output current waveform for a device operating in class B.*

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In a class B operation mode with a piecewise-linear approximation of the transistor transfer characteristic, an active device operates both in the active and pinch-off regions. The magnitude of the output current exceeds a zero value during only half the entire signal period, representing a half-cosine waveform, as shown in ***Figure 3***. In this case, because the parallel resonant LC circuit has a high quality factor, ideally only the fundamental frequency signal is flowing into the load, whereas the higher order harmonic frequency components are short-circuited.

Analytically such an operation can be written as

$$i = \begin{cases} I_q + I\cos\omega t, & -\theta \le \omega t < \theta \\ 0, & \theta \le \omega t < 2\pi - \theta \end{cases} \quad (1)$$

where

I_q = quiescent current
I = output current amplitude
θ = half the conduction angle, indicating the part of the RF current cycle for which device conduction occurs and determines the moment when the output current i takes a zero value

At this moment,

$$i = I_q + I\cos\theta = 0 \quad (2)$$

and θ can be calculated from

$$\cos\theta = -\frac{I_q}{I} \quad (3)$$

Consequently, in a common case,

$$i = I(\cos\omega t - \cos\theta) \quad (4)$$

When ωt = 0, the output collector current has a maximum amplitude of

$$i = I_{max} = I(1 - \cos\theta) \quad (5)$$

From Equation 3, the basic definitions can be derived as

when $\theta > 90°$, then $\cos\theta < 0, I_q > 0$
corresponding to class AB operation

when $\theta = 90°$, then $\cos\theta = 0, I_q = 0$
corresponding to class B operation

when $\theta < 90°$, then $\cos\theta > 0, I_q < 0$
corresponding to class C operation

As a result, the periodic half-cosine output current i can be represented as a Fourier series expansion:

$$i = I_0 + I_1\cos\omega t + I_2\cos 2\omega t + I_3\cos 3\omega t + \ldots \quad (6)$$

The DC, fundamental and higher order harmonic frequency components can be obtained from

$$I_0 = \frac{1}{2\pi}\int_{-\theta}^{\theta} I(\cos\omega t - \cos\theta)\,d(\omega t) = I\gamma_0(\theta) \quad (7)$$

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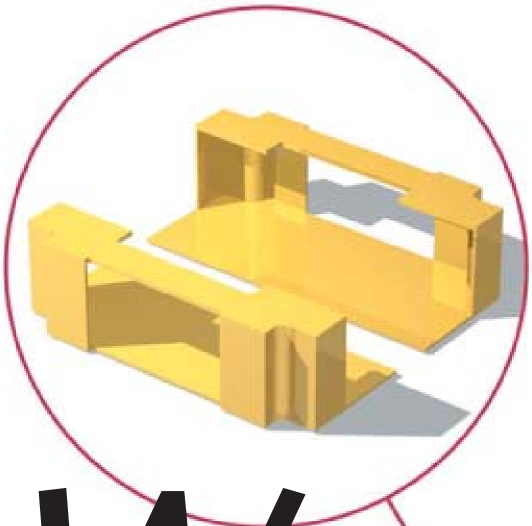

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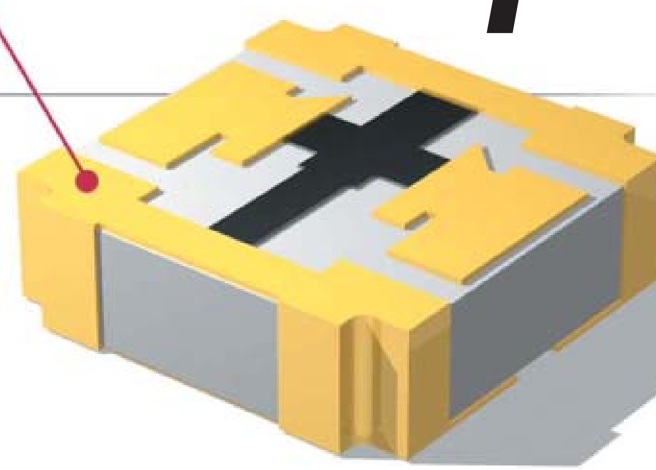

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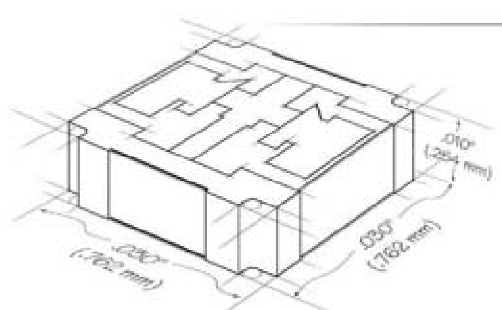

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$$I_1 = \frac{1}{\pi}\int_{-\theta}^{\theta} I(\cos\omega t - \cos\theta)\cos\omega t d(\omega t) = I\gamma_1(\theta) \quad (8)$$

$$I_n = \frac{1}{\pi}\int_{-\theta}^{\theta} I(\cos\omega t - \cos\theta)\cos(n\omega t) d(\omega t) = I\gamma_1(\theta) \quad (9)$$

where

$$\gamma_0(\theta) = \frac{1}{\pi}(\sin\theta - \theta\cos\theta)$$

$$\gamma_1(\theta) = \frac{1}{\pi}(\theta - \sin\theta\cos\theta)$$

$$\gamma_n(\theta) = \frac{2}{\pi}\frac{\sin n\theta\cos\theta - n\cos n\theta\sin\theta}{n(n^2-1)} \quad n = 2, 3, \ldots$$

are the DC, fundamental and nth harmonic current coefficients, respectively.

It should be noted that, in an ideal class B with $\theta = 90°$, the current coefficients for the third and higher order odd harmonics are equal to zero. Consequently, a half-cosine waveform consists of the DC and even-order harmonics only. In a real situation, when the transistor transfer characteristic has a quadratic dependence at its initial part, the output current waveform slightly deviates from an ideal waveform.

In an active region, the cosine voltage amplitude across the tank resistance RL, connected in parallel to the tank circuit, can be written using Equations 7 and 8 as

$$V = I_1 R_L = \frac{\gamma_1(\theta)}{\gamma_0(\theta)} I_0 R_L \quad (10)$$

which is a linear function of the DC current components for a fixed conduction angle and tank resistance. However, for a varying conduction angle, being defined by bias conditions and voltage drop across the current source, the voltage amplitude is a function of θ. For example, the voltage amplitude will be higher by $\pi/2$ in class B with $\theta = 90°$, compared with an idealized non-harmonic condition of class A with $\theta = 180°$. Using the tank loaded Q, $Q_L = \omega_0 C R_L$, where $\omega_0 = 1/\sqrt{LC}$ is the oscillation frequency, Equation 10 can be rewritten as

$$V = \frac{\gamma_1(\theta)}{\gamma_0(\theta)}\frac{\omega_0 C}{Q_L} I_0 \quad (11)$$

showing the voltage amplitude reduction with the degradation of the loaded Q factor. This happens when the voltage amplitude V approaches the saturation region with an increasing shunting effect of the drain-source resistance, reducing the value of R_{sat}. In this case, the voltage waveform across the tank resistance cannot be considered to be purely cosinusoidal because of the significant harmonic contribution. Consequently, any consideration of the voltage amplitude as constant in a saturation region, introduced by Ham and Hajimiri,[7] can only be applied as a first-order approximation, since the contribution of the

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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
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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
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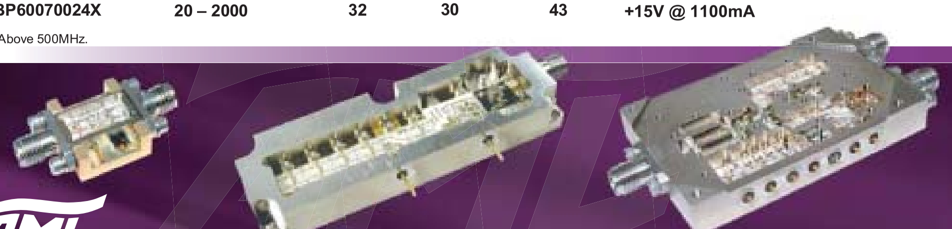

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L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0218-30	2 - 18	30	1	29	30	3
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-44	8 - 12	44	22	42	45	22
L1218-43	12 - 18	43	20	41.5	45	22
Millimeter-Wave Power Amplifiers						
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

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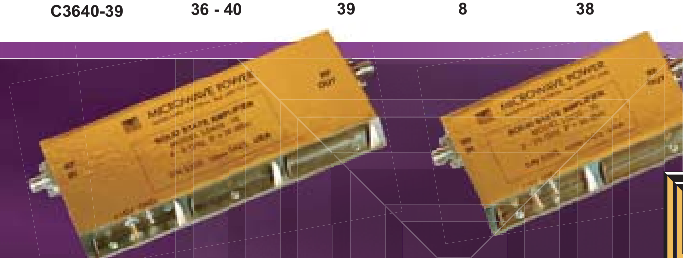
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-40	26.5 - 30.5	40	10	39	0.25	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25



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fundamental voltage spectral component will depend on the overall voltage waveform, which will be different for different load and bias conditions.

Now let us consider a class B operation with increased amplitude of the cosine voltage across the tank, using the transistor I-V curves. In this case, as it follows from ***Figure 4***, an active device operates in saturation, with active and pinch-off regions, and the load line follows a broken line LKMP with three linear sections (LK, KM and MP).[2] The new section LK corresponds to the saturation region, resulting in the half-cosine current waveform with a depression in the top part. With further increase of the voltage amplitude, the output current pulse can be split into two symmetrical pulses containing a significant level of the higher order harmonic components. Similar simulated drain waveforms of a 1.8 GHz differential oscillator, based on a 0.18 μm CMOS process and operating simultaneously in the pinch-off, active and saturation regions, are given in Hajimiri and Lee.[8]

START-UP AND STEADY-STATE CONDITIONS

The determination of the start-up and steady-state oscillation conditions is very often based upon a loop or nodal analysis of the circuit. However, the oscillator analysis using matrix techniques brings out the similarities between several types of oscillators and results in one group of equations, which can be used to analyze the different oscillator configurations.[9] In this case, a two-port network can represent both the active device and feedback element. Depending on the oscillator configuration, in the form of a parallel feedback or a negative resistance (conductance), an oscillator with parallel or series feedback using admittance Y- or impedance Z-parameters, can be respectively modeled.

Three basic oscillator schematics are shown in ***Figure 5***. For the basic representation of a single frequency negative conductance oscillator (a), the steady-state oscillation condition can generally be expressed through Y-parameters as

$$Y_{out} + Y_L = 0 \tag{12}$$

where

$$Y_{out} = Y_{22} - \frac{Y_{12}Y_{21}}{Y_{11}} \tag{13}$$

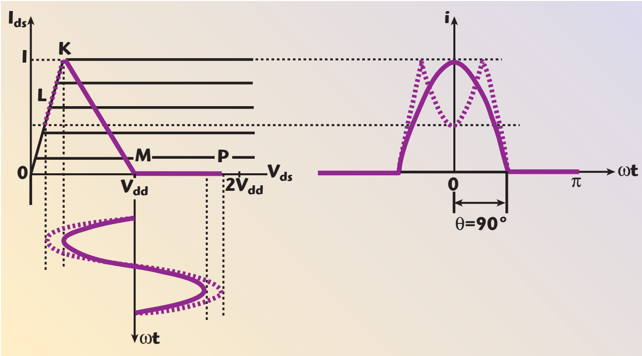
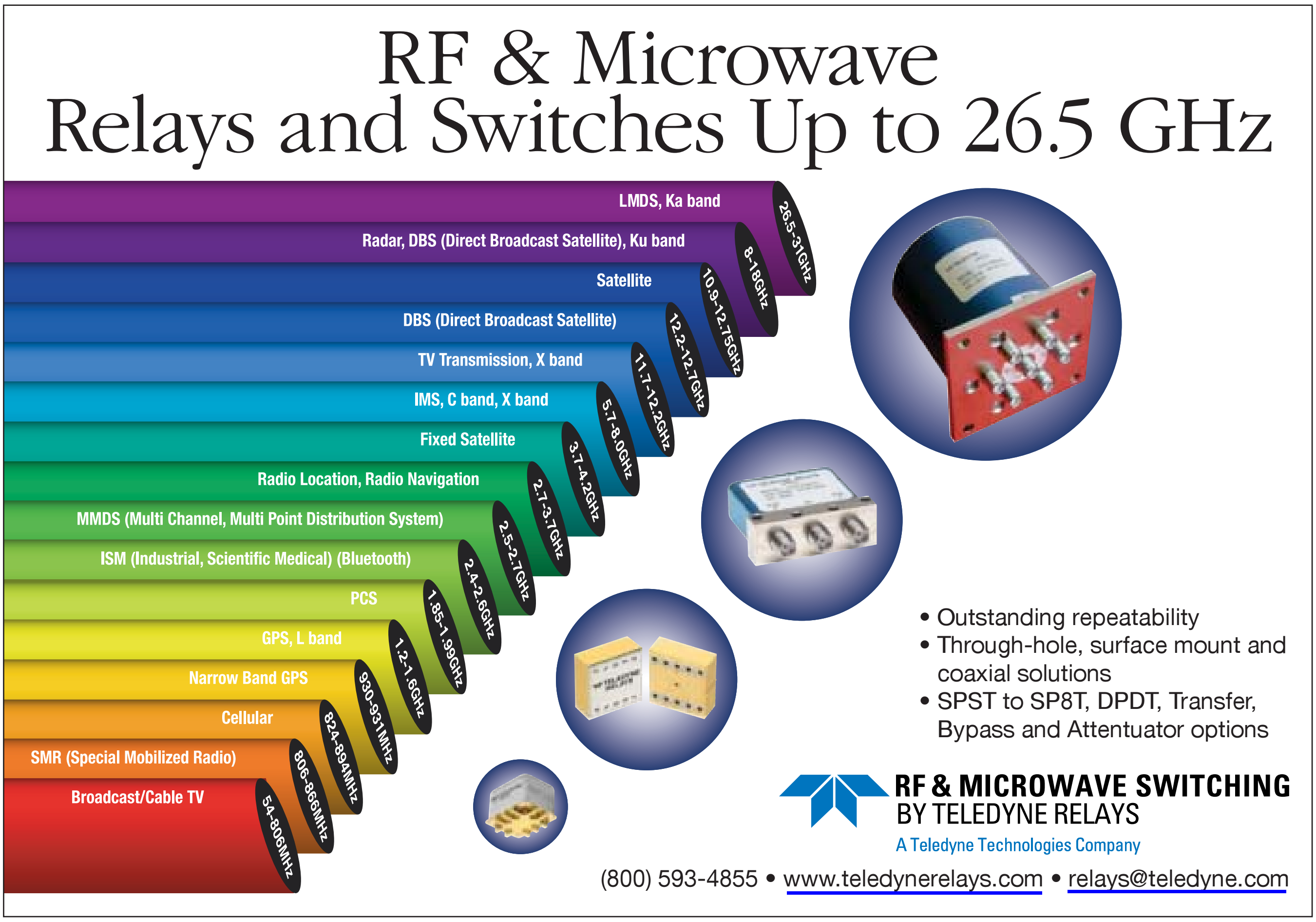


Fig. 4 Collector voltage and current waveforms for a device operating in saturation with active and pinch-off regions.



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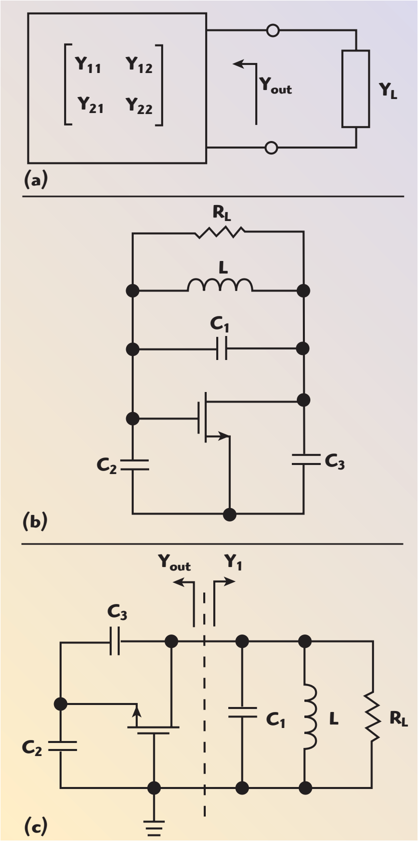


Fig. 5 Basic oscillator schematics.

is the output admittance expressed through the Y-parameters of a loaded two-port network, which includes the device and feedback elements.

The generic schematic of the modified Colpitts oscillator (b), with a parallel resonant circuit, is called a Seiler oscillator.[10] Here, C_2 and C_3 represent the feedback capacitors and R_L is the load resistor, which generally can include any losses in the tank inductor L. Such an oscillator configuration is useful for wideband frequency tuning when the capacitance C_1 in the tank circuit is variable. Note that grounding of any terminal of the oscillator circuit does not change its electrical performance provided there are no changes in the connection of the feedback elements and load to the active device. To analyse the oscillator start-up and steady-state conditions, it is convenient to consider a common gate configuration of this circuit, since the load resistance is connected between the drain and gate terminals. In this case, the common gate admittance matrix $[Y]_{CG}$ for a two-port network expressed through the common source Y-parameters can be written as

$$[Y]_{CG} = \begin{bmatrix} Y_{11} + Y_{12} + Y_{21} + Y_{22} & -(Y_{12} + Y_{22}) \\ -(Y_{21} + Y_{22}) & Y_{22} \end{bmatrix} \tag{14}$$

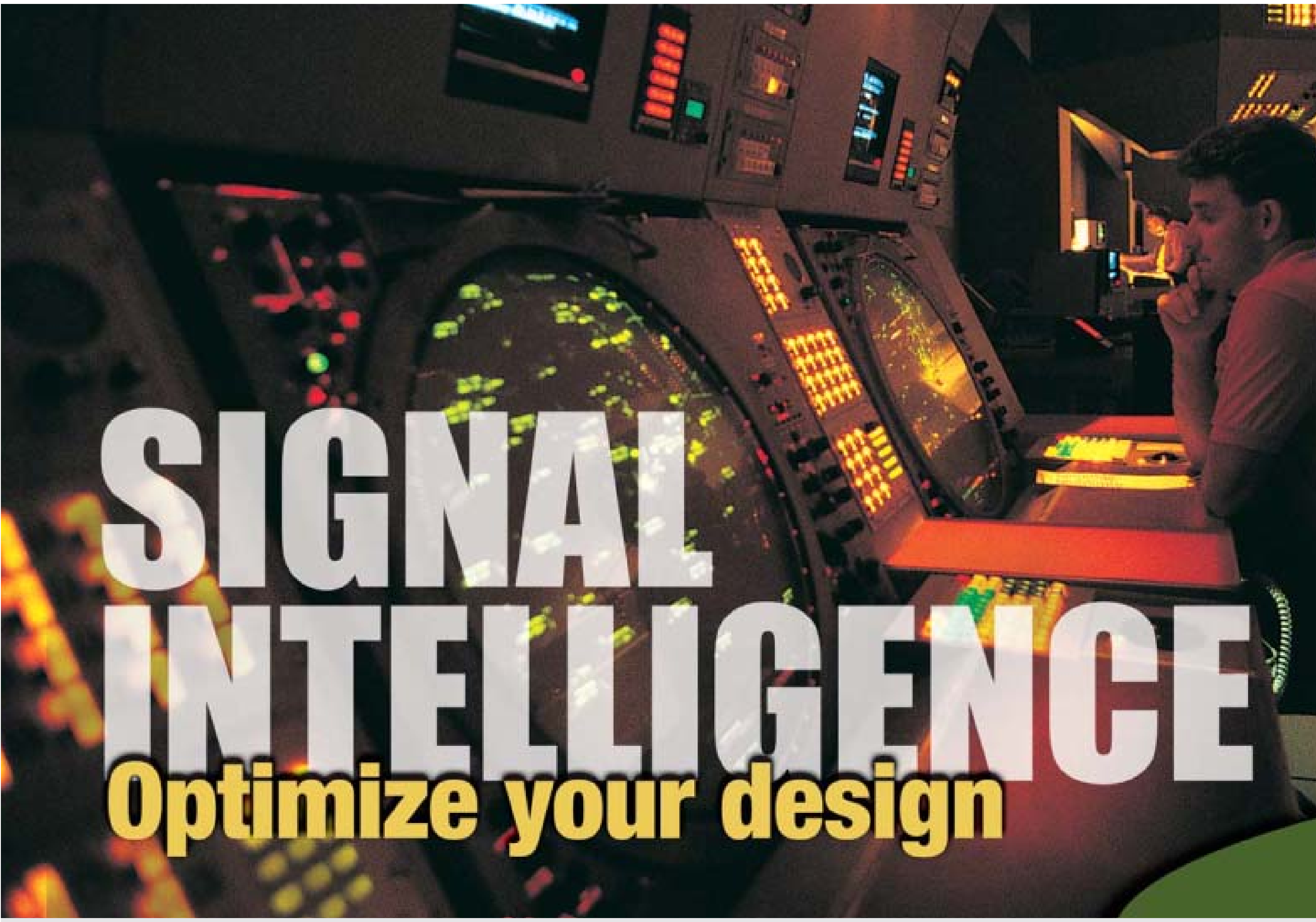
where Y_{ij} (i,j = 1,2) are the common source Y-parameters.[2]

Then, a steady-state oscillation condition for the oscillator circuit (c) can be rewritten through the device common source Y-parameters and feedback admittance $Y_2 = j\omega C_2$ and $Y_3 = j\omega C_3$ as

$$Y_{out} + Y_1 = 0 \tag{15}$$

where

$$Y_{out} = Y_{22} + Y_3 - \frac{(Y_{12} + Y_{22} + Y_3)(Y_{21} + Y_{22} + Y_3)}{Y_{11} + Y_{12} + Y_{21} + Y_{22} + Y_2 + Y_3} \tag{16}$$



$$Y_1 = \frac{1}{R_L} + j\omega C_1 + \frac{1}{j\omega L} \qquad (17)$$

Separate equations for real and imaginary parts of the output and load admittances of a negative conductance oscillator can be obtained from Equation 15:

$$\mathrm{Re}\,Y_{out} + \mathrm{Re}\,Y_L = 0 \qquad (18)$$

$$\mathrm{Im}\,Y_{out} + \mathrm{Im}\,Y_L = 0 \qquad (19)$$

Similarly, the start-up conditions for a negative conductance oscillator are written as

$$\mathrm{Re}\,Y_{out} + \mathrm{Re}\,Y_L < 0 \qquad (20)$$

$$\mathrm{Im}\,Y_{out} + \mathrm{Im}\,Y_L = 0 \qquad (21)$$

To obtain the explicit analytical relationships between the active device and resonant circuit parameters, consider the simplified intrinsic MOSFET high frequency equivalent circuit shown in ***Figure 6***, where C_{gs} is the gate-source capacitance, g_m is the transconductance and C_{ds} is the drain-source capacitance. The admittance Y-parameters of the equivalent circuit are

$$Y_{11} = j\omega C_{gs} \qquad Y_{12} = 0$$
$$Y_{21} = g_m \qquad Y_{22} = j\omega C_{ds} \qquad (22)$$

Substituting the device Y-parameters into Equation 16 allows the real and imaginary part of the output admittance to be represented through the elements of the device parameters as

$$\mathrm{Re}\,Y_{out} = -\frac{g_m \omega^2 \left(C_{gs} + C_2\right)\left(C_{ds} + C_3\right)}{g_m^2 + \omega^2 \left(C_{gs} + C_{ds} + C_2 + C_3\right)^2} \qquad (23)$$

$$\mathrm{Im}\,Y_{out} = \omega \frac{\omega^2 \left(C_{gs} + C_2\right)\left(C_{ds} + C_3\right)\left(C_{gs} + C_{ds} + C_2 + C_3\right)}{g_m^2 + \omega^2 \left(C_{gs} + C_{ds} + C_2 + C_3\right)^2} \qquad (24)$$

From Equations 23 and 24, it follows that, in a common gate configuration, the real part of the output admittance is negative and the imaginary part of the output admittance has a capacitive reactance. At frequencies $\omega << \omega_T$, where $\omega_T = 2\pi f_T$, $f_T = g_m/2\pi C_{gs}$ is the device transition frequency, Equation 23 can be simplified to

$$\mathrm{Re}\,Y_{out} \cong -g_m \left(\frac{\omega}{\omega_T}\right)^2 \frac{C_{ds}}{C_{gs}} \qquad (25)$$

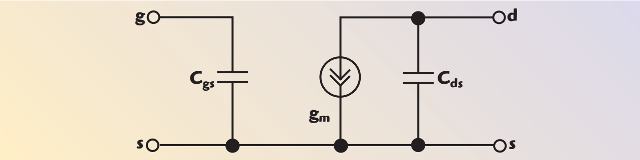
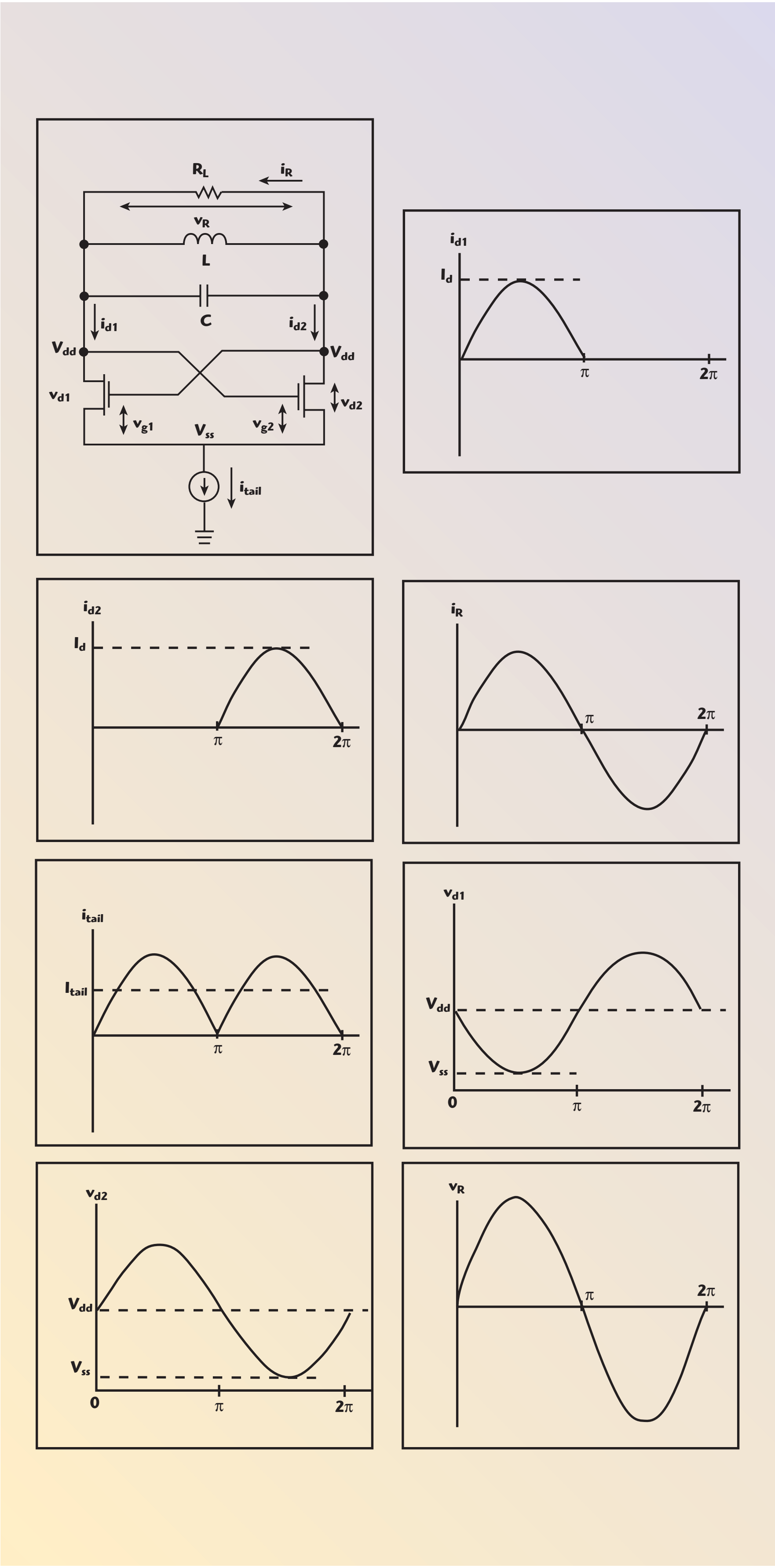


Fig. 6 Simplified MOSFET equivalent circuit.



▲ *Fig. 7 Differential cross-coupled LC oscillator circuit schematic and operation principle.*

Substituting Equations 25 and 24 into Equations 20 and 21, representing the oscillator start-up conditions, yields

$$g_m > \frac{1}{R_L}\left(\frac{\omega_T}{\omega}\right)^2 \frac{C_{gs}}{C_{ds}} \quad (26)$$

$$\omega^2 = \frac{1}{L}\frac{1}{C_1 + \dfrac{C_{gs} + C_{ds} + C_2 + C_3}{g_m R_L}} \quad (27)$$

From Equation 26, it follows that the build-up of the self-oscillations will be more easily provided at lower frequencies, higher ratio of C_{gs}/C_{ds} and smaller losses in the circuit. In addition, the regeneration factor or start-up margin can be improved by selecting the proper values of the external feedback capacitances C_2 and C_3 connected between the gate-source and drain-source terminals in parallel to the gate-source and drain-source capacitances C_{gs} and C_{ds}, respectively. As it follows from Equation 27, the oscillation frequency is a function of not only the external reactive elements but also the device parameters.

In a steady-state mode, the device small-signal transconductance should be considered as fundamentally averaged during the large-signal operation. By using a piecewise-linear approximation, its large-signal definition can be written as $g_m\gamma_1(\theta)$. Thus, assuming constant capacitances C_{gs} and C_{ds} whose values are given by the operating DC bias point, the oscillator steady-state conditions can be rewritten as

$$g_m = \frac{\gamma_1(\theta)}{R_L}\left(\frac{\omega_T}{\omega}\right)^2 \frac{C_{gs}}{C_{ds}} \quad (28)$$

$$\omega^2 = \frac{1}{L}\frac{1}{C_1 + \dfrac{C_{gs} + C_{ds} + C_2 + C_3}{g_m \gamma_1(\theta) R_L}} \quad (29)$$

where g_m and ω_T are the small-signal transconductance and angular transition frequency, respectively. The value of the small-signal gate-source capacitance C_{gs} is equal to the oxide capacitance at low and high bias voltages, and is reduced by approximately two to three times in a region near the threshold voltage. The drain-source capacitance C_{ds} can be considered as the junction capacitance, for which the maximum large-signal value deviates from the small-signal value by not more than 10 to 20 percent.[2] Consequently, as a first-order approximation, the capacitances C_{gs} and C_{ds} can be modeled as the fixed capacitances measured at the quiescent bias voltage.

DIFFERENTIAL CROSS-COUPLED OSCILLATOR

It is most convenient to describe the operational principle of the differential cross-coupled LC oscillator on the example of an ideal class B operation with a piecewise-linear approximation of each transistor transfer characteristic, which means that each transistor conducts exactly half a 180° cycle with zero quiescent current. The simplified equivalent circuit of the differential cross-coupled LC oscillator with the tail current source is shown in ***Figure 7***. If the quality factor of the tank circuit is assumed sufficiently high to provide the sinusoidal voltages applied to the gate-source terminals of the transistors and across the tank resistor R_L, the drain current of each transistor can be represented in the following half-sinusoidal form.

For the first transistor:

$$i_{d1} = \begin{cases} +I_d \sin\omega t, & 0 \le \omega t < \pi \\ 0, & \pi \le \omega t < 2\pi \end{cases} \quad (30)$$

For the second transistor:

$$i_{d2} = \begin{cases} 0, & 0 \le \omega t < \pi \\ -I_d \sin\omega t, & \pi \le \omega t < 2\pi \end{cases} \quad (31)$$

Since, for an idealized piecewise-linear approximation, the third and high order odd harmonics of the drain currents are equal to zero, the total i_R flowing across the tank resistor R_L is the difference of the two out-of-phase drain currents:

$$i_R = i_{d1} - i_{d2} = I_d \sin\omega t \quad (32)$$

representing a purely sinusoidal waveform.

The current flowing into the tail current source through the center point of the circuit is the sum of the drain currents:

$$i_{tail} = i_{d1} + i_{d2} = I_d \left|\sin\omega t\right| \quad (33)$$

containing the DC and even-order harmonic components.

Ideally, even-order harmonics are cancelled out and should not appear at the resistor. In practice, the second harmonic is suppressed by approximately 20 dB or more below the fundamental. It is necessary to connect a bypass capacitor to the center point of the circuit in order to exclude power losses due to even-order harmonics. The current i_L produces a sinusoidal voltage across the resistor R_L equal to

$$v_P = I_d R_L \sin\omega t = V_R \sin\omega t \quad (34)$$

The DC component I_{tail} of the total drain current i_{tail} can be defined by integration over the oscillation period as

$$I_{tail} = \frac{1}{2\pi}\int_0^{2\pi} i_{tail}(\omega t)\, d(\omega t) = \frac{2}{\pi} I_d \quad (35)$$

CONCLUSION

The basic principles of the active device operation regions under DC and RF large-signal modes, based upon using CMOS devices, are presented with the derivation of very simple analytical voltage-current relationships. By using a matrix technique, an analysis of the start-up and steady-state oscillation conditions can be significantly simplified, resulting in explicit analytical dependences between the device and feedback parameters. These conditions are derived for a widely used single-ended MOSFET oscillator with a parallel resonant circuit based on a simplified device equivalent model. The basic operation principle of a differential cross-coupled tail-biased oscillator is explained analytically in the time domain. ■

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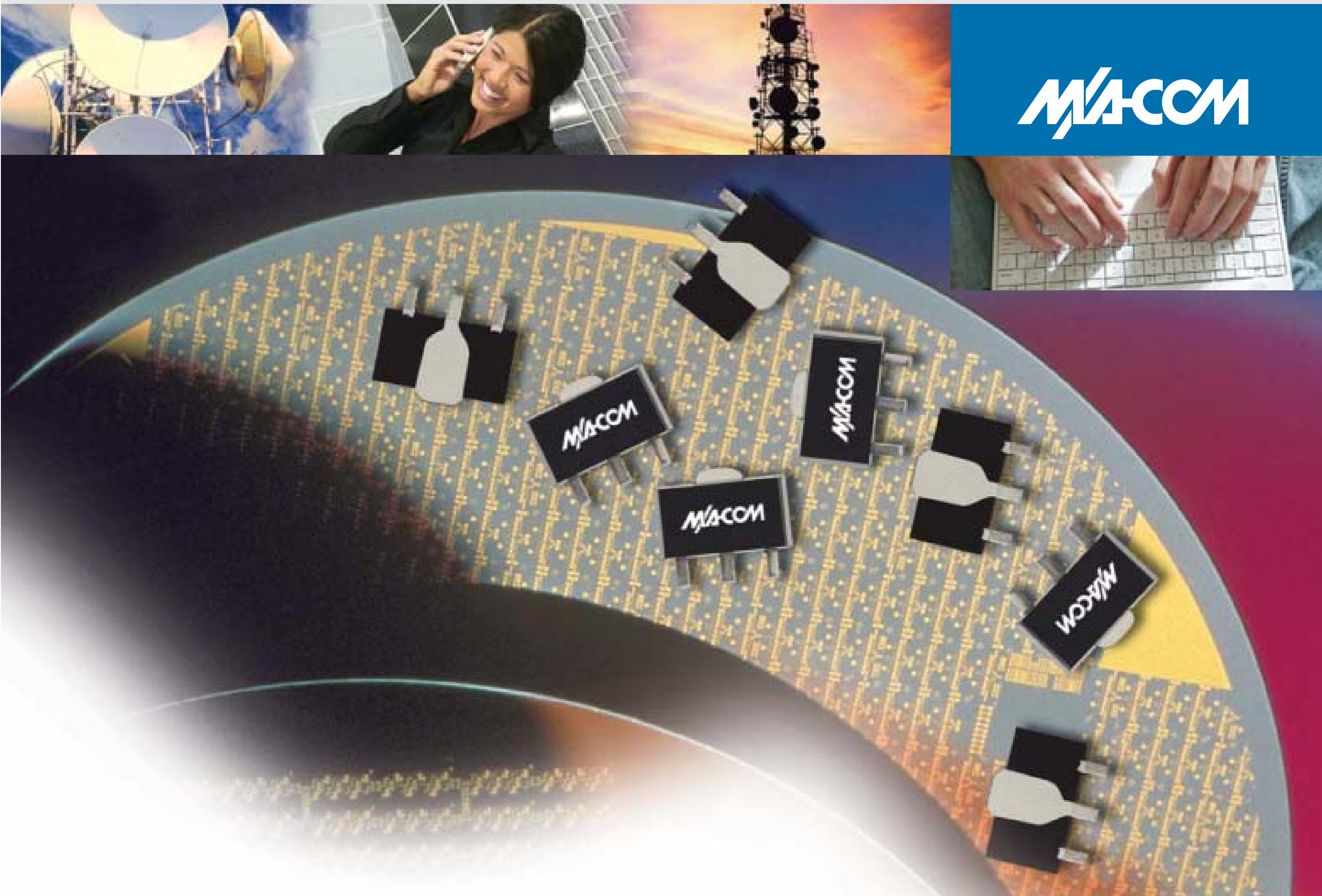
Andrei Grebennikov *received his MSc degree in electronics from the Moscow Institute of Physics and his PhD degree in radio engineering from the Moscow Technical University of Communications and Informatics in 1980 and 1991, respectively. He joined the scientific and research department of the Moscow Technical University of Communications and Informatics as a research assistant in 1983. From 1998 to 2001, he was a member of the technical staff at the Institute of Microelectronics, Singapore, responsible for the design and development of LDMOS FET high power amplifier modules. Since January 2001, he has been with MA/COM Eurotec as a principal engineer, where he is involved in the design and development of the handset advanced transmitter architectures in general and in GaP/GaAs HBT power amplifier modules for new generations of wireless communications systems. His scientific and research interests include the design and development of power RF and microwave radio transmitters for base station and handset applications, hybrid integrated circuits and MMIC of high efficiency, and linear microwave and RF power amplifiers, single-frequency and voltage-controlled oscillators using any type of bipolar and field-effect transistors, and active device modeling.*



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EXPORT COMPLIANCE: UNDERSTANDING ITAR AND EAR

If your company participates in the aerospace and defense industry, you probably have encountered customs agents, customers and other third parties asking whether you are ITAR compliant. While being ITAR compliant is crucial, companies exporting any goods must also remain compliant with regulations enforced by the US Customs Agency, Department of Commerce (Commerce), the Office of Foreign Asset Control (OFAC), the Census Bureau and many others.

Here is a guide to help you learn the basics of complying with the United States exporting laws, including ITAR, the International Traffic in Arms Regulations promulgated by the US Department of State (State) and enforced by the Office of Defense Trade Controls. This guide will help you understand the various checklists and classifications under federal regulations you must review before exporting your products and technical data, and whether you should seek an export license prior to shipping the product or technical data.

Proper export controls demand further training of your staff from executives to sales to engineering to shipping. If your company exports, it should have in place an export compliance program that includes internal and external training of all applicable employees on a regular basis. These mechanisms will serve as the first line of defense against an export audit.

Since the events of September 11, 2001, and the passage of the Patriot Act, in the interest of national defense all export enforcement agencies have increased their efforts at catching and convicting those who violate the export laws. While changing almost daily, however, these export laws are not new. ITAR was first promulgated following World War II, and most of the other laws have also been around for quite some time. The events of 9/11 have heightened agency enforcement with the intent, of course, to curb future acts of terror on the US, its territories and its allies.

RE-EXPORT

Any shipment or transmission of product or technical data from one *foreign country to another foreign country*.

IS AN EXPORT LICENSE REQUIRED?

The threshold question for export compliance is whether an export license will be required by one of the federal agencies before you ship your products or technical data to a foreign end-user, or re-export from one foreign location to another. Note that export licenses control the products you ship, not the purchase orders (so, on a single purchase order some products may require a license while others do not).

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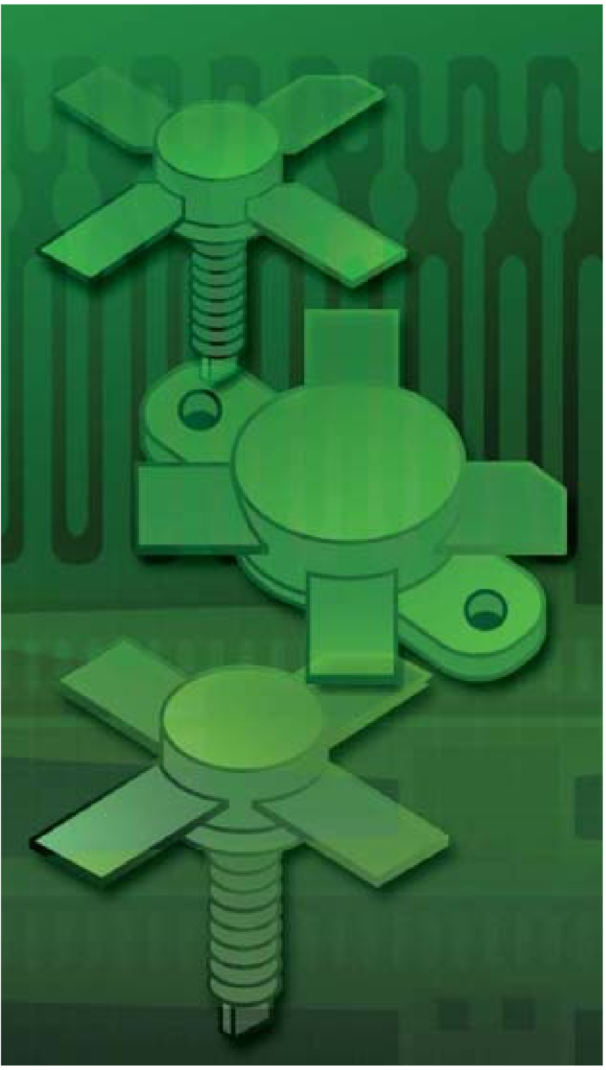

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2N5946	MRF141G	MRF1946A	MRF652S
2N6081	MRF166	MRF221	TDS595
2N6084	MRF166C	MRF429	TPV595A
2N6985	MRF171	MRF448	
	MRF172	MRF450	

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SD1015-06	SD1224-02	SD1407	TH430
SD1018	SD1224-10	SD1414	TH596
SD1143	SD1252	SD1446	TH597
SD1143-01	SD1253	SD1457	TH598
SD1143-03	SD1272	SD1490	UTV8100B
SD1146	SD1274	SD1726	

MS REPLACEMENTS

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MS1227	MS1403	MS1503	

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PENALTIES FOR EXPORTING WITHOUT A LICENSE

The penalties for exporting without a license may be severe, including both criminal and civil penalties to the corporation and even the individuals involved. One sales application engineer was recently convicted of exporting without a license and received a five-year prison sentence and two fines each at $250,000. In this age of corporate executives and Martha Stewart convictions related to securities or obstruction of justice, individual indictments are a key tool that export officials continue to use to demonstrate the heightened scrutiny the US is placing on exports.

TECHNICAL DATA

Technical Data is defined as follows by the Export Administration Regulations (EAR): Information that is required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of *controlled* items requiring a license to export. This information is usually presented in the form of schematics, drawings, photographs and other documentation. This information does not include general scientific, mathematical or engineering principles commonly taught in schools, colleges and universities or information in the public domain. This information also does not include marketing information with respect to function or purpose or general system descriptions, including those documents posted on the company's Web site and available to the public domain.

Several US companies have received penalties for export violations, many of which received multi-million dollar fines. US companies found guilty of violating the various laws will generally be debarred from exporting for three years, and may be debarred for much longer.

US export enforcement agencies do have authority to inspect shipping docks and seize shipments. They do so with "guns and badges" enforcement agents. Such an experience can be very damaging to a company, from the perspective of its employees, its customers and its local community.

DOES DEPARTMENT OF STATE HAVE JURISDICTION?

To determine whether an export license will be required, you must determine which federal agency has jurisdiction over your products and technical data. For companies designing military or space products, the first step is to determine whether your products or technical data are listed on the US Munitions List (USML). For most RF and microwave manufacturers, this review will require a careful reading of the "components" sections in each USML category.

The State Department uses both the Arms Export Control Act (AECA) and the International Traffic in Arms Regulations (ITAR) to control exports. The USML is listed within ITAR. You can check the latest USML on-line at http://www.pmdtc.org/reference.htm.

Typically, a category will cover the big equipment (rockets, launchers, military vehicles and vessels, and space craft, for example). To capture significant components, however, each category will contain a catch-all provision such as "all components used in the items covered by this category if they were specifically designed or modified for military applications."

To determine whether a product is specifically designed or modified for a military application, State uses a special standard of review. This standard of review requires an analysis of why a product was originally designed. That is, what is the genesis of the model? Was the model originally created to meet a specific military or space requirement considered a military use? Commonly, the State Department will look to whether a product was designed based on a customer's specification, including form, fit and function, not just performance.

The phrase "configured" also appears in the components clauses on the USML. For a product to be configured for military or space, State looks to whether the design requires a different arrangement of the product that is specifically for military or space use. That raises a live issue as to whether putting a standard device through various screening levels really rises to the level of "configured," especially where the device structure is not arranged for this application.

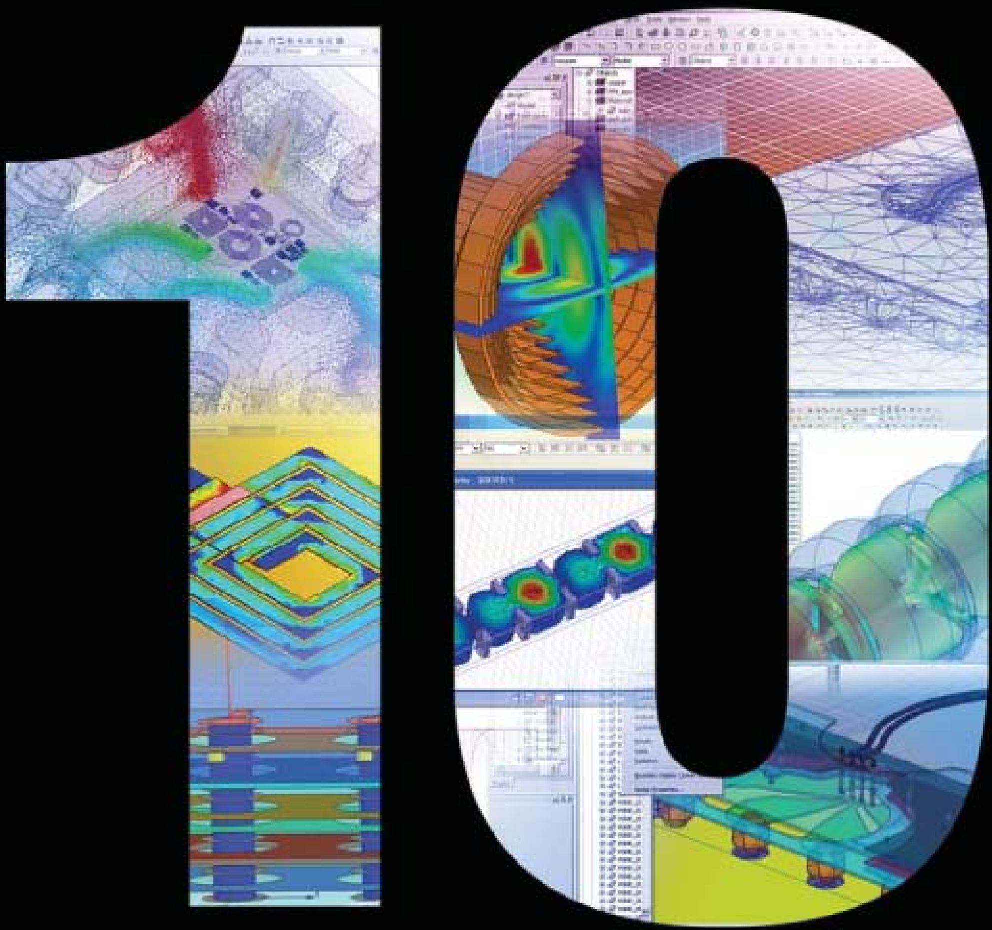
Exporting classifications frequently require engineering to help determine whether a company's products meet the frequency, power and other critical parameters of various components listed on the USML. If your products or technical data are listed on the USML, then your company must be registered with the State Department and you must apply for an export license through State. To do so, State prefers that applicants use its on-line application process (ELLIE, or its new version DDTC).

Also, in determining whether the end-use is really defined as a military application, note the difference between a component designed for the mess hall dishwasher versus that designed for a missile or military radio. State would not consider the dishwasher a "military use" as a radio or missile would be, and thus such dishwasher components are not necessarily covered by the USML. State prefers to review export control classification based upon whether a device will be used in a "military way" for offensive or defensive purposes and not based upon simple service to the military.

COMMODITY JURISDICTION LETTER

If you are not sure whether the USML covers your products, you may wish to seek a Commodity Jurisdiction (CJ) letter through State. This process will require submittal of evaluation materials for State to review, and State will use a cross-functional set of agencies (including Commerce) to ensure it determines jurisdiction accurately. Once State determines whether it has jurisdiction over your products, it will issue a CJ letter to your company explaining whether State or Commerce has jurisdiction.

You must hold all purchase orders and technical data from processing until a CJ letter is secured from State, unless otherwise authorized to proceed without the CJ letter concurrently with the CJ letter request (that is, some long lead-time orders may begin concurrently with a CJ letter request). Management and legal shall consult with the State Department's



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DTA1-1880A		1000	-80
DTA182660A	18-26	10	-60
DTA182670A		100	-70
DTA182680A		1000	-80
DTA264060A	26-40	10	-60
DTA264070A		100	-70
DTA264080A		1000	-80
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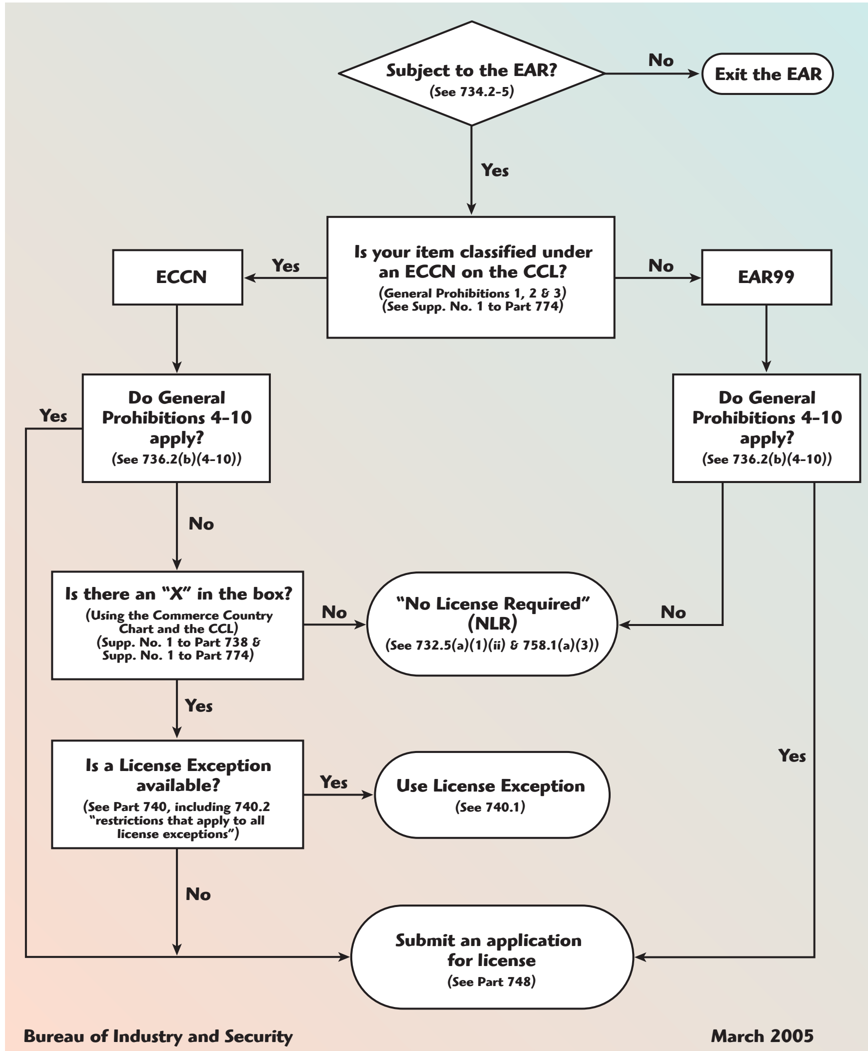

Fig. 1 Export control decision tree (Supp. No. 1 to Part 732).

Response Team in further determining whether the products or technical data in question are on the USML.

If you are certain that your products or technical data are not covered by the USML, then the Department of Commerce will most likely have jurisdiction.

JURISDICTION UNDER COMMERCE

The regulations promulgated by Commerce are called the Export Administration Regulations, or EAR. The EAR contains a helpful flowchart (see ***Figure 1***) by which export managers may determine whether a license is required by Commerce prior to exporting products or technical data. The flowchart contains steps covering commodity classification, "bad guy and country" checklist reviews and whether an export license is required. The Bureau of Industry and Security (export enforcement division of the Department of Commerce) offers outstanding training seminars and they are presented in major metropolitan areas nationwide.

Primarily, under the EAR, you must classify your products against the Commerce Control List to see if they have an Export Control Classification Number (ECCN) or will be designated as "EAR99." Most RF and microwave products will fall under Category 3, but you should study all CCL categories to see if your products are listed elsewhere. Where products are not listed as having a designated ECCN, a catch-all phrase at the end of each category will state: "EAR99 Items subject to the EAR that are not elsewhere specified in this CCL Category or in any other category in the CCL are designated by the number EAR99."

Where doubts persist, seek guidance from management, engineering

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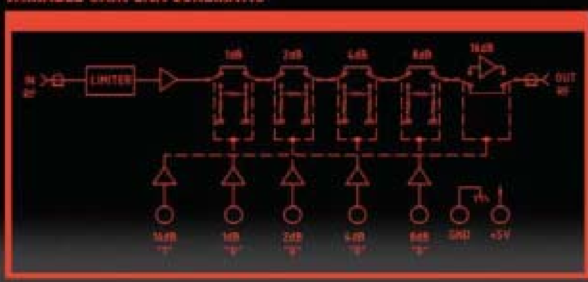

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COMPRESSION, P1dB	+18	+19		dBm	
VSWR			1.3/1 2/1		16 TO 32dB GAIN -1 TO 15dB GAIN
IMPEDANCE		50		OHMS	
ATTENUATION RANGE	0		31	dB	
STEPS	-	-	-		1, 2, 4, 8, 16dB
ACCURACY	-	-	-		±0.3dB + 2% OF ATTEN SETTINGS IN dB) dB
OPERATING TEMPERTURE	-40	+25	+85	°C	TA

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PART NUMBER	OPERATING FREQUENCY (MHz)	NOISE FIGURE (dB)*
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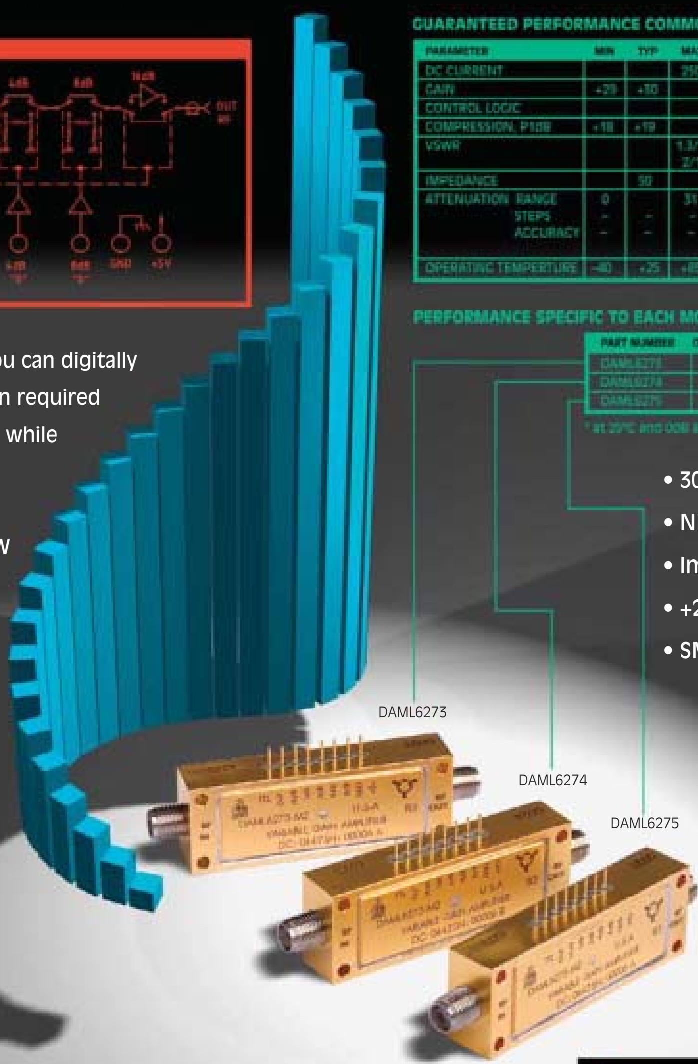

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and legal to properly classify your products. For the latest CCL on-line, visit http://www.access.gpo.gov/bis/ear/ear_data.html and click on your specific product category.

Again, as you can see by the flowchart, just because you have classified products as EAR99 does not necessarily mean that the products may ship as no license required (NLR). You still must consult several prohibitions checklists to determine whether a license is nevertheless required.

CRUCIAL STEPS UNDER THE EAR

There are ten General Prohibitions listed in the EAR. The first three apply to all ECCN classified products, and Prohibitions 4 through 10 apply to both ECCN and EAR99 classifications. Consult the latest EAR and these General Prohibitions at http://www.access.gpo.gov/bis/ear/pdf/736.pdf to ensure compliance with all ten items, when applicable to the classification of the product to be exported.

In some circumstances, a Destination Control Statement is required where product was classified above as having an ECCN (not "EAR99"). A Destination Control Statement advises the recipient of US-origin products of their legal responsibilities and restrictions under US export and re-export regulations.

When a Destination Control Statement is required, place copies of this Statement on all copies of the invoice, bill of lading, airway bill, or other export control document that accompanies the shipment from its point of origin in the US to the ultimate consignee or end-user abroad.

General Prohibitions number Five contains a Red Flags list. Always consult the Red Flags list as defined by BIS at http://www.bis.doc.gov/Enforcement/redflags.htm to ensure all aspects of the End-use Certification and other leading indicators of suspicious activity are captured before you export or transfer technical data.

SPECIAL CONSIDERATIONS

"Technical Data" has been referenced throughout this article along with products because exporting technical data to a foreign national may create a "deemed export" under both State and Commerce. Foreign nationals include your foreign representatives, foreign customers and even your foreign employees who are not permanent residents (e.g., residing and working here in the US on visas).

> **DEEMED EXPORT**
>
> Any release or transmission by *your company personnel or approved representatives* of technical data to a *foreign national* located within the United States.

COMPLIANCE PROGRAMS

To ensure compliance with all US export laws, and to follow Commerce's flowchart in detail, all companies in the RF and microwave industry should implement an Export Compliance Program. Even where a company has exported only "EAR99" classified products under the EAR, a compliance program can help prevent shipping EAR99 product to embargoed or restricted countries, denied persons and specially designated nationals. Note that even EAR99 classified products may require a license to export.

A solid compliance program should contain procedures on acquiring an end-use certification (EUC) from your customers. The EUC will help you determine whether the customer intends to re-export your products, which could in turn violate US export laws. Periodically, State and Commerce enforcement agents will travel abroad to follow your products to their final destination. If your products require an export license to the end-user or country, you and your company are ultimately responsible and liable for the product arriving there legally (with an export license when required).

The compliance program should also require your employees to run verification checks against the screening lists of "bad guys" and restricted countries. See the sidebar for screening list web sites, and note that several companies offer export control software systems that streamline this screening process through a single interface. Do not assume that because your company does not ship to the "bad guys" that you are clear of liability for an export violation. Many cases exist where products are re-exported from an unrestricted country to a final destination or party

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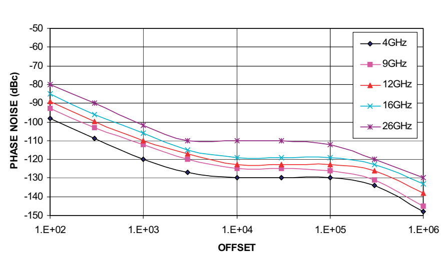

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Foreign Persons List:
http://www.pmdtc.org/docs/forper.txt
Specially Designated Nationals and Blocked Persons (OFAC):
http://www.ustreas.gov/offices/enforcement/ofac/sdn/index.html

without a license where one was required by a US agency.

These lists should be checked at the time an RFQ or order is received, when you suspect a foreign national may acquire technical data or plans to visit your facility, and prior to all international shipments. An authorized, trained export employee should check the name of the end-user, freight forwarder, distributor and end-use country against these lists. If a match exists, this employee should have authority to hold up a shipment, and you must seek an export license immediately. Obviously, the sooner these checks occur prior to product sitting on a dock, the better.

TRAINING

A successful compliance program must absolutely have a periodic training component to ensure that authorized export control personnel have sufficient and on-going training. Training should be provided for your company's specific export procedures as well as third party training programs offered by the US agencies, law firms and export consulting firms on the new changes and trends to the export laws.

AUDITS

Because export laws and the "bad guy lists" are constantly changing, your export compliance program should be reviewed by qualified, trained staff including in-house counsel, or outside legal or consulting firms, or all of the above. Lawyers who provide legal advice on superseded laws risk committing malpractice. You do not want to explain to export officials that your company is guilty of the equivalent because it did not periodically audit its export compliance program for accuracy and completeness against the current laws.

RECORD KEEPING

The final element to implementing a successful export compliance program is to require record retention. All records associated with the review of each export, re-export, deemed export, or exports conducted under a license exception should be retained by the company and the responsible individuals for five years from the date the item is exported (that is, the shipment or technical data actually leaves the United States, not just the company's dock or facility, or is re-exported from a foreign country). These records should include but not be limited to end-use certifications, commercial invoices, copies of Shipper's Export Declarations, Destination Control Statements, air waybills or bills of lading, and any internal export control forms, logs and checklists the company uses in its compliance program.

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VOLUNTARY DISCLOSURES

Each of the enforcement divisions for the agencies discussed in this article offer voluntary disclosure programs where companies discover exports occurred without a license though one was required. The latest trend with voluntary disclosures is that the agencies are treating them as mitigating factors in the penalty phase of enforcement. While penalties may be reduced, they are nevertheless levied in many cases due to the seriousness of export control violations and in the interest of national security.

OTHER AGENCIES CONTROLLING EXPORTS

Generally, OFAC controls transactions with respect to finances, but OFAC also controls any shipments through or to embargoed countries or shipments using embargoed country vessels. Therefore, certain payments made to your company under international purchase orders may come under the jurisdiction of OFAC as may shipments of your company's product that may be transported on embargoed country carriers or vessels. Note the danger of using a Cuban-owned vessel to transport goods even to a NLR country or party.

The Office of Antiboycott Compliance enforces US law prohibiting US firms from recognizing a foreign boycott not sanctioned by the United States. The Arab League boycott of Israel is the principal foreign economic boycott that US companies must be concerned with today. The antiboycott laws, however, apply to all boycotts imposed by foreign countries that are unsanctioned by the United States. The antiboycott rules prohibit companies from entering into:

- Agreements to refuse or actual refusal to do business with or in Israel or with blacklisted companies.
- Agreements to discriminate or actual discrimination against other persons based on race, religion, sex, national origin or nationality.
- Agreements to furnish or actual furnishing of information about business relationships with or in Israel or with blacklisted companies.
- Agreements to furnish or actual furnishing of information about the race, religion, sex, or national origin of another person.

There are some key reporting requirements for your company under the antiboycott laws. Management must submit quarterly reports showing requests employees received in the previous quarterly period to take certain actions to comply with, further, or support an unsanctioned foreign boycott. Under the Tax Reform Act, management must also report "operations" in, with, or related to a boycotting country or its nationals and requests received to participate in or cooperate with an international boycott. The Treasury Department publishes a quarterly list of "boycotting countries." Consult this web page to learn how to report: http://www.bis.doc.gov/antiboycottcompliance/oacrequirements.html#whatscovered.

The US Census Bureau, through its Foreign Trade Division and the US International Trade Commission, controls exports to the extent that it requires a commodity number classification for virtually every commodity or material exported. The Census Bureau uses these classifications to simply count total commodities exported. This classification system is known as the Harmonized Tariff Schedule (HTS). Consult the latest HTS to classify your company's products to be exported and assign each product a corresponding HTS number: http://www.usitc.gov/tata/hts/bychapter/index.htm.

The Office of Management and Budget (OMB), meanwhile, governs the North American Industry Classification System (NAICS, pronounced, "Nakes"), which also

TABLE OF AUTHORITIES

AECA	Arms Export Control Act (22 USC 2778)
ITAR	International Traffic in Arms Regulations (22 CFR Parts 120 to 130)
EAR	Export Administration Regulations (15 CFR Parts 730 to 774)
ANTIBOYCOTT	
TAX REFORM ACT	
HTS	Harmonizing Tariff Schedule of the Unites States (USITC Publication 3745) Wassenaar Arrangement (http://www.wassenaar.org/)

requires counting those commodities made in Canada and Mexico. (In 1997, the OMB revised the old Standard Industrial Classification (SIC) numbering system into the current NAICS numbering system, and then modified the 1997 version of NAICS in 2002. The 2002 NAICS is the current version to use as of the date of this publication; the next published version of NAICS is scheduled for 2007.) However, the intent of NAICS is to capture data on the manufacturers and producers of commodities more so than the commodities themselves. Consult the latest version of NAICS to classify your company's products at http://www.census.gov/epcd/www/naics.html. When shipping documentation and catalogs or other items that are not manufactured goods, review NAICS for their separate classification numbers.

SEEK LEGAL ADVICE

This article is intended to provide the reader with accurate and authoritative information regarding export compliance. It was not published as legal advice. If you require legal or other expert advice, you should seek the services of a competent attorney in your jurisdiction or another export professional. Many communities will have attorneys who practice in the area of international law, which often covers US export laws and foreign treaties. In addition, several reputable consulting firms serve companies in all areas of export compliance. ■

Shawn Cheadle *was formerly general counsel, corporate secretary, and regional vice president of Cougar Components Corp., where he ran Cougar's Colorado facility. Since the acquisition of Cougar Components by Teledyne Technologies, he is now serving as assistant secretary and senior contracts counsel of Teledyne Cougar Inc. In his new role, his primary practice areas include contracts, defense priority ratings, export compliance, and merger and acquisition support. He has been a member of the Colorado Bar and Denver Bar Association since 1995. He sits on the Board of Directors for the Association of Corporate Counsel, Colorado chapter, where he is first vice president and vice president, communications. He received his juris doctor degree from the University of Denver, College of Law, and his BA in english from San Jose State University.*

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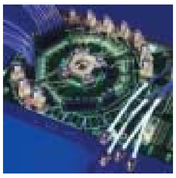
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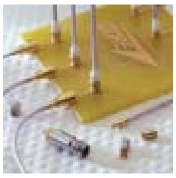
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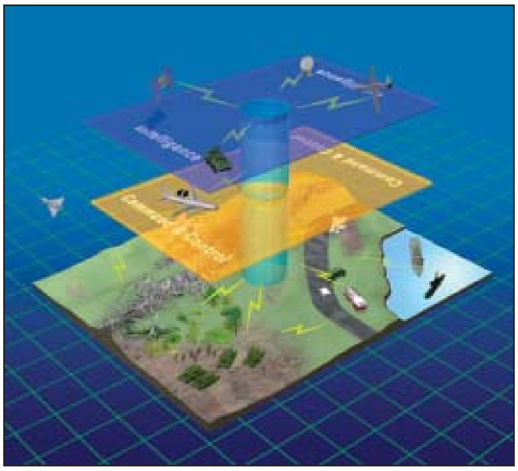
NEXT-GENERATION RADIOS: NEW PATHS FOR COMMUNICATIONS

Anyone who deals with military communications systems today is certain to come face-to-face with the concept of network-centric warfare. The heart of this concept is a reliable and ubiquitous communications system. Success in combat requires that the necessary information and communications links always be made available exactly when and where needed (see ***Figure 1***).

THE CHALLENGES

Traditional radio communications systems do not meet this requirement. They are usually designed to meet the needs of a largely closed group of users. Accordingly, they use waveforms that have been optimized for the mission at hand and whose characteristics reflect the state of technology at the time they were developed. In today's terms, a waveform means the entire functionality involved in a radio between the input and output of voice, data and video at the user interface and the signal on the antenna. This primarily includes protocols, coding and modulation. A few examples of waveforms are SATURN, Link 16 and TETRA. The main weaknesses in communications systems and conventional waveforms are a lack of interoperability, insufficient networking capability and low data throughput. A large number of incompatible waveforms are in use today. Current systems can handle only one or, at most, a few of these waveforms. This leads to user groups that can communicate with each other only to a limited extent. However, armed forces are increasingly collaborating in various groups (task forces). Traditional systems cannot meet the requirements of these mission concepts. In addition, most waveforms do not allow information switching via relay stations, as is customary in telephone networks and in the Internet. They lack mechanisms for networking (routing; layer 3 in the Open System Integration (OSI) model) and transport security (that is ensuring the reliability and integrity of the information; layer 4 in the OSI model). They are limited to providing point-to-point, point-to-multipoint and broadcast links (layer 2 in the OSI model). In addition, the data throughput of the waveforms is too low to support the applications necessary for network-centric warfare. Solutions are already taking shape. In all probability, a new standard for the architecture of radio-based communications systems will meet the requirements for interoperability not only at the air interface but also inside the radios. The Software

Fig. 1 Next-generation radios must satisfy requirements for network-centric warfare.



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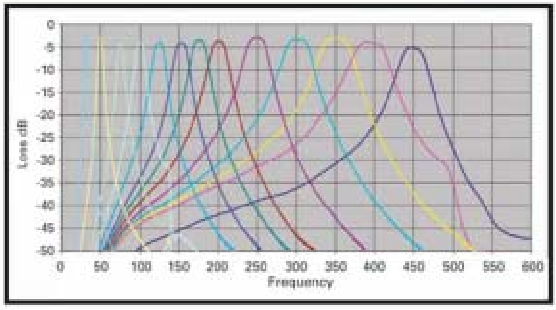

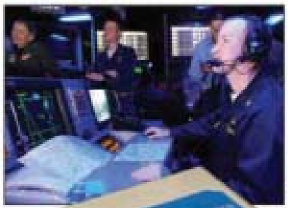

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Communications Architecture (SCA) developed on behalf of the United States Department of Defense pursues this objective. The Software Defined Radio (SDR) Forum and the Software-based Communication Domain Task Force of the Object Management Group (OMG) support the SCA as a common standard. The SDR Forum includes approximately 120 companies from the radio communications industry, research institutions and government offices. The OMG consists of about 800 members from the software industry and end users.

The future Internet Protocol, version 6 (IPv6) standard will form the basis for networking the systems. To increase data throughput, broadband waveforms will be used.

INTEROPERABILITY VIA SOFTWARE

Modern, high end radios will have an architecture similar to that of a PC, with highly complex and highly specialized plug-in cards. Since the radio's central control and monitoring functions will be integrated into its software, functionality can be programmed as needed to the extent allowed by the hardware. Such radios are referred to as software-defined radios (SDR). Versatile software of this type is made usable by implementing abstraction layers and standardized software components. The advantage of such an architecture is that the number of waveforms that the radio can handle is limited only by the internal storage capacity. The user can also modify the functionality of the loaded waveforms when necessary by installing software updates. Of course, the hardware must be powerful enough to handle the waveforms. Performance depends on the possible channel bandwidths, the linearity and power of the amplifier, the possible hop rates, the frequency range covered, the timing or antenna characteristics. Interoperability is achieved by installing waveform software. Today's SDRs can already do this. However, this does not satisfy the objective of being able to install a waveform on any and every radio. The waveform will function only on instruments of the same product family, because this family has a proprietary software platform. The platform prevents the waveform software from being used on just any instrument. This is similar to the PC world, where Windows applications cannot be run on UNIX machines. The only way to overcome this problem is to create a common standard. This standard must standardize the radio's central control, define the interfaces between the common software components used and make hardware control uniform. The SCA, which is pursuing this objective, has four main principles. First, the interfaces to the operating system will be standardized. A subset of the POSIX standard, which is derived from UNIX, will be defined. The waveforms must use exclusively this subset for system accesses. At the same time, the operating system must make these interfaces available. Second, CORBA™, which is an objected-oriented communications standard for distributed systems, will generally be used for communicating between software components. Third, the mechanisms for loading and changing waveforms and other applications will be precisely defined. The instance that handles this task is the core framework. Fourth, building blocks will determine the basic modularity for the waveforms and will define the application programming interfaces (API) for some of the software components.

The SCA has limitations in two areas that are currently being further developed to ensure easy portability of waveforms. First, the specifications on how radio-specific hardware is mapped in the software are insufficient. Parts of the radio will remain proprietary unless a uniform hardware abstraction layer (HAL) is defined. The US Department of Defense has recognized this weakness and has expanded the standard in cooperation with Rohde & Schwarz and other interested companies. Second, some interfaces between the software components have not yet been made uniform. Solutions have already been proposed, however, for some areas.

Despite these weaknesses, the SCA represents a giant step forward in standardizing radio architectures. It is currently the only proposal that holds the promise of industry-wide standardization of radios and thus easy portability of waveforms. Interoperability on the air interface, that is the ability to load several waveforms on one radio, is already possible today with an acceptable amount of effort by using multiband SDRs. For some SDR families of instruments, the migration path to SCA has already been plotted out and is highly recommended.

NETWORKING VIA THE INTERNET PROTOCOL

When it comes to networking, there is no getting around the Internet Protocol (IP). This is particularly true when information networking is involved. The Internet is not limited to the transport of data. Solutions such as voice over IP and video streaming make it possible to use the Internet to transmit information previously restricted to telephone and broadcasting networks. Thus, it is only logical to select the Internet Protocol as a standard for networking in radio communications. The new IPv6 version of the protocol offers several characteristics not available in version IPv4 that are relevant to the integration of mobile user equipment (mobile IP, IPSec). As a result, some radio system customers have already adopted IPv6. However, a fair amount of effort is involved in order to transfer Internet functionality to highly mobile networks, that is to networks with a rapidly changing topology that has no infrastructure. Before further steps are taken, solutions must be found for three areas in which radio-based networks differ from the classic Internet. At present, the transmission and connection set-up protocols on which the TCP/IP are based — layers 1 and 2 in the OSI model — are designed for cable connections. Thus, the mechanism for collision avoidance in data transmission, for example, is not suitable for radio links, because additional measures must be taken in order to detect and prevent collisions. This means that data throughput fails when collisions occur. One solution is to use radio-specific protocols. In addition, the mechanisms for setting up routing information, such as for setting up path information for the efficient forwarding of data packets, are designed for networks based on a fixed infrastructure. They are not suitable for highly mobile networks. Solutions are currently being developed in the area known as "ad hoc networking." The objective is to de-

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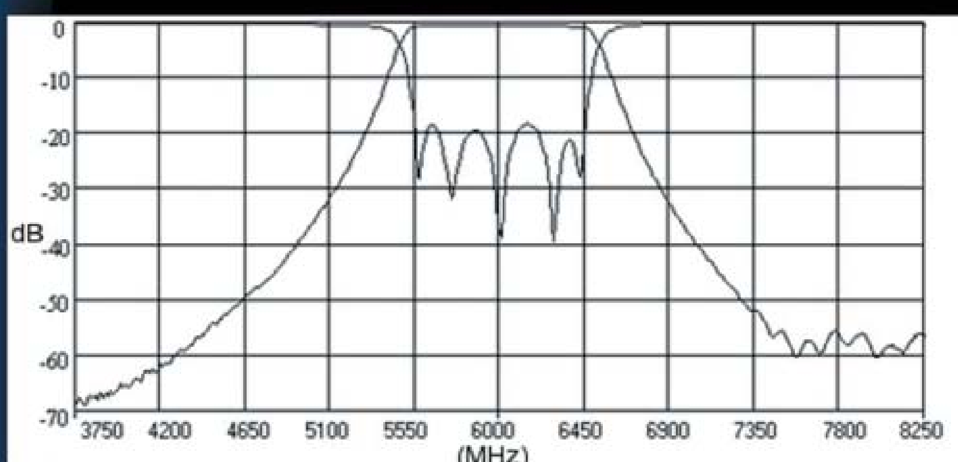

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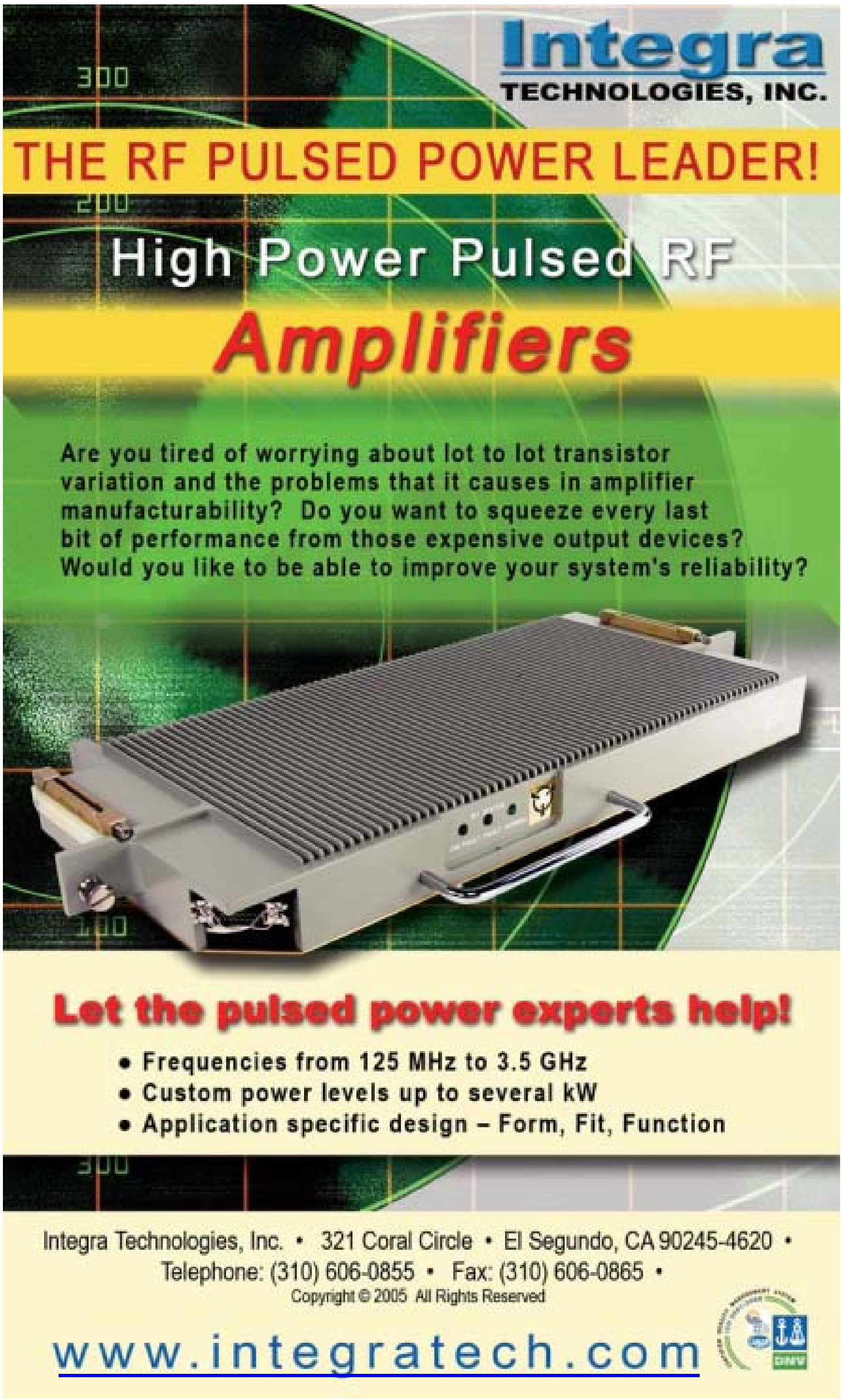
velop algorithms that can determine the best routes for the data packets to be forwarded without involving extensive communication effort. Third, both the Internet Protocol as well as the transmission of routing information take up a large portion of the bandwidth of a radio link. It is often necessary to route multiple links through one node. As a result, the bandwidth of a single link can drop below an acceptable limit. To ensure optimum use of the bandwidth, corresponding boosters are combined under the term Quality of Service (QoS). Since most solutions are designed for high bandwidth networks, they are only of limited use with mobile networks. Intensive research is also being done in this area. The available bandwidth can be used efficiently by applying the described mechanisms for automatic network management. However, the bandwidth is insufficient for the numerous command support applications that are planned (transmission of videos, synchronization of databases). Only broadband waveforms can offer the required data throughput.

▲ *Fig. 2 Software-defined radios of the R&S M3TR family in actual use.*



QUALITY MEANS HIGH DATA THROUGHPUT

Waveforms are currently being developed that permit a data throughput of 2 to 5 Mbps over a distance of up to 10 km for ground-to-ground links. Only waveforms with a bandwidth of several megahertz can do this. Thus, the lower frequency bands are not useful for transmission, because they would not provide enough channels having this bandwidth. Yet, higher frequencies have the drawback that the range is lower for the same transmit power. If you want to increase the transmission rate from, for example, 16 kbps to 3.2 Mbps under the same general conditions such as carrier frequency, range or receiver sensitivity, the transmit power must be 200 times greater, because the transmission rate and required transmit power are proportional to each other. Likewise, if the carrier frequency is increased from, say, 200 to 2000 MHz, the transmit power must again be increased by a factor of 50 (in a rural area). These examples provide a very rough idea of the challenges associated with high data rates. However, the actual range is highly dependent on the current environmental conditions, which can easily cause the calculated values to change. For example, when field trials were conducted in a rural area, the actual results from the R&S M3TR tactical radio (see ***Figure 2***) were always twice as good as the values projected by the theoretical models. However, this does alter the main relationship between data rate, transmit frequency, and transmit power and range. The ratio between data rate and required transmit power can be improved through a variety of measures

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such as using optimum modulation methods, channel coding and directional antennas. Nevertheless, the amount of energy for a mobile user and thus the associated maximum transmit power usually remains limited. As a result, relay stations will be unavoidable for long-distance links at high data rates despite their drawbacks. In contrast, narrow-band waveforms require far fewer relay stations. Consequently, the new broadband waveforms are more likely to complement rather than replace waveforms with narrower bands.

THE FUTURE STARTS TODAY

Many of today's radio systems carry the disadvantages of proprietary waveforms, insufficient networking capability and inadequate throughput for future applications. As the networking of armed forces becomes more common, it will become increasingly necessary to replace these systems with solutions that can handle the future. One approach is to restrict the number of waveforms to just a few that are each optimized to a specific mission condition. The requirements are clear: A waveform is needed that is suitable for the efficient transmission of large amounts of data (high data rate (HDR)). A further waveform should be capable of transmission at a comparably high data rate even if a jammer is present (anti-jamming (AJ)). Yet another waveform should minimize the probability of detection (low probability of detection (LPD)) and interception (low probability of interception (LPI)). Additional waveforms should ensure efficient communication across long distances as well as communication via satellite. If these various waveforms are combined in a single packet, the result is described as a waveform made up of multiple signal shapes (signals in space). However, this interpretation appears useful only if the waveform can be scaled as a whole, such as by adapting it to the mission conditions at hand by setting a few generally valid parameters.

The characteristics of the next generation of radio communications systems are of particular interest for military planning. The current research projects, the capabilities of today's software-defined radios and the standards that have been adopted suggest that the next generation will fulfill the SCA. The next generation will be able to handle IPv6 via radio, can be networked ad hoc, will offer a broadband waveform with a high data rate and will support an acceptable number of waveforms currently in use. Of course, the next generation will not meet all requirements, but the SCA will provide the radio communications system with an open and flexible architecture. New technologies can easily be added to this architecture, and existing system parts can be reused. This will have a positive impact on logistics, life span, performance and migration effort, ultimately making the system more economical.

Boyd Buchin *is involved in software R&D and design in the Radiocommunications Systems Division at Rohde & Schwarz.*

Rüdiger Leschhorn *is head of technologies and studies in the Radiocommunications Systems Division at Rohde & Schwarz.*

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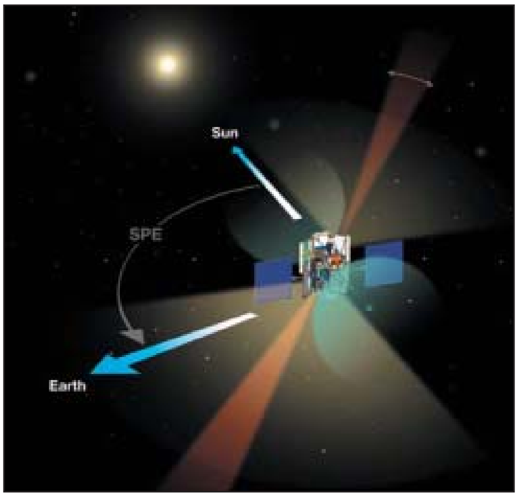
TECHNICAL FEATURE

THE MEDIUM-GAIN ANTENNA OF THE MESSENGER SPACECRAFT

This article describes the design and performance of the medium-gain antenna developed for the MESSENGER spacecraft. The electrical design and performance will be presented, as well as the mechanical design that was necessary to endure the harsh mission environment.

On August 3, 2004, the MESSENGER probe[1] was launched on its six-year journey to the planet Mercury. The acronym MESSENGER derives from MErcury Surface, Space ENvironment, GEochemistry and Ranging. Commissioned by NASA, and built and operated by the Johns Hopkins University Applied Physics Laboratory (JHU/APL), the probe carries a suite of scientific instruments that will conduct a study of Mercury upon entering orbit around that planet in March of 2011. Communications with the spacecraft take place through an on-board telecommunications system that includes an X-band solid-state power amplifier and three kinds of antennas:[2] a high gain phased array whose main beam can be electronically steered in one plane, a medium-gain "fan-beam" antenna and a low gain horn with a broad pattern. The high gain antenna is used as transmit-only at 8.4 GHz, the medium-gain and low gain antennas transmit at 8.4 GHz and receive at 7.2 GHz, and all three antennas operate with right-hand circularly polarized (RHCP) radiation. One of each of these antennas is mounted on the front of the probe facing the sun, and one of each is mounted to the back of the probe facing away from the sun. This article describes the design and performance of one of these antennas, the medium-gain antenna.

Fig. 1 Illustration of the MESSENGER spacecraft and antenna patterns.



Communication between the probe and Earth can be understood with the aid of ***Figure 1***. Consider a spherical coordinate system whose origin is at the probe, with the z-axis pointing toward the sun. The line from sun to probe makes an angle with the line from probe to Earth; it is referred to as the sun-probe-Earth (SPE) angle and corresponds to the elevation angle θ in a spherical coordinate system. This angle can vary between 0° and 180° during the mission. Since the solar panels must always face the sun, any change to the spacecraft attitude is restricted to a roll motion about the sun-probe line; this move-

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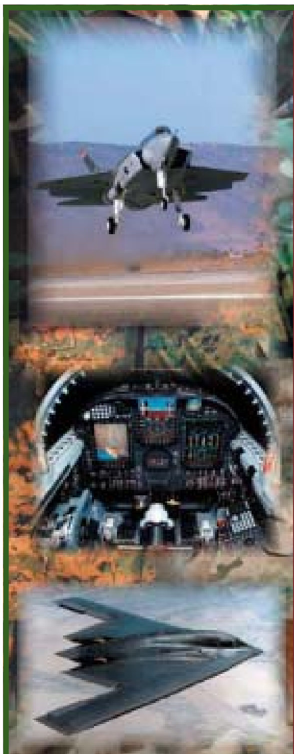

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AP1053	10-1000	11.0	1.5	26.0	97	39/58	15	100
ARJ109	0.5-200	10.8	4.5	28.5	96	44/75	15	235
AR1096	600-1000	14.2	2.1	28.0	96	42/58	15	230
AP348	10-250	13.5	3.2	25.0	95	42/57	15	108
AP2009	10-2000	11.0	3.5	28.0	95	40/50	15	188
AP1051	10-1000	11.5	1.5	23.0	94	35/52	8	89
AP2079	10-2000	10.3	3.1	24.5	94	38/54	15	125
AC652	10-600	10.8	1.3	18.8	93	32/45	5	50
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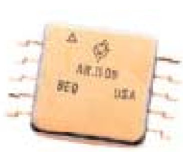
*True Dynamic Range. Specifications are typical. See individual data sheets for details.



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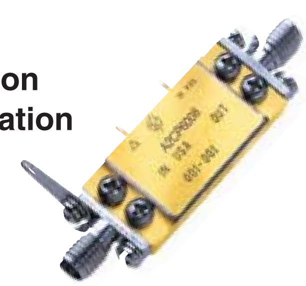

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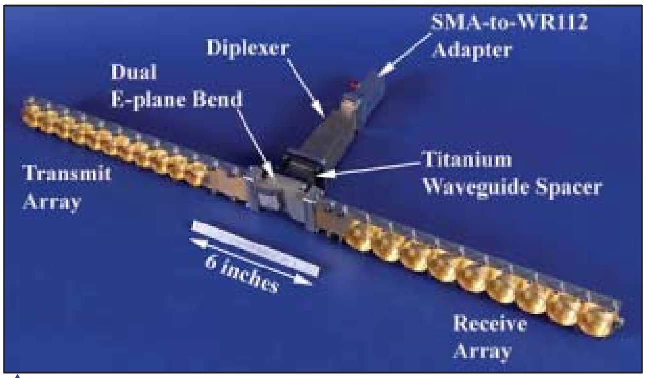


▲ *Fig. 2 The MESSENGER fan-beam antenna.*

▲ *Fig. 3 The helical radiating elements.*

ment corresponds to a change in azimuthal angle ϕ. The figure, superimposed upon the probe, shows the radiation patterns for the front and back antennas. The low gain antennas each have patterns that cover a hemisphere with maximum gains of 6 dBic. The medium-gain antennas each provide a 90° by 7.5° fan-beam with a peak gain of 15 dBic, while each high gain antenna electrically scans a 12° by 2.5° beam within a quadrant with a peak gain 28.5 dBic[3] (the beamwidth specifications are for the 3 dB points). The medium- and high gain antenna patterns on the front and back of the probe sweep through a hemisphere of space as the probe is rolled about the sun-probe line. Thus the medium- and high gain antennas can provide a communication link for any location of the Earth at data rates that are medium and high, respectively, compared with the data rate of the low gain antennas.

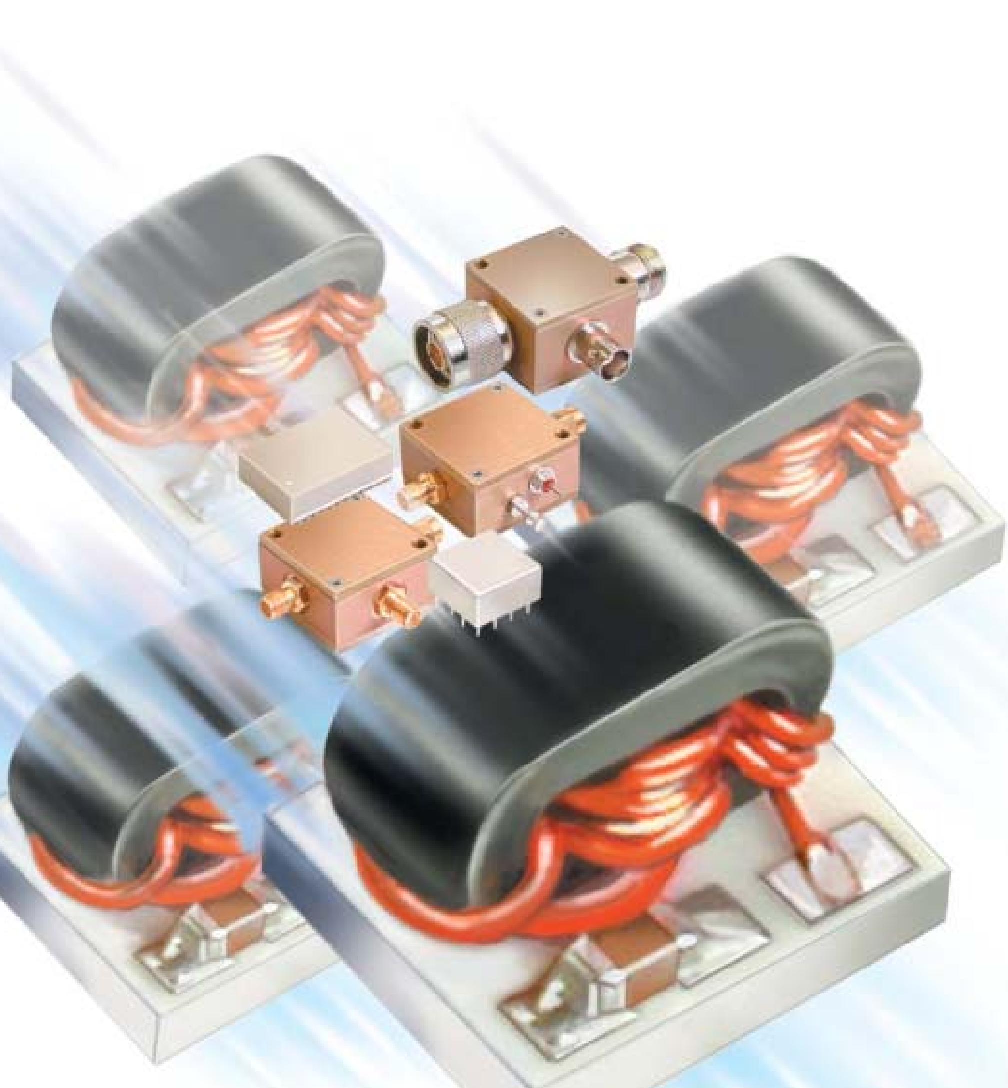
ELECTRICAL DESIGN

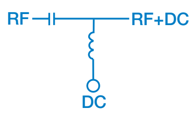
Figure 2 is a photograph of a flight spare fan-beam antenna. It is constructed mainly of aluminum to minimize weight and to withstand the expected mission temperatures of –100° to +300°C. Various components of the antenna assembly are labeled in the figure, including an SMA-to-WR112 waveguide adapter, a diplexer, a titanium waveguide spacer and a dual E-plane waveguide bend. The radiating portions of the antenna are labeled as the transmit array and the receive array. The individual radiating elements in each array are short helix antennas. These elements are fed through the broad wall of a rectangular waveguide that is short circuited at the end. WR112 aluminum waveguide was chosen for this application because its operating band encompasses both the transmit and receive frequencies. Some electrical isolation between adjacent helices is accomplished by surrounding each helix with a short cylindrical wall. The short helix radiating elements were patterned after the design by Nakano, et al.,[4] who studied the radio frequency (RF) properties of helices less than 2λ long (where λ is the free space wavelength). In particular, it was shown that the short helix can produce good quality circularly polarized radiation. This property, along with a half-power beamwidth of nearly 90°, made the short helix radiator a natural choice for this application. Also described by Nakano, et al., is a linear array of short helix radiators fed by waveguide that had a matched load at one end.[5] The fan-beam antenna design described here closely follows the work of Nakano, et al., with some small differences. First, the Nakano antenna is a traveling wave antenna, whereas the fan-beam antenna is a standing wave antenna. Second, the method employed to tune out the reactance of each helix probe is different. In the Nakano antenna, tuning was accomplished with capacitive stubs that are located a short distance from the helix probes. For the fan-beam antenna, tuning is accomplished with thin inductive irises that are co-located with the helix probes. A tuning element co-located with a waveguide discontinuity (the helix probe) will have interactions with the evanescent waveguide modes, and this effect must be taken into account in the design. Third, the fan-beam antenna had to withstand the temperature extremes of the space mission. This environment imposed specific requirements on helix installation techniques and compatibility of the thermal properties of materials, and necessitated thorough environmental testing. More will be said about this in the mechanical design section of the article.

The fan-beam antenna was designed to have a minimum 3 dB beamwidth of 6° at 7.2 GHz and 5° at 8.4 GHz in the narrow cut of the pattern, and for both frequencies a minimum 3 dB beamwidth of 90° in the wide cut of the pattern and an axial ratio of 3 dB maximum. A linear array of short helices was designed for each frequency, each array having a helix separation corresponding to $\lambda_g/2$ at the respective frequency (where λ_g is the wavelength in the waveguide). The number of helices in each array was determined by the $\lambda_g/2$ spacing and by the total array length. For the desired half-power beamwidth in the narrow cut of the pattern, the total array length L may be calculated by the approximate formula:[6] L = 50°λ/beamwidth. The total length is then divided by $\lambda_g/2$, which yields 11 helices for the transmit array and nine helices for the receive array.

The $\lambda_g/2$ helix spacing, and the short circuit located $\lambda_g/4$ from the last helix, place the helix probes at the maxima of the standing wave. The electric field at adjacent maxima is 180° out of phase, and so adjacent helices are rotated about their probe axes to orient them 180° differently from each other. This arrangement allows adjacent helices to radiate in phase, even though they are being excited by an electric field that is 180° out of phase. ***Figure 3*** shows a close-up photograph of two adjacent helix radiators; note their relative mechanical orientation is 180° apart.

An array, as described, can be modeled as a transmission line with N shunt admittances in parallel, where N is the number of helices in the array. This is so because of two properties of transmission lines.[7] First, the value of a shunt admittance is the same when viewed from a reference plane that is $n\lambda_g/2$ away from the ad-





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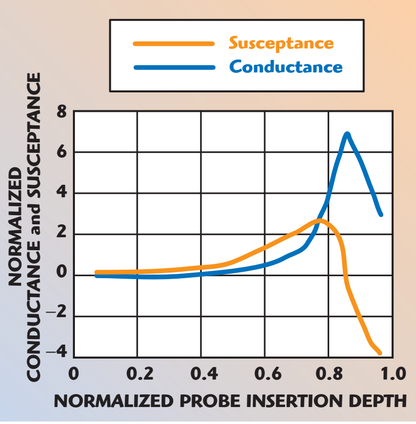
mittance (where n is an integer). Second, the short circuit at the end of the waveguide appears as an open circuit when viewed from a reference plane located $(2n+1)\ \lambda_g/4$ from the short circuit. Therefore, a reference plane that is $n\lambda_g/2$ from the first helix sees N shunt admittances in parallel with each other, all in parallel with an open circuit. Transmission line theory says that the input port of the waveguide will be matched (therefore maximizing antenna radiation) when the total shunt admittance equals the characteristic admittance of the line. Since the characteristic admittance of a waveguide is a function of frequency, it is convenient to normalize it when taking measurements and therefore the goal is a total shunt admittance of unity. This means that the normalized admittance of each helix probe should be 1/N when the antenna is tuned properly.

The normalized admittance of a helix probe has a susceptance that must be tuned out. Measurements of normalized admittance were performed on one helix located $\lambda_g/4$ from a waveguide short circuit, as a function of normalized probe insertion depth (normalized to the height of the waveguide). The measurement results are shown in ***Figure 4***. As expected,[8] the shunt susceptance is capacitive except for large insertion depths when the probe almost touches the floor of the waveguide. The amount of power coupled to a helix increases with larger probe insertion depth. Since the number of helices in an array was expected to be at least nine to generate the required pattern, the power coupled to each helix is modest and therefore the required insertion depth is small enough to have a capacitive susceptance. This susceptance can be canceled using a suitable inductive element co-located with a helix probe. Alternately, a capacitive tuning element located a distance $\lambda_g/4$ from the probe may be used. Waveguide tuning elements have been described under the following assumptions:[9] propagation of only the dominant mode, and sufficient distance from other discontinuities such that all higher order evanescent modes have decayed to insignificant levels. Interference with evanescent modes could not be avoided in the fan-beam antenna design. No matter where a matching element is placed for a helix, it will be affected by evanescent modes of that helix or modes of another helix that is close by. This outcome violates one of the above assumptions, implying that the standard formulas for a tuning el-



▲ *Fig. 4 Measured admittance of a helix probe versus insertion depth.*

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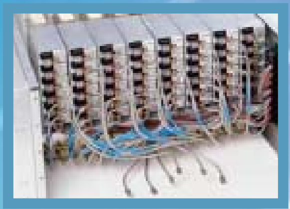
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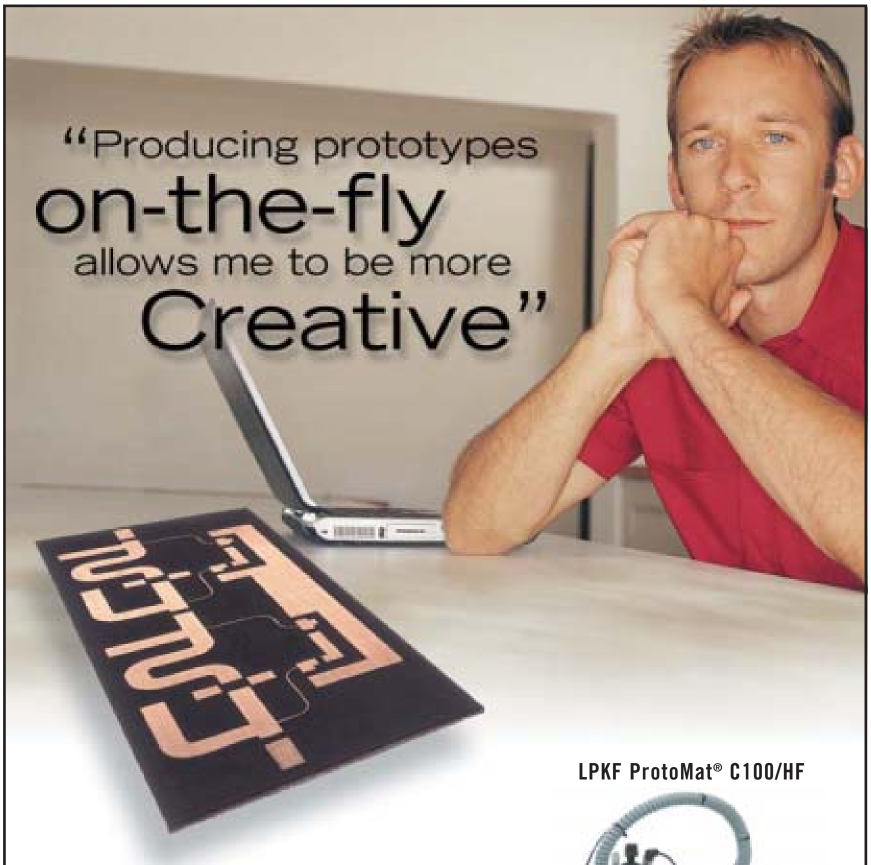
ement may not be accurate. It was decided to tune out the capacitive reactance of the helix probes by using a thin inductive iris co-located with each probe. Though the standard formulas for the thin inductive iris are not as accurate in this situation, the actual performance may be checked via direct measurement.

The first trial helix arrays were built by sequential tuning of the individual helices. The process began with a shorted waveguide connected to the network analyzer, and the helix closest to the short circuit ($\lambda_g/4$ away) was inserted through the broad wall. Heat-shrink tubing was placed on the helix probe in order to give an electrically insulating snug fit in the hole of the waveguide wall. Metal shims were inserted on each side of the probe through slits in the narrow wall of the waveguide to form an inductive iris; the slits were narrow enough to give a tight friction fit of the shims. The helix probe depth and shim insertion depth were adjusted until a normalized conductance of 1/N was obtained, with negligible susceptance. Then the next set of helix and metal shims was installed, and the combination was tuned until the total normalized admittance was 2/N with negligible susceptance. The process was repeated until all helices and inductive irises were installed, and the total normalized admittance was unity with negligible susceptance. The $|S_{11}|$ of the engineering model arrays was typically better than –20 dB at the center frequency.

The flight helix arrays were built by parallel tuning of the helices and irises. Parallel tuning ensures that all the probes are the same and that all the inductive irises are the same. All the helices were soldered into the removable broad wall of the waveguide (described in the next section), and their probes were trimmed to a starting length. The waveguide body was machined to include inductive irises with a starting gap width. The broad wall assembly with helices was assembled to the waveguide body and a measurement of the input admittance was performed, and then the broad wall was removed again. Based on the measurement, the helix probes were trimmed and/or the inductive iris widths were machined larger. Another measurement was made, and the process was repeated until the total normalized admittance reached the center of the Smith chart. ***Figure 5*** shows a lid assembly with helices and a waveguide body with inductive irises.

The remaining components in the fan-beam antenna assembly are as follows. The titanium waveguide spacer is meant to provide thermal insulation



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▲ *Fig. 5 The lid assembly and waveguide body for the 7.2 GHz array.*

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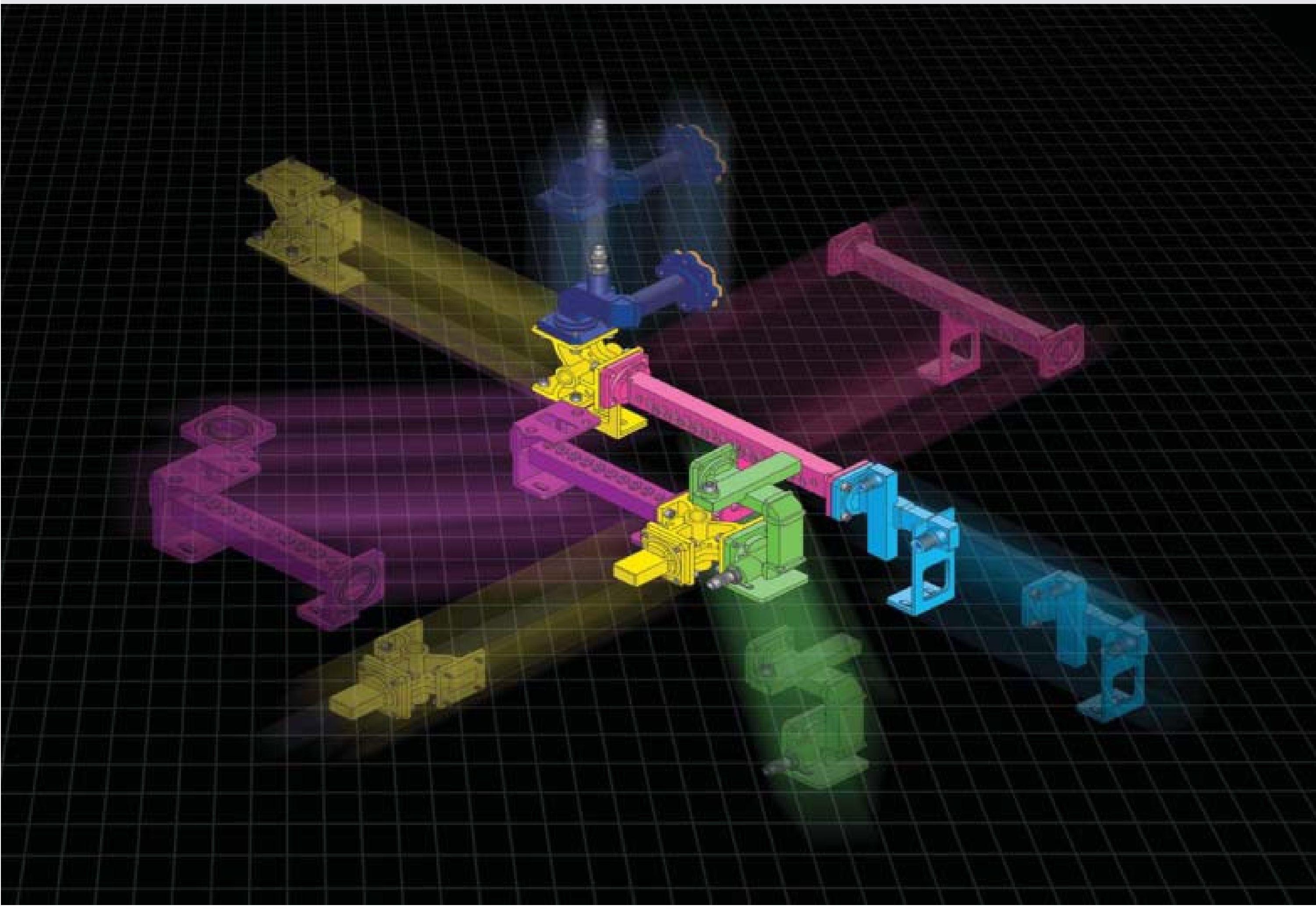

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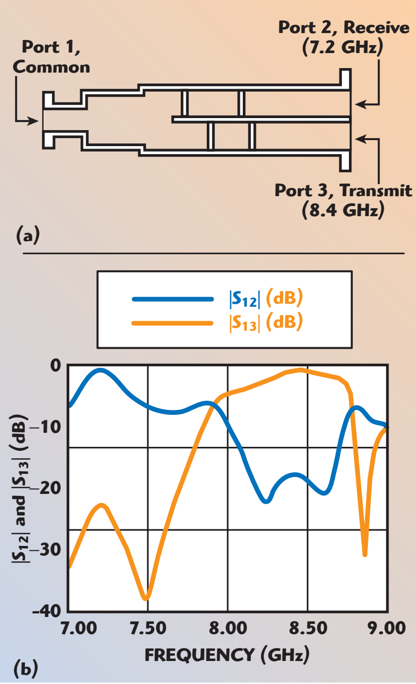
between the arrays, which are subject to direct solar heating, and the rest of the antenna, which is shaded by the spacecraft body. Electrically, it acts as a simple extension of the transmit and receive ports of the diplexer. The diplexer itself is a straight-junction type designed at JHU/APL and manufactured by Continental Microwave. The filter of each channel uses two appropriately spaced vanes between the centerlines of the broad walls. A cross section through the center of the broad walls is shown in ***Figure 6***, along with measured S-parameters. A high isolation diplexer is employed elsewhere in the RF system to protect the receiver front end from the transmit power level. The SMA-to-waveguide adapter is a standard product from Continental Microwave, except that the waveguide flange was machined to a smaller height. The specified maximum operating temperature of the adapter is 120°C and is the main reason for using a titanium spacer to provide some thermal isolation between the hot fan-beam antennas and the adapter.

Expansion and contraction of the antenna dimensions over the temperature range from –100° to +300°C have an effect on the antenna performance. Measuring these effects on the antenna pattern while heating and cooling the antenna to these temperature extremes is very difficult and inconvenient. Fortunately, a correlation between temperature and operating frequency was established. This correlation enabled the effects of temperature to be checked by measuring the antenna performance at ambient temperature but at frequencies that are offset from the center frequency. Such measurements are shown in the Antenna Performance section of this article. To demonstrate the validity of this approach, the $|S_{11}|$ of the antenna versus frequency was measured at several temperatures. ***Figure 7*** shows the $|S_{11}|$ of the transmit array of the antenna for three different temperatures. $|S_{11}|$ was measured while the array rested on a hot plate, and temperature was monitored with a thermocouple probe. The minimum $|S_{11}|$ at 15° and 105°C occurs at frequencies of 8.4291 and 8.4116 GHz, respectively. The temperature difference between the two traces is 90°C. Since the array is con-



▲ *Fig. 6 Mechanical drawing (a) and measured performance (b) of the diplexer.*

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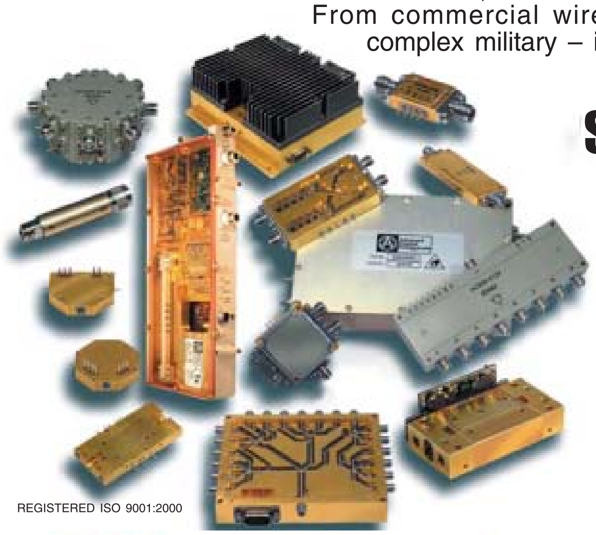

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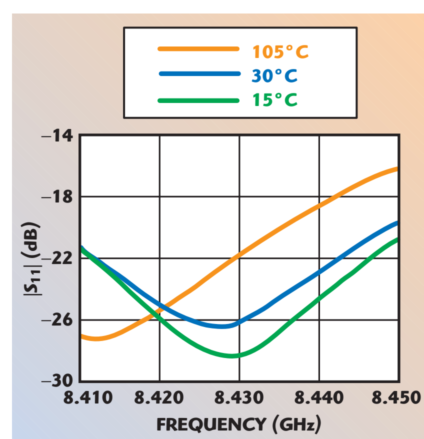
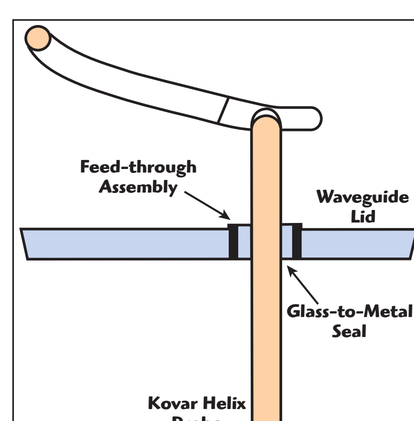
structured mostly of aluminum, the coefficient of thermal expansion is approximately 24 ppm/°C. Multiplying this coefficient by the temperature difference gives a fraction of 0.00216, and the fractional frequency shift should correspond to (1 – 0.00216) = 0.99784. Multiplying 8.4291 GHz by 0.99784 gives 8.4109 GHz, which is only 0.7 MHz away from the frequency of minimum $|S_{11}|$ at 105°C, an error of only 0.008 percent.

MECHANICAL DESIGN

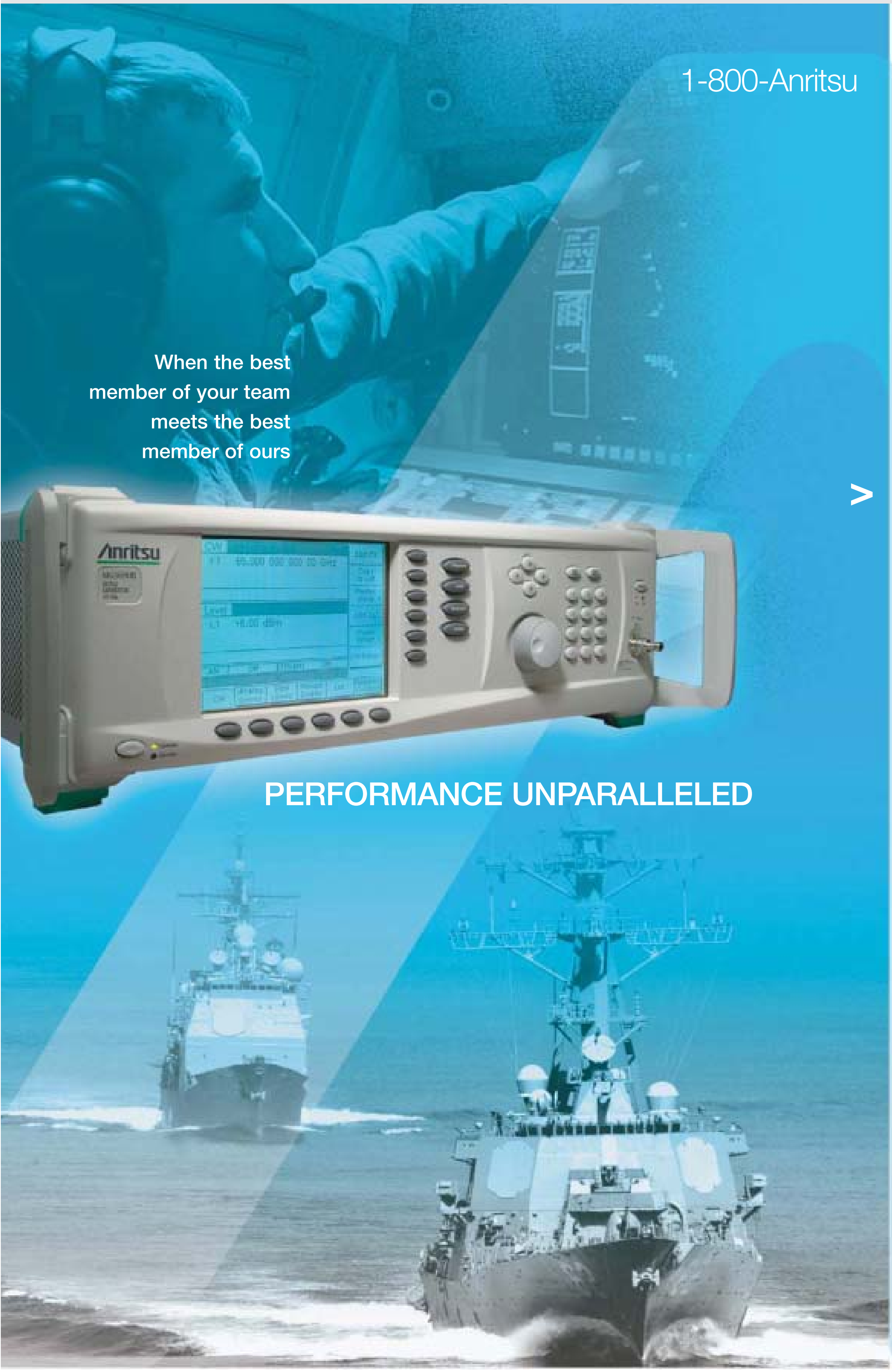
Attaching the helices to the broad wall of the waveguide presented a challenge, because the attachment had to function electrically and also had to be mechanically robust. The final solution uses a DC feed-through structure, of the type commonly used to bring DC power through the chassis of an RF module, fastened to the helix probes. The process involves a glass-to-metal seal between the glass bead of the feed-through and the metal helix probe.[10] The helices had to be fabricated of Kovar[11] in order to accept the glass-to-metal seal, since Kovar has a coefficient of thermal expansion that is similar to glass. The helices with feed-throughs were then gold plated.[12] The removable waveguide wall is also gold plated[13] and has holes drilled to accept the feed-throughs. Helices were inserted into the holes until the feed-through flange rested on the wall surface. They were rotated about their probe axes to obtain proper phasing as described earlier, and then were soldered in place using a gold-silicon solder[14] at approximately 400°C. ***Figure 8*** shows a drawing detail of a helix with feed-through, mounted to the waveguide lid. Samples of helices soldered to the waveguide lids were put through rigorous tests to make sure that the solder bond would not fail in the flight environment. The assemblies were subjected to thermal cycling between –100° and +300°C with a ramp rate of 20°C per minute



▲ *Fig. 7 Measured return loss of the transmit array versus frequency for three temperatures.*



▲ *Fig. 8 Mechanical drawing of the helix with feed-through.*



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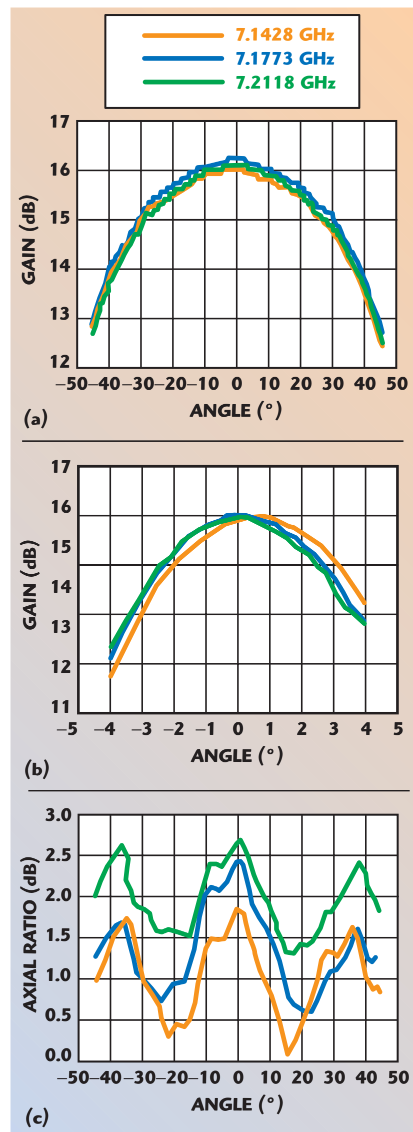
and a soak time of 15 minutes at each temperature extreme. After this procedure, the sample helices were pulled until failure of the solder bond occurred. The force required to break the solder bond was well beyond any forces the helices would experience during the mission.

The flight units were subjected to six thermal cycles in a vacuum over the temperature extremes just described, with a 30-minute soak time at each plateau. Return loss was monitored before, during and after the thermal vacuum cycling, and patterns were measured afterwards to make sure that no damage was done to the antennas. The flight units were also subjected to sine vibration and random vibration along each of three orthogonal axes. The return loss was monitored before, during and after the vibration testing in order to check for damage. No damage was found on the flight units after completion of environmental testing.

ANTENNA PERFORMANCE

Figure 9 shows plots of antenna patterns for an engineering model fan-beam antenna mounted on a flat ground plane. It shows, respectively, the wide pattern cut, narrow pattern cut and wide pattern axial ratio at three frequencies near 7.2 GHz. These patterns come close to the ideal 90° sector fan-beam shape with a reasonable axial ratio. Patterns at the transmit frequency of 8.4 GHz showed similar performance; for the flight units mounted on the spacecraft, however, the patterns were slightly distorted owing to the proximity of the high gain antenna that is tuned to the same frequency.



▲ *Fig. 9 Receive array patterns at 7.2 GHz; (a) wide plane, (b) narrow plane and (c) wide plane axial ratio.*

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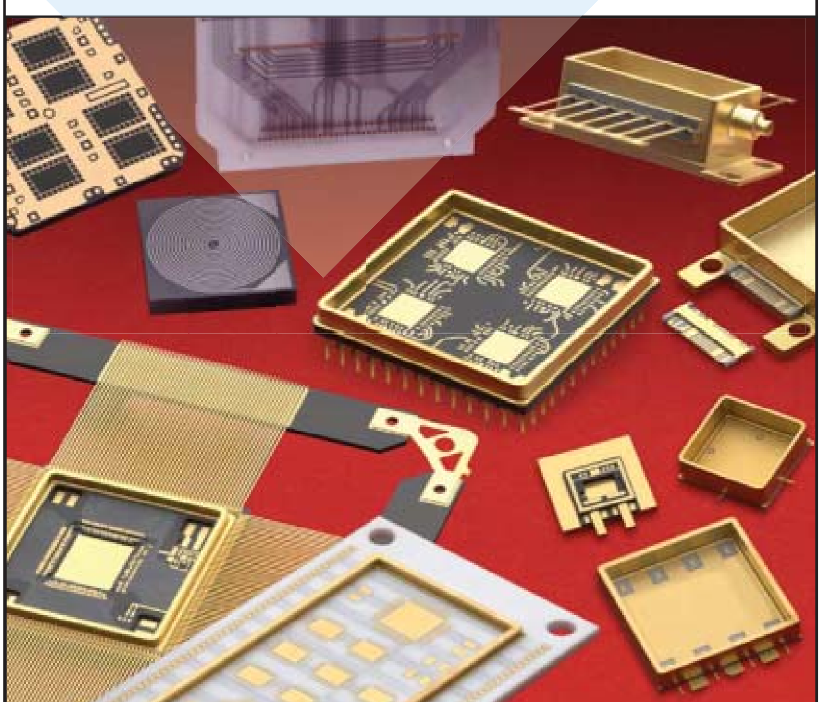

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The reason for measuring the patterns at three different frequencies is to gauge the effects of thermal expansion and contraction on antenna performance, as explained previously. The lower frequency extreme corresponds to thermal expansion due to a temperature increase of 200°C, while the upper frequency extreme corresponds to thermal contraction due to a temperature decrease of 200°C. The fan-beam antenna was designed for nominal performance at a temperature of +100°C, and so a ±200°C change covers the expected temperature swing of –100° to +300°C. The peak gain over this temperature swing changes by less than 0.5 dBic. ■

ACKNOWLEDGMENTS

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10. Attachment of feed-throughs to the helices was performed by Metal Processing Co. Inc., 75 Westech Drive, Tyngsboro, MA.
11. Kovar bar stock of 0.030" diameter was obtained from Ed Fagan Inc., 769 Susquehanna Ave., Franklin Lakes, NJ; helix fabrication was done by Kirk-Habicht Co., 8905 Kelso Drive, Baltimore, MD.
12. Gold plating of helices with feed-throughs was performed by Metal Processing Co. Inc. The specification is: MIL-C-26074 Flash (Nickel Underplate) MIL-G-45204, Type 3, Class 2, 25 microinches minimum (gold).
13. Gold plating of the waveguide lid was performed at the Applied Physics Laboratory. The specification is: Zincate per ASTM-B-253, Electroless Nickel Plate 200-250 microinches thick per MIL-C-26074C, Class 1, Electrodeposit Gold Plate, 100-150 microinches thick per MIL-G-45204C, Type III, Grade A.
14. Williams Advanced Materials, 2978 Main St., Buffalo, NY, solder alloy WS363 (96.85% Au, 3.15% Si).

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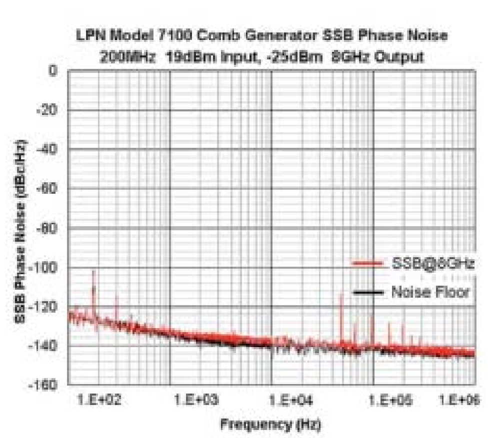

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AN IMPROVED MICROWAVE WEED KILLER

Microwave heating can replace toxic chemicals in agriculture to control vegetation and in particular to kill weeds. A suitable horn-antenna array, presented in this article, allows the parallel operation of a large number of magnetrons and an efficient illumination of the target with a spatially-incoherent microwave field at the same time. This antenna design was tested with 12 magnetrons used in a microwave weed killer developed and built for the department of agriculture at the University of Padova, Italy.

Applications of microwave heating are well known and are described in many publications (an exhaustive list of references is given by J. Thuery[1]). A very promising application of microwave heating in agriculture is to replace toxic, dangerous and environment-unfriendly chemicals used to control vegetation, as described in many articles and patents.[2]

A major disadvantage of microwave heating in agriculture is its comparatively higher cost, both in terms of equipment cost as well as cost of the energy required for operating the equipment. Inside a domestic microwave oven, the microwave field is contained in a closed resonator and most of the available microwave power is dissipated in a useful way in the food to be heated. On the other hand, unwanted energy losses in an open environment and in the presence of lossy but unwanted targets like soil are much higher in most agriculture applications.

Because of high energy costs, microwave heating may not be competitive with chemicals or with other thermal methods for vegetation control, like direct burning with an open flame. The energy budget of microwave heating can be improved if the shape and polarization of the microwave field is tailored to the particular target. In particular, standing-wave patterns may produce non-uniform results in weed killing. Further, unsuitable polarization of the incident microwave radiation may not induce currents in sensitive parts of the weeds to be killed.

Most experiments described in the available literature mention the use of a single antenna (or a small number of antennas) fed by a single high power microwave source. In the presence of reflections, such a source will generate a standing-wave pattern with deep minima, where the heating effect of microwaves is very low. Unwanted weeds, located in the field minima, will most likely survive such an irradiation. Moving the microwave source on-board a vehicle will only solve the problem of field minima in the direction of motion, while the standing-wave pattern will remain unaffected in the perpendicular direction.

In most agriculture heating experiments, the antenna beam is directed downwards, towards the soil, where most of the incident microwave power is dissipated. The polarization of the microwave field is parallel to the soil surface. Since thin, sensitive parts with small

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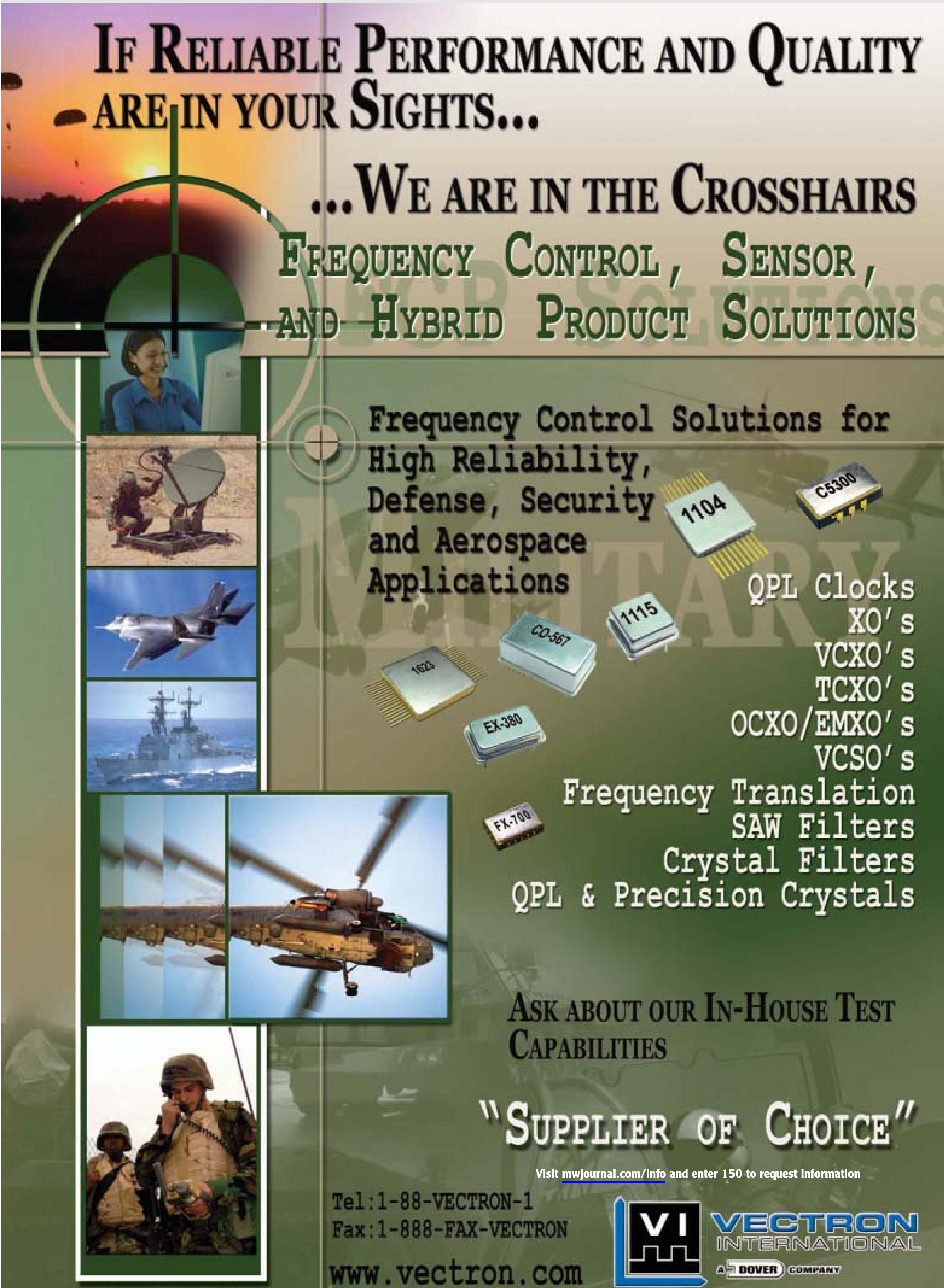
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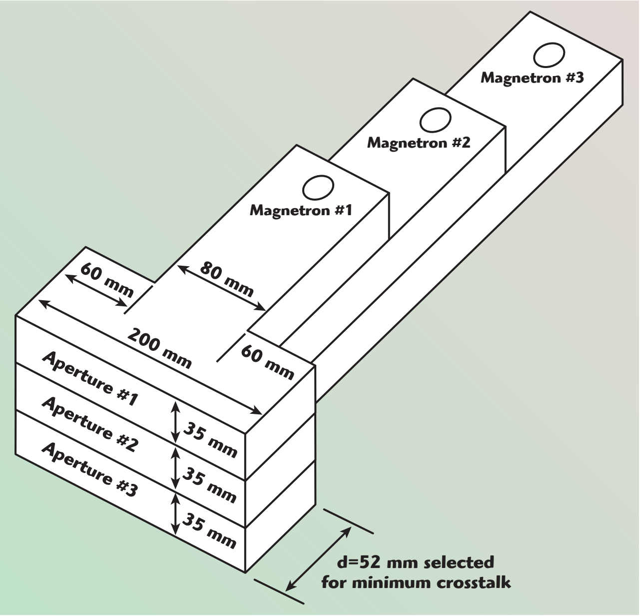
cross-sections of most plants are predominantly vertical, these are heated rather inefficiently in an indirect way.

An efficient microwave source should generate a spatially-incoherent field at least in one horizontal direction, while the source motion solves the standing-wave problem in the other perpendicular horizontal direction. Furthermore, the microwave source should provide at least some vertical component of the electric field to induce currents in thin vertical parts of the plants to be killed. Finally, the design should consider practical constraints, like generating large amounts of microwave power with the parallel operation of a number of small, inexpensive sources.

HORN-ANTENNA ARRAY

A spatially-incoherent field, providing uniform heating, can be generated in many different ways, such as moving the radiating antenna with respect to the target, using separate mode stirrers or using a number of independent, unsynchronized sources. Since a large amount of microwave power had to be generated with a number of small, inexpensive "microwave-oven" magnetrons operating in the 2.45 GHz frequency range, it was decided to operate the magnetrons in an independent, unsynchronized way to generate a spatially-incoherent field at the same time.

Reducing mutual coupling among the single magnetrons is therefore required for at least two reasons: to prevent mutual damage to the magnetrons and to generate a spatially-incoherent field. Mutual coupling of the magnetrons can be reduced in different ways: by designing an antenna array with small mutual coupling among the single elements and by operating the magnetrons in a pulsed way, turning them on sequentially.



▲ *Fig. 1 Design of the horn-antenna array.*

The design of the horn-antenna array is shown in ***Figure 1***. The horns are stacked in the E plane and are wide open in the H plane. Such horns have a large phase error in the H plane at the aperture. This phase error can be used to efficiently control the coupling between adjacent apertures, thus allowing a tight stacking of many antennas in the E plane.

The dimensions shown correspond to the prototype built for standard magnetrons operating in the 2.45 GHz ISM frequency band. The (internal) waveguide dimensions of 80 × 35 mm were chosen according to the available aluminum hardware and standard waveguide sizes used in microwave ovens. The waveguide width makes a step transition to 200 mm to generate a large phase error on the aperture. By selecting a length d = 52 mm for the wider section, the mutual coupling between two adjacent apertures could be reduced to approximately –25 dB at 2.45 GHz and below –20 dB across the whole 2.4 to 2.5 GHz ISM frequency band.

The practical construction of the horn-antenna array is shown in ***Figure 2***. The wide walls of the rectangular waveguides are made from 1 mm-thick aluminum sheet, while the narrow walls are made from 35 mm-wide aluminum "U" profile. All of the alu-

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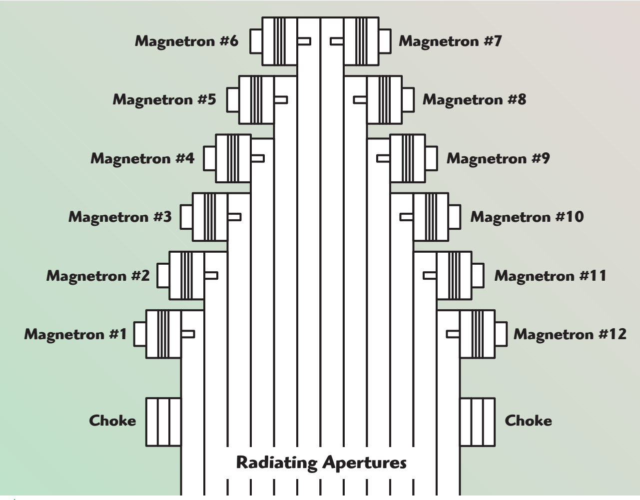
▲ *Fig. 2 The horn-antenna array.*

minum parts are fastened together with M3 bolts so that the whole antenna can be disassembled if necessary.

Since the sizes of the waveguides are close to those used in standard microwave ovens, no particular efforts were required for impedance matching of the magnetrons. Their probes were simply installed exactly in the same position as in their standard application in microwave ovens. Since 12 horns were stacked in the E plane, the whole (active) aperture size amounts to approximately 432 × 200 mm.

A larger number of magnetrons could be used by reducing the waveguide height to less than the current 35 mm. This is desirable, both to improve the spatial incoherence and to make the E-plane radiation pattern of the single horns as wide as possible to increase the vertical component of the electric field hitting the target. Unfortunately, there is no simple mechanical solution to make the waveguide-height transition.



▲ *Fig. 3 Installation of the magnetrons.*

The installation of the magnetrons is shown in ***Figures 3*** and ***4***. For mechanical simplicity, only straight waveguides were used. These are of different lengths to allow the installation of the 12 magnetrons. The magnetrons used were of the types 2M218 and 2M219K. Both types provide a nominal average output power of 800 W, include permanent magnets, cooling fins for forced-air cooling and RFI filters on the cathode and filament connections. The total average output microwave power at 2.45 GHz is in the 9.6 kW range.

To control the sidelobes of the complete antenna and limit dangerous high power microwave radiation in unwanted directions, some additional hardware is required, as shown in ***Figure 5***. Simple flat metal plates are efficient to stop TE waves on both sides of the array in the H plane. Three chokes, one-quarter-wavelength deep, were installed on each side of the array in the E plane to stop TM waves.

POWER SUPPLY AND OPERATION MONITOR

A simple power supply, including a magnetic-shunt transformer, a high voltage capacitor and rectifier, was used for each individual magnetron. Such a power supply allows the operation from a standard 230 V AC, 50 Hz supply, just like any microwave oven. The operation of the magnetron is pulsed with a large duty cycle of approximately 40 percent at the 50 Hz frequency.

Because of the large overall power, approaching 15 kVA, due to the reactive loading of the magnetic-shunt transformers, a three-phase 400 V AC, 50 Hz supply was selected for the whole weed killer with 12 magnetrons. The three-phase power supply was actually an advantage, allowing a simple solution to turn on the individual magnetrons sequentially. The power supplies of adjacent magnetrons are simply connected to different phases of the three-phase supply so that the magnetrons do not operate at the same time. In this way, the operation of the magnetrons is unsynchronized and the resulting microwave field does not form standing-wave patterns with deep minima.

When using a large number of consumer-grade components, like

▲ *Fig. 4 The installed magnetrons.*

▲ *Fig. 5 Radiating apertures.*

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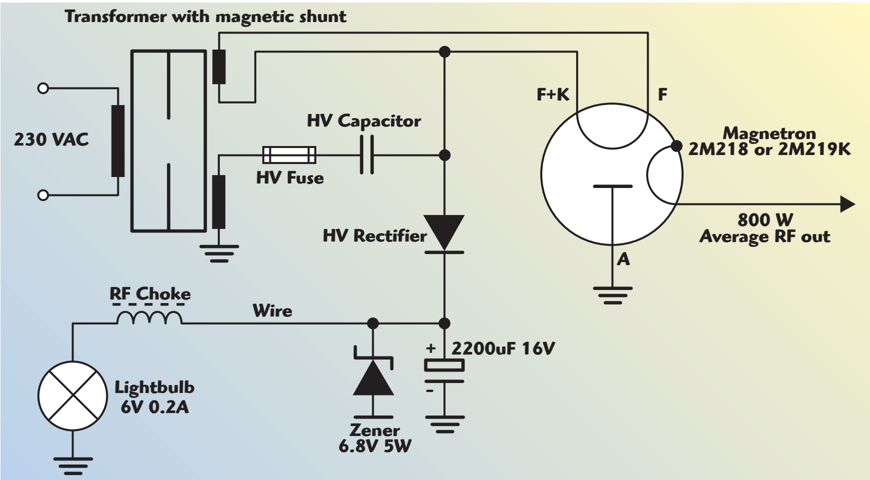

▲ *Fig. 6 Power supply and operation monitor circuit diagram.*

"microwave-oven" magnetrons and corresponding power supplies, component failures are not unexpected. Unfortunately, in the parallel operation of several magnetrons, the failure of a single microwave source may go unnoticed, compromising the result of the experiment. An efficient and reliable monitor of the operation of each individual magnetron was therefore required.

The circuit diagram of the magnetron power supply and corresponding operation monitor is shown in ***Figure 6***. The use of complex and delicate electronic components like microprocessors was intentionally avoided, since these would hardly survive the intense microwave-radiation environment. The monitor circuit simply checks the DC current through the magnetron by turning on an indicator lamp.

▲ *Fig. 7 Power supply components and cooling fans.*

The monitor circuit is inserted in series with the high voltage rectifier. In this way, the magnetron anode and the transformer winding can be grounded in the conventional way. There is no high voltage present on the indicator lamp either. The indicator lamp is a 6 V, 0.2 A, incandescent light bulb and its filament will only turn bright three to four seconds after turn on, when the cathode of the magnetron reaches its operating temperature.

The light bulb is protected from excessive current with a 6.8 V Zener diode, since the magnetron achieves its nominal output power at an average current of 300 mA. The 2200 μF capacitor averages the current during the pulsed operation of the magnetron. The RF choke is installed close to the socket of the light bulb, so that the latter is not turned on or even destroyed by stray microwave radiation.

There is a total of 12 power supplies and 12 monitor circuits with 12 indicator light bulbs, one for each of the 12 magnetrons, as shown in ***Figure 7***. The power supply components are installed on one side of the waveguide antenna array while the indicator lamps and cooling fans are installed on the other side.

The first tests of the assembled high power microwave source are shown in ***Figure 8***. The apparatus was installed upside-down so that the radiating apertures were facing the sky. Two fluorescent tubes were used as simple in-

▲ *Fig. 8 Upside-down operation, testing for stray radiation.*

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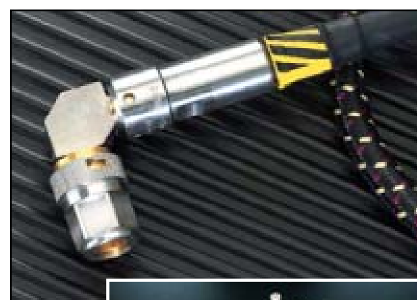

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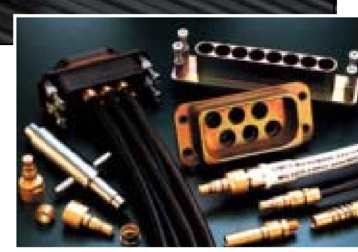

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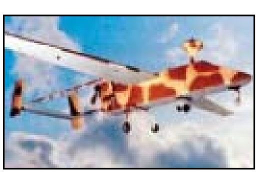

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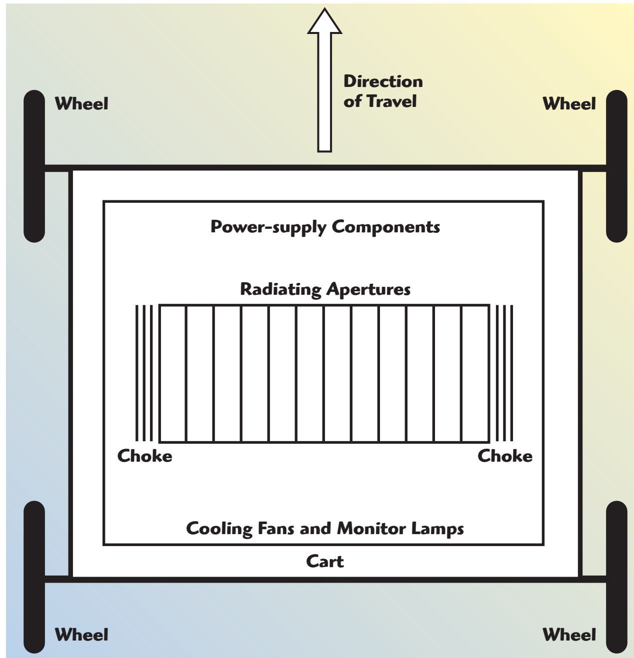


▲ *Fig. 9 Installation of the microwave source on a cart.*

▲ *Fig. 10 First functional tests in Padova.*

▲ *Fig. 11 Microwave weed killer in operation.*

dicators of the high power microwave radiation. The main purpose of this test was to verify the correct operation of all components and estimate the efficiency of the cooling fans.

A microwave-radiation meter, Wandel & Goltermann model EMR-300, was used to find safety distances for human operators in different directions. The efficiency of the metal plates and quarter-wavelength chokes around the radiating apertures could be estimated with the same instrument.

PRACTICAL EXPERIMENTS

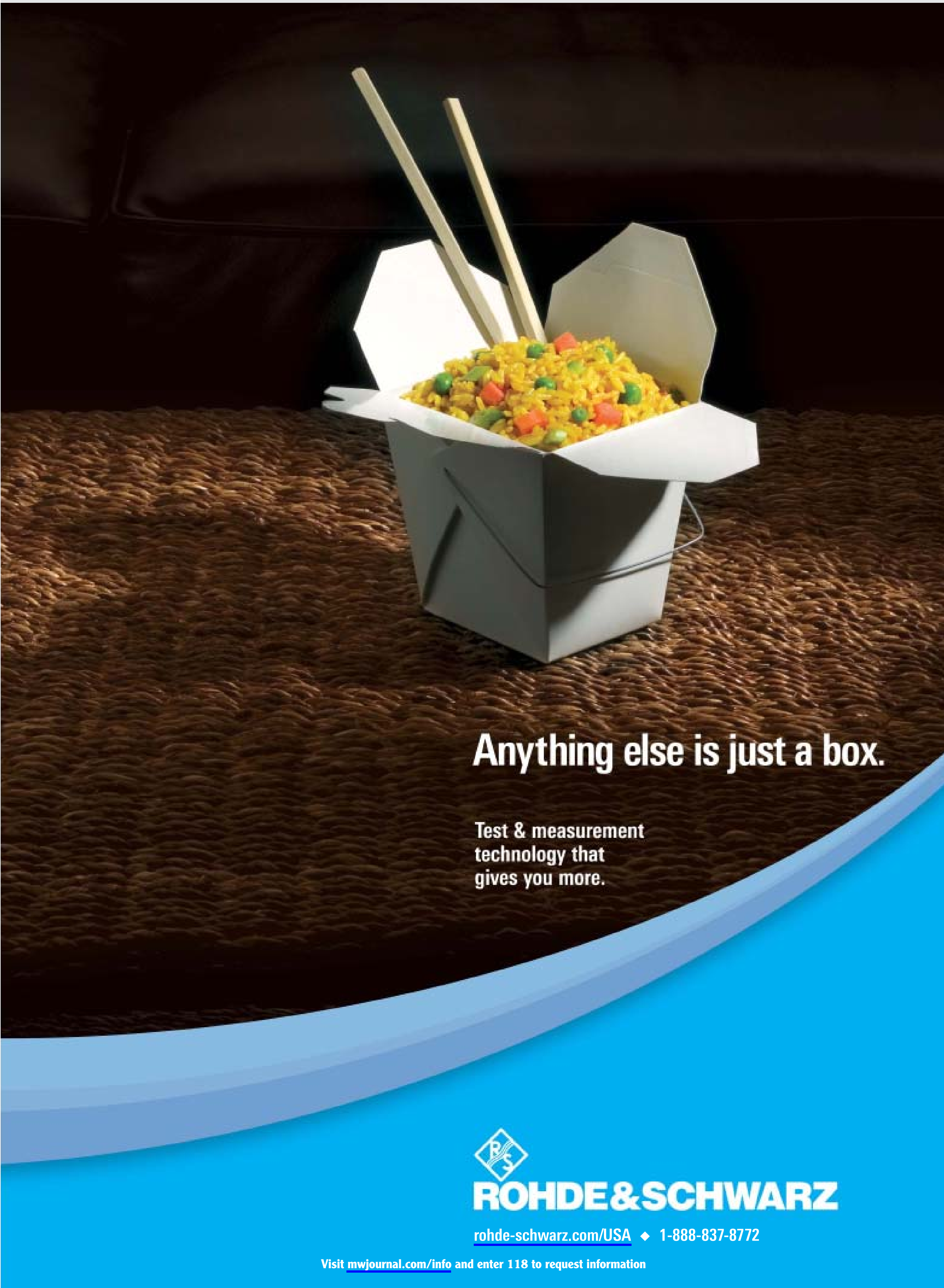
After the functional tests in the antenna test range of the department of electrical engineering at the University of Ljubljana, Slovenia, the high power microwave source was shipped to the department of agriculture at the University of Padova, Italy, where it is being used by the research group of professor Cesare De Zanche.

The high power microwave source was installed on a small cart. The wheels of the cart are oriented so that the direction of travel is perpendicular to the horn-antenna stack. The orientation of the antenna array is best described on the bottom-view drawing seen in ***Figure 9***. The cart is further equipped with two screws to adjust the height (spacing) of the radiating apertures above the soil.

Since all of the practical experiments had to be performed in the field, a three-phase 400 V AC, 50 kVA generator was selected as the power source. The generator was driven by a tractor engine, as shown in ***Figure 10***. Surprisingly, the magnetrons and their power supplies survived all of the field test, in spite of the consumer-grade components and the known imperfections of the generator, such as voltage and/or frequency fluctuations.

A practical experiment of irradiation of different weed cultures with microwaves is shown in ***Figure 11***. The cart is pulled over the weed cultures at a precisely-controlled speed using a winch driven at constant rpm. Unfortunately, the wire pulling the cart is so thin that it is almost invisible.

The weeds were mainly heated by microwave absorption. However, some taller plants touched the horns and produced arcing and fire. Experiments were made at different speeds of the cart and at different heights (different spacings) of the radiating apertures above the weeds. Stray microwave radiation was monitored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▲ *Fig. 12 Microwave treated weeds.*

with a Holaday model HI-1501 Microwave Oven Leakage Meter at all times for safety reasons. The immediate effects of microwave heating of different weeds are shown in ***Figure 12***. Even in these conditions, some plants may survive. On the other hand, some apparently unaffected plants may die a few days or weeks later.

CONCLUSION

Compared to an earlier microwave source, with a single magnetron and a single horn antenna used in the experiments by the group of professor De Zanche, the new source provided a considerably more uniform illumination of the target. This is probably due to both the incoherent radiation in one direction (in the E plane of the radiating horns) and moving the source in the other horizontal direction (in the H plane of the radiating horns) above the target.

The early prototype with a single magnetron and single horn antenna was simply positioned over the weeds to be treated. In this way, the horn formed a closed cavity with standing-wave patterns, clearly visible on the heating effects on the weeds. The new source, with 12 unsynchronized magnetrons, was held at least 10 cm or more above the soil, so microwave power could escape on the sides. Nevertheless, the new source provided almost twice the power efficiency; the energy required to kill the same amount of weeds was almost halved.

Furthermore, it was noticed that the efficiency of the new source, with 12 unsynchronized magnetrons, decreased rather quickly by lifting the source higher, from the initial 10 cm up to 25 cm above the weeds. This is probably due to the fact that the vertical component of the electric field decreases much faster than the horizontal component when the distance is increased. Finally, at larger spacings, heating non-uniformities in the form of standing-wave patterns started to appear as expected from theory.

At the time this article was written, the experiments by professor De Zanche's group were still going on. Although the new source shows an improved power efficiency, the latter still needs to be improved further to be competitive with other forms of weed destruction. All of the current experiments were done at 2.45 GHz, due to the inexpensive magnetrons for this frequency range. Some other microwave or even RF frequencies may be more efficient for weed killing as well as different antenna designs. ■

ACKNOWLEDGMENTS

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Matjaz Vidmar *received his BSEE and MSEE degrees from the University of Ljubljana, Slovenia, in 1980 and 1983, respectively. He received his PhD degree in 1992, also from the University of Ljubljana, for developing a single-frequency GPS ionospheric correction receiver. He is currently teaching undergraduate and postgraduate courses in electrical engineering at the University of Ljubljana. His research interests include high speed electronics for optical fiber communications at 40 and 80 Gbps. He is also taking part in amateur satellite projects. He developed very high efficiency VHF and UHF transmitters that were successfully flown in space on the Microsat mission in 1990 and microwave receivers that were successfully flown in space on the Amsat-P3D mission in 2000.*

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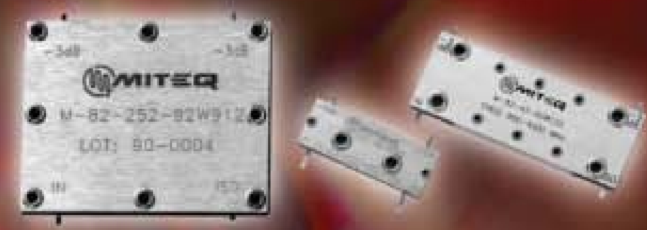

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400 – 550	M-42-551-92W102	250	0.2	2.0	20/25	0.20	1.2:1
400 – 700	M-42-72-92W012	250	0.5	2.0	20/25	0.30	1.2:1
400 – 1000*	M-42-13-92W102	250	0.6	2.0	18/20	0.25	1.2:1
400 – 1000	M-42-13-95WB302	500	0.6	2.0	20/23	0.20	1.2:1
400 – 1000	M-42-13-91KW402	1000	0.6	2.0	20/25	0.20	1.2:1
440 – 880	M-441-881-92W102	250	0.5	2.0	20/25	0.20	1.2:1
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1000 – 2000	M-13-23-95WB302	500	0.5	3.0	18/22	0.20	1.2:1
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1200 – 1400	M-122-142-95WB302	500	0.4	2.0	20/25	0.20	1.2:1
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A Compact LTCC Bandpass Filter Using Resonators Loaded with Spiral-shaped Open-circuited Stubs

In this article, a new compact multi-layer low temperature co-fired ceramic (LTCC) bandpass filter is proposed. It is composed of two quarter-wavelength resonators and a K-inverter. The resonators are loaded with two open-circuited stubs, giving an advantage in size-reduction and control of the spurious responses. The K-inverter is composed of two short-circuited stubs whose value can be adjusted by changing their length and width. There is no via-hole in the proposed filter structure, so the fabrication process is simple. The grounding of the resonators and inverters is done by connecting them to the side ground. The fabricated filter has a wide upper stop-band characteristic and the total filter size is 2.0 × 1.2 × 1.1 mm.

Recently, as wireless communications systems get smaller and lighter and are able to perform multi-functions, microwave components that have a small size and better performance are required. One of the methods used to meet these requirements is the low temperature co-fired ceramics (LTCC) process technology. The multi-layer technology using LTCC has become popular to meet the demands for compact size, high integrity and low cost.

Nonlinear circuits in wireless communications systems, such as mixers and amplifiers, usually generate unwanted frequency components in addition to the amplified desired signals. The unwanted frequency components are usually an image signal, harmonic components and intermodulation distortion components. These unwanted frequency components deteriorate the communications system performance.

Microwave filters are an essential component in wireless communication systems. Filters, with higher performance such as low insertion loss in the passband and high attenuation over a wide upper stop-band, are usually required. However, conventional bandpass filters that are composed of half- or quarter-wavelength resonators have inherently spuri-

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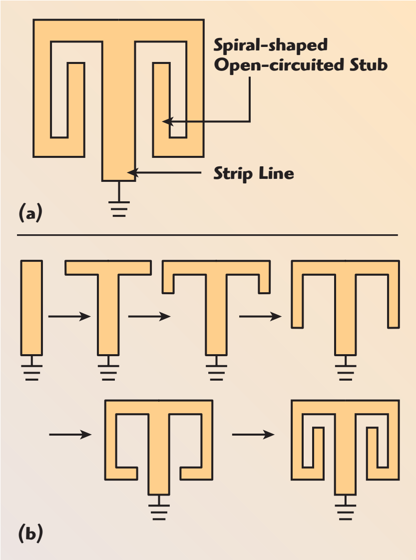
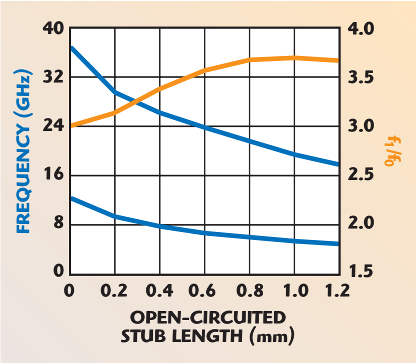


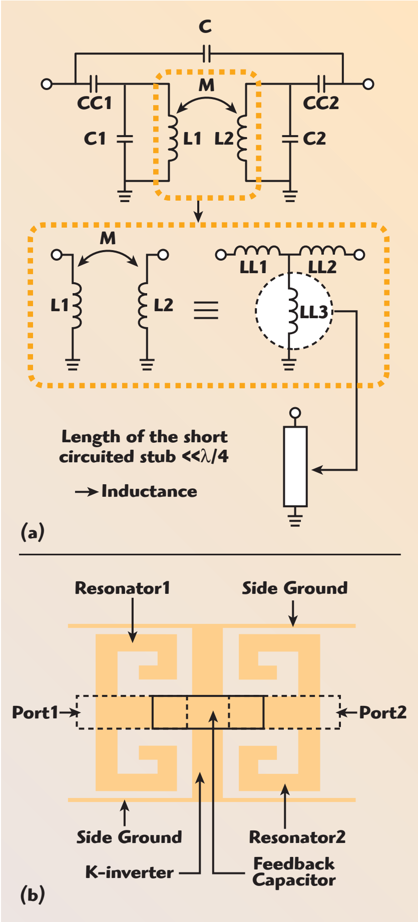
▲ *Fig. 1 Resonator loaded with spiral-shaped open-circuited stubs; (a) resonator structure and (b) the evolution process.*



▲ *Fig. 2 Resonant and first spurious frequency versus open-circuited stub length.*

ous passbands at $2f_0$ and $3f_0$, where f_0 is the center frequency of the bandpass filter. Cascaded low pass and band-stop filters may be used to suppress the spurious passbands at the cost of extra insertion loss and size. Otherwise, slow-wave resonators and bandpass filters using slow-wave resonators are used to control spurious responses within a compact filter size.[1–3] In wireless communication systems, the performance will be improved if filters with low insertion loss and wide upper stop-band can be used.

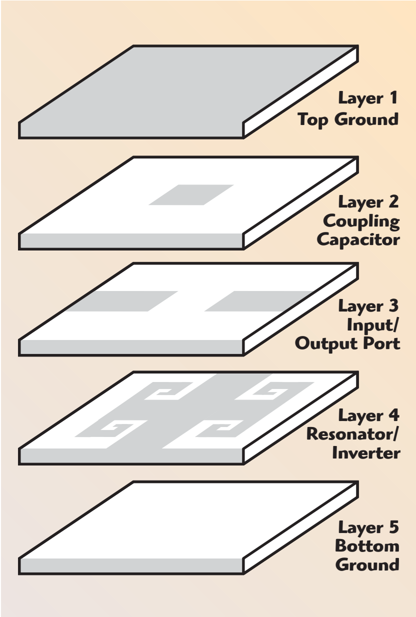
In this article, a quarter-wave-length resonator, loaded with spiral-shaped open-circuited stubs, is proposed. The proposed resonator is a slow-wave resonator, and so the efficient control of the distance between resonator patterns permits the control of the spurious response characteristics. Using the proposed resonator, a multi-layer, two-pole, bandpass filter was designed, fabricated and measured. LTCC process technology was used in the filter fabrication.



▲ *Fig. 3 Equivalent circuit of the proposed filter (a) and the top view of the filter layout (b).*

RESONATOR LOADED WITH SPIRAL-SHAPED OPEN-CIRCUITED STUBS

Figure 1 shows the proposed resonator and the evolution process that led to it. The resonator is composed of a main strip line and two spiral-shaped open-circuited stubs. The length of the spiral-shaped, open-circuited stubs determines the fundamental resonant frequency (f_0) and the first spurious frequency (f_1). The effect of the length of the open-circuited stubs on the resonance characteristics was calculated using EM simulation. The length of the main strip line is 1.0 mm, the dielectric constant of the LTCC substrate is 36 and the ground plane spacing is 0.864 mm. ***Figure 2*** shows the simulated results. The ratio f_1/f_0 increases, as the length of the stub gets longer.



▲ *Fig. 4 Three-dimensional view of the filter layout.*

FILTER PROPERTIES

Figure 3 shows the simple equivalent circuit that is used in the filter design and the top view of a multilayer filter layout. This filter schematic has a feedback capacitor between the input and output ports and provides two finite transmission zeros on each side of the filter passband.[4] In the filter layout shown, the short-circuited stubs are equivalent to a shunt inductor and operate as a K-inverter.[5] The value of the K-inverter can be adjusted by changing the length and width of the short-circuited stubs. Because the total pattern of the filter must be embedded in a fixed space, in this case, the value of the K-inverter can be adjusted only by changing the width of the short-circuited stubs.

LTCC FILTER IMPLEMENTATION

Using the LTCC process technology, a 5.25 GHz, multi-layer, bandpass filter was fabricated for orthogonal frequency-division multiplexing (OFDM) wireless LAN communications. After co-firing, the dielectric constant and loss tangent of LTCC substrates are 36 and 0.002, respectively. The conductivity of the metal is 5.8×10^7 S/m. The height of the unit green sheet is 0.036 mm; the total height is approximately 1.08 mm.

Figure 4 shows a three-dimensional view of the final filter layout.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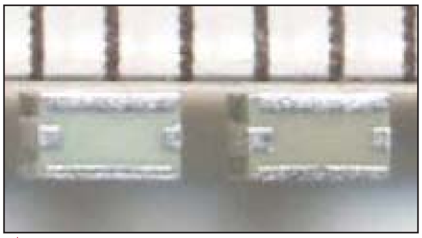

Fig. 5 Photograph of the fabricated LTCC filter.

TABLE I

SUMMARY OF THE FABRICATED BANDPASS FILTER CHARACTERISTICS

Frequency range (GHz)	5.15 to 5.35
Insertion loss (dB)	1.5 max
Attenuation (dB)	30 at $2f_0$ 20 at $3f_0$
Passband ripple (dB)	0.1 max
VSWR	1.5 max
Characteristic impedance (Ω)	50

There are three important conductor pattern layers that are embedded in the strip-line structure. When the filter schematic was converted into a three-dimensional structure, no via-hole was used. The short-circuited stubs are grounded by connecting them to the side ground walls. By not using via-holes, several advantages are gained, including easy and simple fabrication, reduction of fabrication error and elimination of the problem originated from via-holes. ***Figure 5*** shows a photograph of the fabricated LTCC bandpass filter. Its size is 2.0 × 1.2 × 1.1 mm.

EXPERIMENTAL RESULTS

The fabricated filter characteristics were measured using a vector network analyzer (Agilent 8510C) and a test fixture designed for filter measurements (see ***Table 1***). Since thousands of filter samples per process pass were manufactured, variables were assigned to each pattern layer parameter in order to examine the overall filter characteristics accordingly and the variation in filter characteristics were observed. In the case of the short-circuited stub that behaves as a K-inverter, as the stub is made wider, the value of the K-inverter is higher and the passband is wider. From the feedback capacitor, two transmission zeros on both sides of the passband are created and these transmission zeros are nearer to the passband as the length of the feedback capacitor is increased.

Figure 6 shows the filter's measured S-parameters in the passband and harmonic bands. The filter, made with the proposed resonators, has a wide upper stop-band and the attenuation values are 30 dB at $2f_0$ and 20 dB at $3f_0$. The insertion losses of the fabricated filters are very low, less than 1.5 dB.

CONCLUSION

In this article, a resonator, loaded with spiral-shaped open-circuited stubs, and a well-known filter schematic having two finite

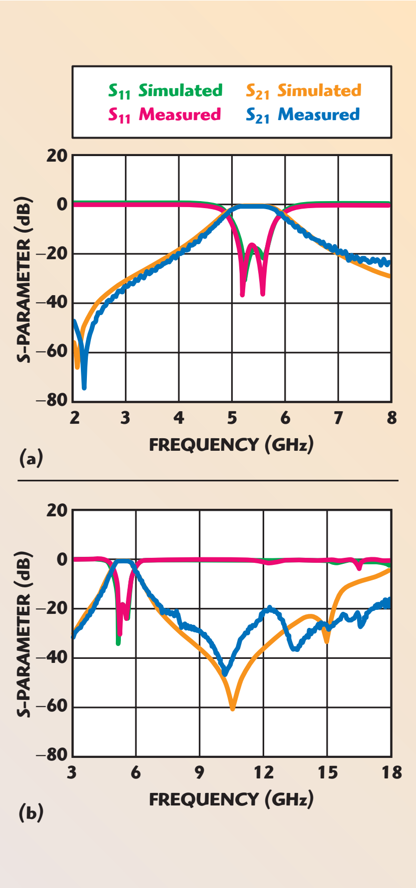

Fig. 6 Simulated and measured S-parameters of the passband filter; (a) passband and (b) spurious.

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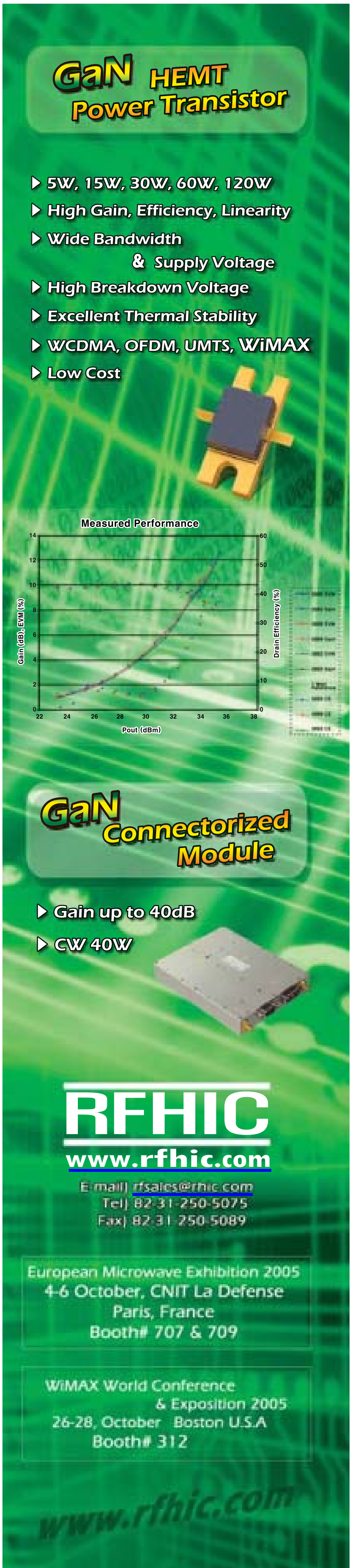

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transmission zeros, was proposed. A new, multi-layer LTCC bandpass filter was designed and fabricated using the proposed resonator. The filter is composed of the resonators and a K-inverter utilizing two short-circuited stubs. By using the advantages of size reduction and the ability to control the spurious response of the proposed resonator, it is possible to design compact bandpass filters with a wide upper stop-band. Since the structure has no via-hole, the fabrication process is very simple and easy, and the errors arising from the via-hole process can be suppressed. ■

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A 24 GHz Network Analyzer

The network analyzer has established itself as an important tool in the development and production of RF and microwave equipment. It allows RF components to be almost completely characterized, which is otherwise only possible through considerable effort and by using several test instruments. Today, however, the demand for higher frequencies and data transmission rates, together with new communication technologies are placing increasing demands on test and measurement equipment. Modern network analyzers must therefore not only be fast, accurate and flexible, but also support the user in carrying out complex measurements.

With these requirements in mind, Rohde & Schwarz has developed a new generation of network analyzers. The R&S ZVB is for the medium class and available with two, three or four ports in frequency ranges up to 4, 8 and 20 GHz. The new, premium-class R&S ZVA24, which is highlighted in this article, covers the frequency range from 10 MHz up to 24 GHz and comes with either two or four ports.

TEST CAPABILITIES

This new high end network analyzer features a dynamic range of more than 130 dB, an IF bandwidth of up to 1 MHz and a measurement speed of < 3.5 µs per test point. Such a powerful instrument is thus especially suitable for demanding applications in the development of RF components, where maximum accuracy, dynamic range and sensitivity as well as flexibility are what count.

Like all of the company's network analyzers, the R&S ZVA24 uses the tried-and-tested fundamental mixing concept, which allows the receivers to attain a high dynamic range and low trace noise even at a large measurement bandwidth. A separate generator is provided for each pair of test ports. The signals can be output at the two test ports simultaneously or in turn.

Due to the system concept, the extremely fast and independent synthesizers for the generator and receiver, and the separate reference and measurement channels of the reflectometers, the analyzer features comprehensive test capabilities and high flexibility. This is important especially for complex frequency converting and balanced measurements on active components such as amplifiers, mixers or frequency converters.

Frequency converting devices are crucial components in many RF and microwave applications, and therefore require comprehen-

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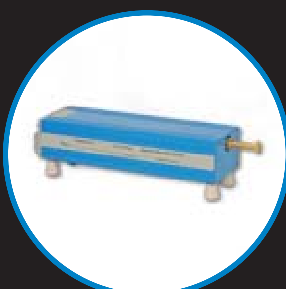

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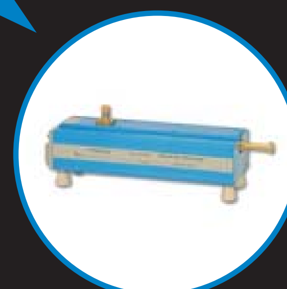

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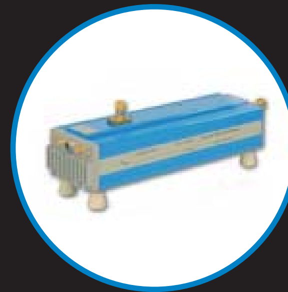

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If the sensitivity of the receivers or the output levels of the generator do not suffice for special measurements, direct generator and receiver access is an option. The signal paths of the receivers and generators are routed to the front panel via SMA connectors, allowing the user to bypass the internal couplers and access the generators and receivers of all reflectometers directly.

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INTUITIVE OPERATION

Although the network analyzer satisfies virtually all requirements with regard to test capabilities and specifications, the intuitive operating concept enables even inexperienced users to perform and comprehensively document complex measurements quickly. The intelligent operating concept not only facilitates the solving of difficult measurement tasks quickly and easily, it can also handle a large number of traces and measurement data. The instrument can be operated via context-sensitive pull-down menus using the mouse as well as via hard keys and soft keys.

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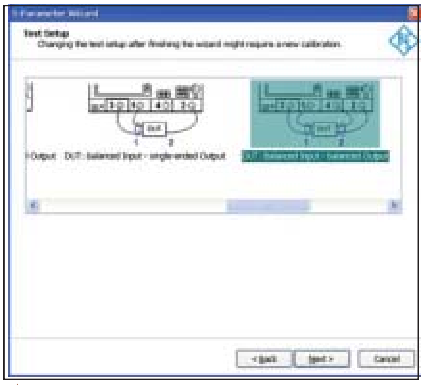

Fig. 1 A Wizard guides the user step-by-step through the measurement set up, queries all necessary inputs and provides default settings for the measurement task at hand.

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	FMS2001QFN	SPDT	Prod	0.65 @ 2GHz	24 @2GHz	>38	High Power, Low loss, Excellent Linearity
	FMS2002	SP3T	Prod	0.7 @ 2GHz	22 @2GHz	>38	Linear high power switch with low insertion loss
	FMS2002QFN	SP3T	Prod	0.7 @ 2GHz	22 @2GHz	>38	Linear high power switch with low insertion loss
	FMS2003	SP4T	Prod	0.7 @ 2GHz	24 @2GHz	>38	Linear high power switch with low insertion loss
	FMS2003QFN	SP4T	Prod	0.7 @ 2GHz	24 @2GHz	>38	Linear high power switch with low insertion loss
	FMS2013	SPDT	Pilot	0.75 @ 2.5GHz	>50 @2.5GHz	>30	Absorptive wideband very high isolation switch
	FMS2020	SPDT	Pilot	0.4 @ 2.5GHz	>30 @2.5GHz	>36	Linear wideband switch, high isolation, low insertion loss
	FMS2020QFN	SPDT	Pilot	0.95 @ 6GHz	>18 @2.5GHz	>36	Linear wideband switch, high isolation, low insertion loss
	FMS2022	SP4T	API	1.2 @ 4GHz	>30 @ 4GHz	>28	Absorptive high isolation switch with low insertion loss
Handset Switches	FMS2010	SP6T	Pilot	<0.7(Tx) @ 4GHz @ 2.5GHz	>40 (Tx-Rx) @ 2.5GHz	>38 (Tx)	Quad band GSM antenna switch, Very low Tx loss and excellent Tx-Rx isolation; Excellent harmonic performance
	FMS2011	SP6T	Pilot	<0.7(Tx) @ 4GHz @ 2.5GHz	>40 (Tx-Rx) @ 2.5GHz	>38 (Tx)	Quad band GSM antenna switch, Very low Tx loss and excellent Tx-Rx isolation; Excellent harmonic performance
	FMS2014QFN	SPDT	Pilot	0.5 @ 2GHz	>27 @ 2GHz	>36	High Power, Very low loss, Excellent harmonic performance
	FMS2016	SP4T	API	0.6 @ 1.8GHz	>30 @ 1.8GHz	>36	High isolation and low loss GSM Antenna switch die, Excellent harmonic performance
	FMS2016QFN	SP4T	Pilot	0.65 @ 2GHz	>30 @ 2GHz	>36	High isolation and low loss GSM Antenna switch
	FMS2018	SP7T	API	<0.7 (Tx) @ 2.5GHz	>40 (Tx-Rx) @ 2.5GHz	>38	Multi-band GSM-UMTS antenna switch, Very low Tx loss and excellent Tx-Rx isolation
WLAN Switches	FMS2007	DPDT	Pilot	0.9 (2.4GHz) 1.3 (5.8GHz)	39 @ 22.4GHz 28 @ 6GHz	30	Low loss and very high isolation WLAN diversity switch; 802.11 a, b & g enabled
	FMS2007QFN	DPDT	Pilot	0.85 (2.4GHz) 1.1 (5.8GHz)	37 @ 2.4GHz 25 @ 6GHz	>32	Low loss and very high isolation WLAN diversity switch; 802.11 a, b & g enabled
	FMS2017	DPDT	Pilot	0.55 (2.4GHz)	>23 @ 2.4GHz	>35	Low cost single band WLAN diversity switch; 802.11b&g
	FMS2017QFN	DPDT	Pilot	0.6 (2.4GHz)	>23 @ 2.4GHz	>36	Low cost single band WLAN diversity switch; 802.11b&g
	FMS2006	SPDT	Pilot	0.6 @ 6GHz	25 @ 6GHz	30	Multi-band WLAN applications; very low insertion loss;High isolation
	FMS2021	DPDT	API	<0.7 @ gGHz	>25 @ 6GHz	30	Multi-band WLAN applications; very low insertion loss;High isolation

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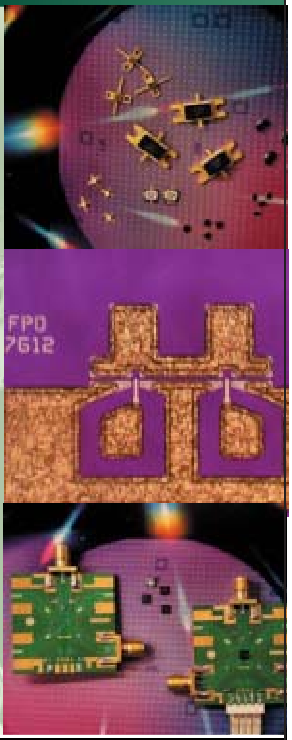

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MCA1-60	7	1600-6000	6.2	30	7.95
MCA1-85	7	2800-8500	5.6	38	8.95
MCA1-12G	7	3800-12000	6.2	38	10.95
MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
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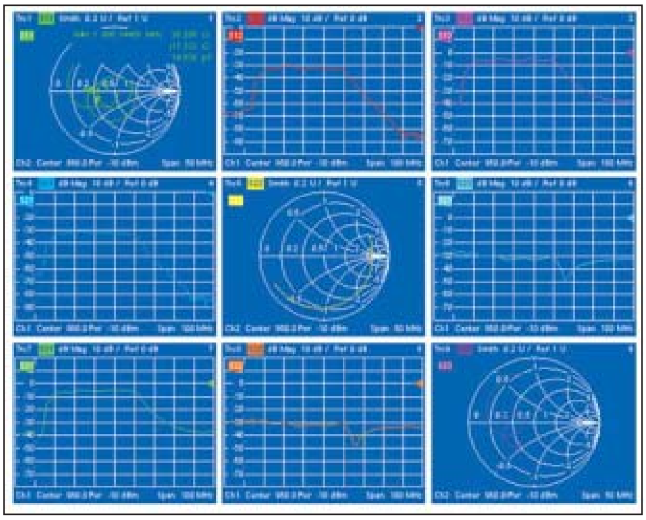

Fig. 2 The measurement results can be subsequently displayed in various diagrams on the screen, and the traces combined as desired and linked to mathematical formulas.

required (illustrated in ***Figure 1***). The S-parameter wizard, for example, helps to configure a complete measurement of all 16 mixed-mode S-parameters with just a few keystrokes.

In addition, there are extensive on-line help functions that include many detailed explanations as well as the required IEC/IEEE bus commands. The Undo button can cancel a series of operating steps or simply correct wrong entries, including presets.

The virtually unlimited number of set ups can be saved on the R&S ZVA24's integrated hard disk and called up at any time. Up to 100 set ups can be loaded in the analyzer's RAM simultaneously, allowing users to switch from one set up to another within milliseconds by pressing a key, clicking the mouse or entering a control command.

Furthermore, up to 20,001 test points per trace can be saved, and convenient marker and analysis functions for evaluating measurement results as well as import and export possibilities for different formats are available. Traces — even from different measurement channels — can be combined as desired in individual diagrams (see ***Figure 2***) and also linked to mathematical functions by means of the versatile formula editor. A DUT can thus be measured under a wide range of stimulus conditions, and all relevant parameters can be displayed on the screen. All traces, measurement channels and the marker can be labeled to make them clearer to distinguish. During the measurements, any existing matching network or parasitic effects can be easily included in the calculations by means of an integrated (de-)embedding function (shown in ***Figure 3***).

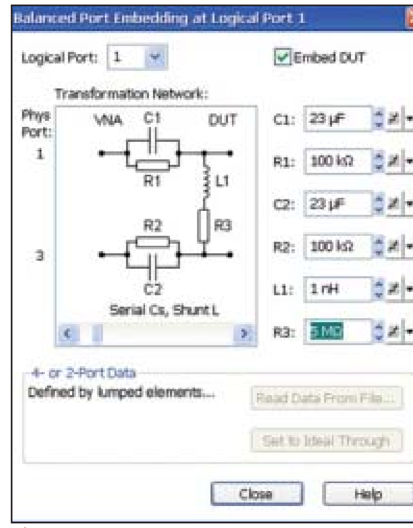

Fig. 3 The (de-)embedding function allows matching networks or parasitic effects to be taken into account in the measurements.

Fig. 4 The calibration unit allows a complete four-part calibration with 201 points to be performed in less than 30 seconds.

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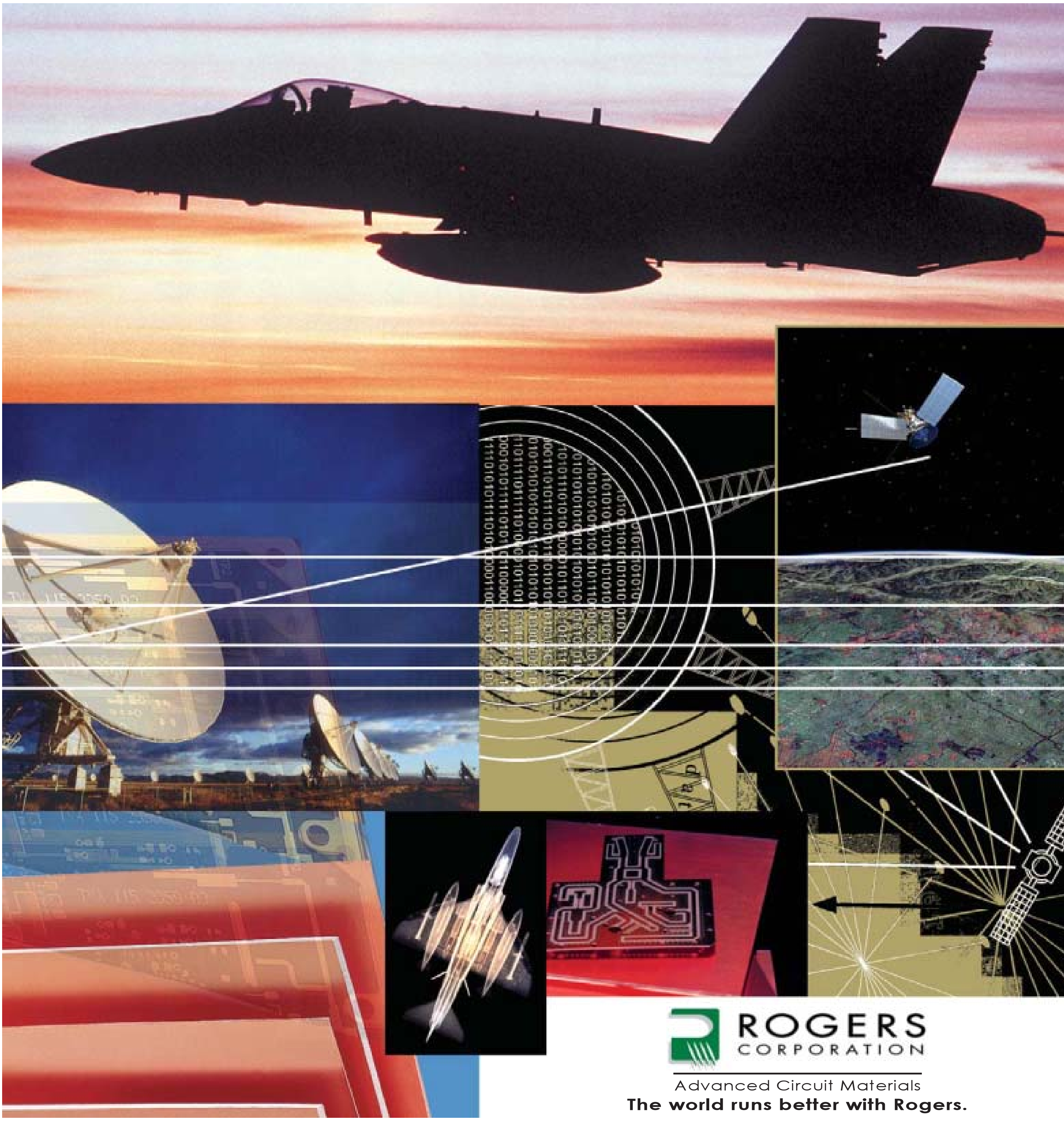

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CALIBRATION

Although manual calibration methods can be used for multiport measurements, they are very time-consuming, error-prone and cause relatively strong mechanical wear of the calibration standards. For the new family of network analyzers, Rohde & Schwarz therefore offers automatic calibration units for single-port and multiport calibrations (see ***Figure 4***). Providing ports, port groups from 1 to 4 can be calibrated independently. Controlled and powered via a USB interface, and providing high temperature stability, the units are ready to operate very shortly after being connected. The calibration runs automatically, allowing, for example, a complete four-port calibration with 201 points to be completed in less than 30 seconds.

The new R&S NWA series supports not only the classic through, open, short, match (TOSM) calibration method but also a number of other calibration methods. Since each of the R&S ZVA24's ports is equipped with its own reference receiver, adaptable and efficient seven-term calibration methods such as through/line, reflect, line (TRL/LRL), through, open, match (TOM), through, network, attenuator (TNA) and through, reflect, match (TRM) can also be used. Calibration in test fixtures or on wafers is thus possible with high measurement accuracy.

CONCLUSION

The R&S ZVA24 is an instrument that sets standards in terms of specifications, test capabilities and operating concept. It provides developers with a future-proof solution. This analyzer is particularly suitable for demanding measurement tasks in the lab and for special tasks in production. It belongs to a new generation of premium vector network analyzers that includes the medium-class R&S ZVB, outlined previously, and the R&S ZVT8 — a network analyzer for demanding production and laboratory applications up to 8 GHz, which can be fitted with up to eight integrated test ports. All models feature comprehensive functionality, high flexibility and a powerful state-of-the-art user interface. Therefore, they can easily and efficiently solve a wide range of development and production measurement tasks.

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CALIBRATION SOFTWARE FOR AUTOMATED MULTIPORT WAFER LEVEL TESTING

As wireless communications such as 3G cellular networks and wireless LAN play an increasing role in everyday life, data transfer rates, broadband communication channels and carrier frequencies are increasing. To meet these demands, the industry is turning to differential and multiport designs for RF and microwave components. During the design and production phases, these complex designs require an exact calibration of the test system.

Mechanically, production testing is challenging due to the constant repositioning of the wafer probes. These probes must be adjusted for the difference between the dimensions of the device under test (DUT) and the calibration standards used. Additionally, the calibration procedure must often be run at various times during an automated test process, after which the test resumes. This means that the calibration software must be able to interface easily with the user's automated testing software.

Regarding the calibration set up, calibrating a high frequency multiport on-wafer test system is a complex and tedious process. It requires detailed knowledge of all system components and their interactions. This task becomes more complicated as the number of calibration ports and types of calibration standards increase. Due to this complexity, multiport calibration software requires new principles regarding the architecture and the graphical user interface (GUI).

Consequently, SUSS MicroTec has developed SussCal® 6, claimed to be the only multiport on-wafer calibration software that provides a fully automated calibration procedure. It supports automated probe manipulators and automatically saves and recalls the position of the DUT and calibration standards and their alignments.

Additionally, it can be remotely controlled by the user's test software, allowing the calibration process to be called at any time during testing. The system is then calibrated and returns to the automated test process where it left off. This ensures full repeatability and does not require input from the operator.

The calibration software uses a plug-in architecture for all software components including calibration procedures, hardware drivers and tools. All available components are automatically recognized at start up, so the software need only be installed once. Further up-

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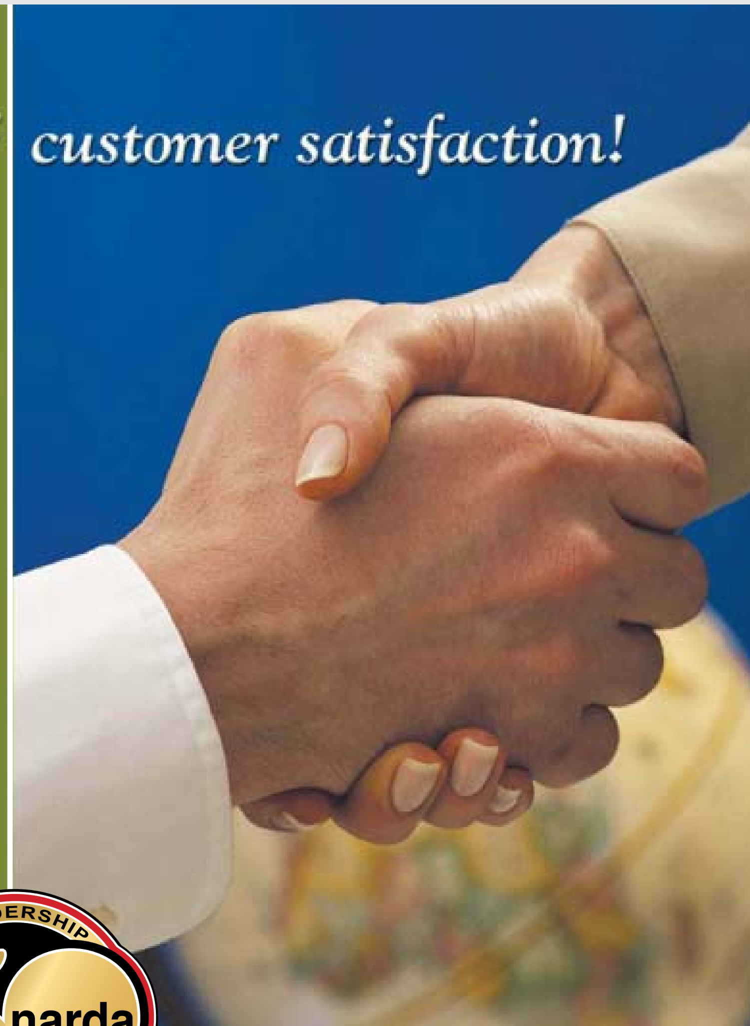

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dates simply require the adding and/or replacement of selected SussCal® 6 components, and it is not necessary to have system administrator rights to carry out an update.

In order to address the issue of complexity, the software guides the user through three sections to set up the calibration: the System Settings Wizard, the Substrate Wizard and the Calibration Project Wizard. After set up, the user can control the procedure in the Calibration Control Center and also has a number of various tools available. The following is a brief walkthrough of the software interface of SussCal® 6.

SYSTEM SETTINGS WIZARD

An automated multiport wafer level measurement system consists of the probe system, a multiport VNA, calibration substrates, wafer probes, a control PC with software and interfaces between the PC, the probe system and the VNA (see ***Figure 1***).

The calibration software puts all of these components together and the System Settings Wizard simplifies this complex procedure. It automatically runs when the program is activated for the first time and configures the probe system, the VNA and the interfaces.

The physical interface between the control PC, the probe system and VNA can be GPIB, LAN, USB or RS-232. Based on the Virtual Instrument Software Architecture (VISA), the software interface drivers allow the user to freely choose the interface type as well as the model (for example, National Instruments, Agilent, etc.). In addition, a direct link to the company's probe system and ProberBench™ software over the SUSS Control Interface (SCI) is supported.

▲ *Fig. 1 The automated multiport wafer level measurement system consisting of the probe system, a multiport VNA, calibration substrates, wafer probes, a control PC with software and interfaces between the PC, probe system and VNA.*

SUBSTRATE WIZARD

A calibration procedure requires well known reference elements to be measured, namely calibration standards. These are fabricated on a wafer — the calibration substrate — which is typically a piece of ceramic having a set of standard groups (open, short, load and line) that are required for different calibration types. The type of calibration substrate, the location of the standards and the position of the substrate on the chuck have to be defined to enable the user to choose the desired standards for system calibration. This is done by the Substrate Wizard.

The specifications of the calibration substrate, standards and matching wafer probes are located in a substrate definition file — the csd-file. This is a source for the Substrate Definition Tree, which is a hierarchical view of the substrate properties and

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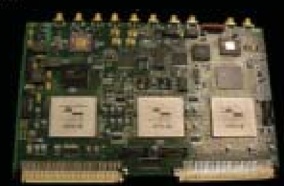

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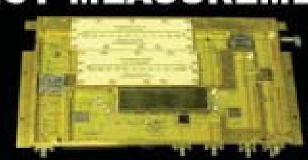

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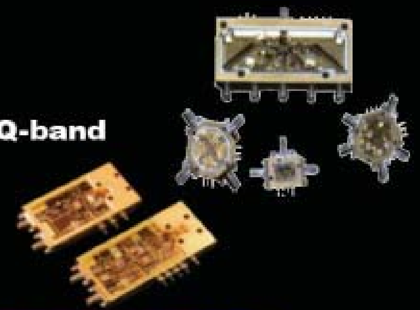

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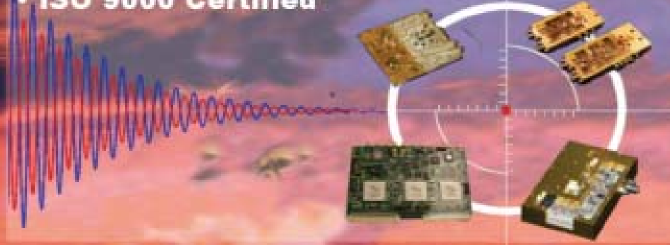

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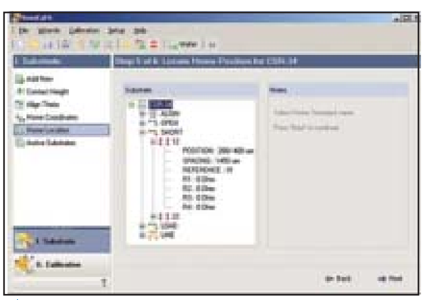
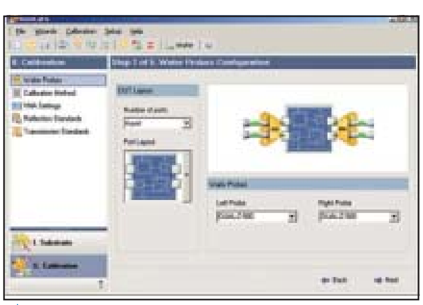
is pictured in ***Figure 2***. There are three branches of the tree: type of standards, definition of the standards and specifications of the standards.

Csd-files for all SUSS calibration substrate families are provided with the SussCal® 6 package. If customized calibration substrates are used or the calibration standards are embedded on the test wafer, the required csd-file can easily be created with a text editor.

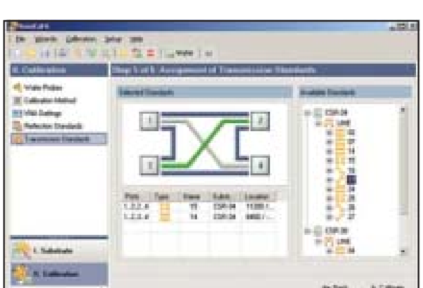
The new version 6 of the calibration software can handle an unlimited number of calibration substrates, automatically compensating for their alignment differences from the DUT. Moreover, standards can be picked up from different substrates and used in one calibration project. This allows engineers to define one, two and multiport and/or differential standards within the same calibration project. This is important for measuring components with single-ended or differential inputs or outputs.



▲ *Fig. 2 The Substrate Definition Tree is a hierarchical view of the substrate properties.*



▲ *Fig. 3 An example of the first step of the Calibration Project Wizard.*



▲ *Fig. 4 The selected standard is dropped onto the picture and the available standards for the defined calibration method are shown.*

Also, partially damaged substrates can now be saved for reuse.

To define the substrate required for the calibration, the corresponding csd-file has to be added in the first step of the Substrate Wizard, while the next steps concern the alignment procedure. Alignment defines the physical position of the added substrate on the probe system chuck and saves the substrate contact height (chuck Z-position and the separation value), the rotation angle (the chuck theta) and the X-Y coordinates of the substrate home position. These steps can be repeated if a new substrate has to be added to the list of the active substrates.

Alignment data for each substrate from the active substrates list can be recalled at any time by simply pressing one button. This feature allows fast navigation between different calibration substrates, simple verification of the alignment settings and quick

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access to the desired calibration standard. As soon as the Substrate Wizard has finished, the user is guided to the final step — the Calibration Project Wizard (CPW).

CALIBRATION PROJECT WIZARD

A top-down approach is used in the CPW for defining calibration parameters. The user is guided from the very general level of settings, such as the number of VNA ports, the layout of the DUT ports, the definition of wafer probes and port mapping, to very specific settings, such as the calibration method name and the selection of standards to be measured. The calibration software uses an intelligent control algorithm to prevent users from defining wrong or impossible parameters. It automatically limits the number of choices and steps according to the previously defined parameters and supports the operator using clear and straightforward graphical illustrations.

Figure 3, for example, demonstrates the first step of the Calibration Project Wizard, defining the number of calibration ports, their layout and the selection of the matching wafer probes. It also solves the typical problems of multiport wafer level set up, namely the multiple ways to connect wafer probes to the VNA ports. The VNA port mapping step allows the user to assign the relationship between the selected wafer probe and the VNA port. Therefore, the system can be easily reconfigured without frustrating cable reconnections if the DUT is changed. All-important VNA settings (that is, frequency list, power level, averaging factor, etc.) can be defined within the CPW or can be kept without changes.

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When the desired calibration method is defined, the required calibration standards have to be assigned for the measurements. In contrast to two-port calibration, additional types of calibration standard realization are required. For instance, the four-port SOLT calibration procedure needs six connections of measurement ports (six thru standards). These standards are typically realized in five different types. The user then needs to make sure that the selected thru standard actually connects the correct ports, a very time consuming procedure.

With SussCal® 6, the standard assignment procedure is visualized by using special graphical components and a drag-and-drop interface. The selected standard is picked up from the substrate definition tree and dropped onto the picture showing the required standards for the defined calibration method (see ***Figure 4***). The standard assignment step of the CPW automatically verifies the selected standard type and the ports connected. In doing so, it prevents the user from selecting a wrong element or connecting the wrong ports.

The standard assignment is the last step of the Calibration Project Wizard. Once defined, the calibration data can be saved into a project file, after which the user is guided to the Calibration Control Center.

CALIBRATION CONTROL CENTER

The Calibration Control Center is designed to make calibration progress control as simple as the operation of an MP3-player, with the operator choosing to start, stop, pause and resume. Also, the sequence for the automated standard measurement can be easily modified, much like a play list. It is possible to run the calibration in manual mode, measuring and re-measuring standards in any desired sequence. Another feature is access-level control whereby engineers can set and lock the test parameters, which then prevent technicians from changing the set up.

TOOLS

Many tools are available such as the substrate verification tool, which monitors the alignment of the selected substrate from the list of active substrates and helps the user to verify the standard's quality. As plug-ins, new tools can be simply added to the already installed application at any time.

CONCLUSION

With SussCal® 6, the once complex and tedious task of setting up a fully automated calibration process is quick and simple. It easily handles automated testing, and the plug-in architecture ensures maximum compatibility and a stable system with minimum downtime. Running on a standard Windows-PC, the calibration is configured through a logically ordered top-down process. This reduces the time and effort needed for defining the calibration, and significantly increases the accuracy and repeatability of multiport calibration and measurement. Therefore, engineers can be sure that the right parameters will be extracted for device modeling and monitoring production testing will be more efficient.

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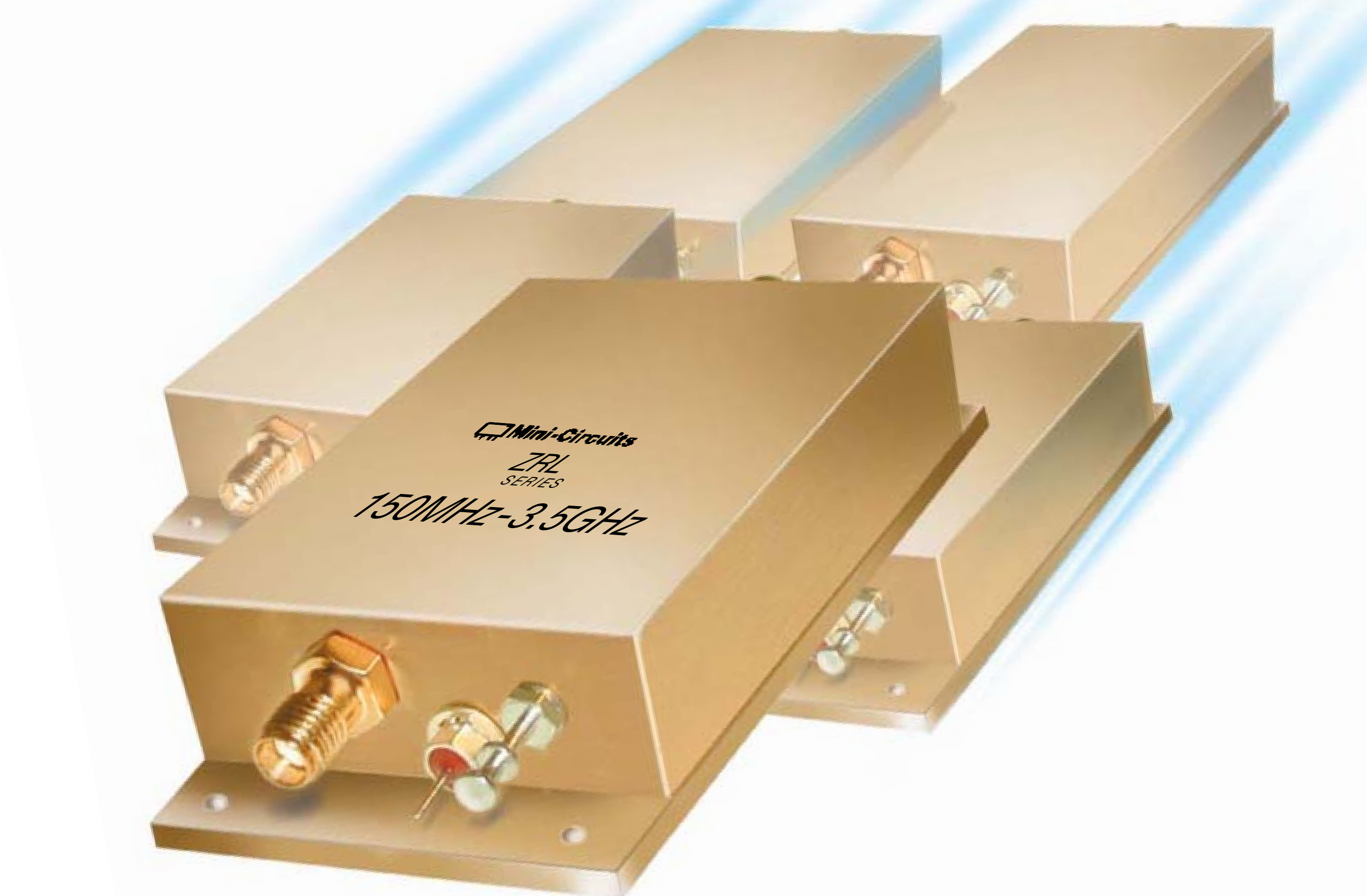

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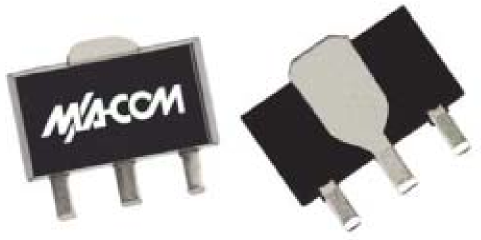

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As consumers adopt more data intensive applications and want access to that data in more locations, the need for high speed wireless data communications is increasing dramatically. There are a host of wireless standards emerging to satisfy this need for increased data. 2.5G/3G, Wi-Fi and WiMAX systems are all vying for their share of the data network.

The amount of data transmitted relates to the available bandwidth. Unfortunately, bandwidth for these systems is not unlimited and turns out to be a scarce, valuable commodity. This forces system designers to develop more complex modulation schemes to increase the spectral efficiency and transmit more data in a given frequency channel. Complex modulation schemes place a premium on system linearity to maintain the integrity of the transmitted data. While any component in a transmit-receive communications system can introduce distortion and nonlinearities to a signal, the transmit amplifier chain is a significant contributor because this is one of the last operations performed on the signal before it is radiated.

To address the need for higher linearity in the transmit amplifier chain for a wide variety of emerging wireless data standards, M/A-COM is expanding its portfolio of amplifiers by introducing a family of broadband, high linearity driver amplifiers. The MAAMSS0048, MAAMSS0049 and MAAMSS0050 are gain blocks with output P1dB levels of +27, +28.5 and +30 dBm, respectively. These driver amplifiers are suitable for 2.5G/3G, Wi-Fi, WiMAX and a host of other applications. All the amplifiers in this family are housed in lead-free, RoHS-compliant, SOT-89 plastic packages.

This amplifier family is fabricated using a GaAs HBT process and achieves high intercept performance over a 20 dB power range. The usable bandwidth for this family of amplifiers is very broad. Each of the three driver amplifiers covers 250 to 4000 MHz. The user tunes the amplifier to optimize performance for a specific frequency range with external matching components. The data sheets for these devices contain recommended layouts and tuning schemes for a variety of wireless frequencies. The IC Products Applications Group of M/A-COM should be contacted for

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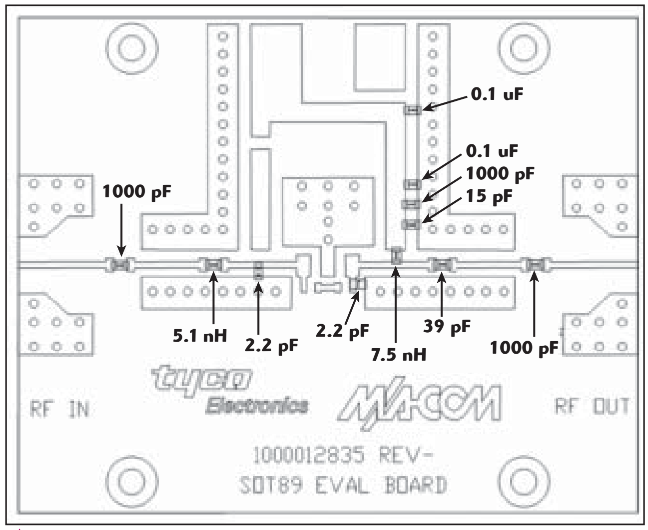


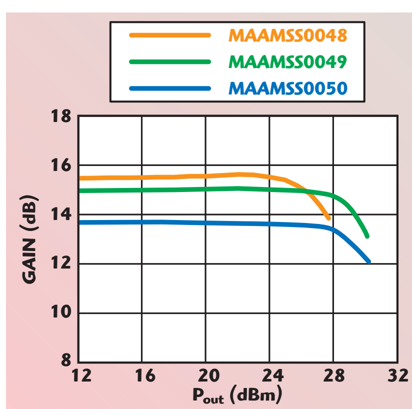
▲ *Fig. 1 2150 MHz tuning scheme for the MAAMSS0050 amplifier.*

performed on the three amplifiers mentioned. ***Figure 2*** shows their gain versus output power performance at 2170 MHz, while ***Figure 3*** plots their output IP3 versus power output at 2140 MHz. These plots show that the gain and output intercept point performance stay very flat up until the amplifiers start to compress. This small variation over output power ensures that the system performance is well behaved. The performance for this family of driver amplifiers is summarized in ***Table 1***.

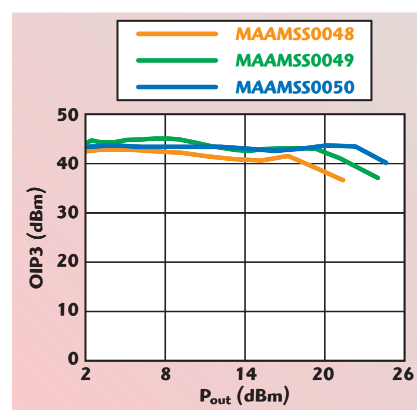
frequency requirements not covered by the tuning layouts shown in the data sheets. This group works with customers to specify the best tuning scheme for a particular requirement.

The layout shown in ***Figure 1*** is suggested for a 2110 to 2170 MHz operation. After using this tuning recommendation, measurements were

To ensure the reliability of this class of amplifiers, the company has performed extensive temperature stress testing. These accelerated thermal stress tests, for devices produced



▲ *Fig. 2 Output power at 2170 MHz, using the suggested tuning scheme.*



▲ *Fig. 3 Output third-order intermodulation product versus output power.*

TABLE I

DRIVER AMPLIFIER PERFORMANCE

Parameter	Conditions	MAAMSS0048	MAAMSS0049	MAAMSS0050
Frequency (MHz)		250 to 4000	250 to 4000	250 to 4000
Gain (dB)	2140 MHz	15.5	15	13
P1dB (dBm)	2140 MHz	27	28.5	30
OIP3 (dBm)	18 dBm/tone 1 MHz spacing	40	43	43
Noise figure (dB)	2140 MHz	3.5	3.5	4.5
Supply voltage (V)		5	5	5
Quiescent current (mA)		160	230	420

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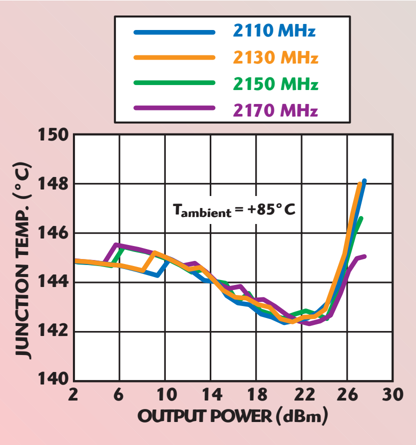
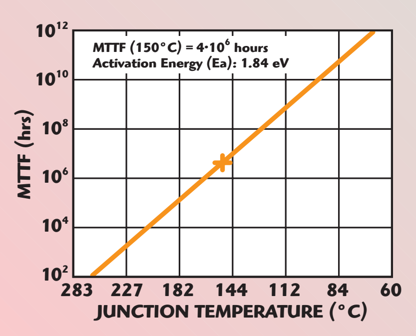
with the HBT process, yield data points on a lifetime versus junction temperature plot. By plotting the best-fit curve through these points, the slope constant and activation energy (E_a) are determined using the classic Arrhenius life-stress relationship. Using this relationship, the mean time to failure (MTTF) can be determined for any junction temperature. By carefully measuring the input power, output power and DC dissipation, the total power dissipation within the junction of the amplifier can be determined. This, coupled with the thermal resistance, determines the junction temperature. ***Figure 4*** summarizes these results for the MAAMSS0048 at four frequencies between 2110 and 2170 MHz. From this data, the junction temperature can be conservatively set at +150°C (at an ambient of +85°C) in the Arrhenius plot. From the plot of mean time to failure versus temperature, shown in ***Figure 5***, an MTTF of 4×10^6 hours is achieved for this family of amplifiers operating at a maximum junction temperature of 150°C.



▲ *Fig. 4 MAAMSS0048 device junction temperature versus output power for four different frequencies.*



▲ *Fig. 5 MTTF versus device junction temperature for the high linearity RF driver amplifiers.*

In summary, a family of high output intercept point, broad bandwidth driver amplifiers with P1dB levels of +27, +28.5 and +30 dBm has been developed. These devices come in lead-free, RoHS-compliant, SOT-89 packages for easy surface-mount assembly. The broad frequency coverage and external tuning make them suitable for a variety of wireless applications.

For higher gain amplifiers, M/A-COM will soon be extending its family of drivers with MAAMSS0056, MAAMSS0057 and MAAMSS0058. These are two-stage amplifiers with output P1dB levels of +27, +30 and +33 dBm, respectively.

M/A-COM Inc.,
Lowell, MA (800) 366-2266,
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Gali 1	DC-8000	12.7	12.2	4.5	27	108	40	3.4	.99
Gali 21	DC-8000	14.3	12.6	4.0	27	128	40	3.5	.99
Gali 2	DC-8000	16.2	12.9	4.6	27	101	40	3.5	.99
Gali 33	DC-4000	19.3	13.4	3.9	28	110	40	4.3	.99
Gali S66	DC-3000	22	2.8	2.7	18	136	16	3.5	.99
Gali 3	DC-3000	22.4	12.5	3.5	25	127	35	3.3	.99
Gali 6F	DC-4000	12.1	15.8	4.5	35.5	93	50	4.8	1.29
Gali 4F	DC-4000	14.3	15.3	4.0	32	93	50	4.4	1.29
Gali 51F	DC-4000	18.0	15.9	3.5	32	78	50	4.4	1.29
Gali 5F	DC-4000	20.4	15.7	3.5	31.5	103	50	4.3	1.29
Gali 55	DC-4000	21.9	15.0	3.3	28.5	100	50	4.3	1.29
Gali 52	DC-2000	22.9	15.5	2.7	32	85	50	4.4	1.29
Gali 6	DC-4000	12.2	18.2	4.5	35.5	93	70	5.0	1.49
Gali 4	DC-4000	14.4	17.5	4.0	34	93	65	4.6	1.49
Gali 51	DC-4000	18.1	18.0	3.5	35	78	65	4.5	1.49
Gali 5	DC-4000	20.6	18.0	3.5	35	103	65	4.4	1.49
Gali 74+	DC-1000	25.1	18.3	2.7	38	120	80	4.8	2.35

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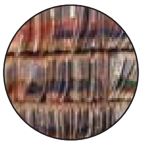


CATALOG UPDATE

▲ RF Power Products

This catalog features the company's RF power products that include bipolar, VDMOS and LDMOS technologies. All of the products are based on silicon and span the frequency range of 1 MHz to 3.5 GHz using supplies from as low as a few volts to as high as 300 V. These high power silicon RF and microwave power transistors are for applications in ISM, avionics, and L-band and S-band radar.

Advanced Power Technology RF,
Santa Clara, CA (408) 986-8031,
www.advancedpower.com.

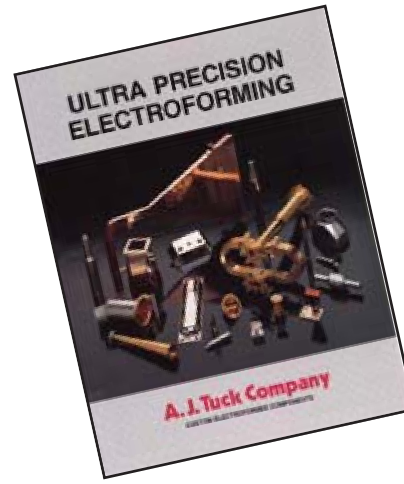
RS No. 310

▲ Short Form Catalog

This 24-page short form catalog highlights the company's microwave, wireless and broadband components that are used in commercial and military industries. The components include attenuators, adapters, bias tees, DC blocks, gain equalizers and terminations.

Aeroflex/Inmet,
Ann Arbor, MI (888) 244-6638,
www.aeroflex-inmet.com.

RS No. 311

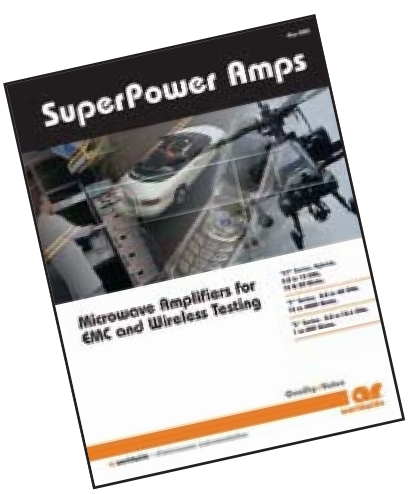


▲ Ultra Precision Electroforming

This brochure features the company's design and manufacture of precision, close-tolerance custom electroformed components. The full-service electroforming facility offers engineering, and machining capabilities that employ the latest state-of-the-art applied machining and electroforming technologies.

A.J. Tuck Co.,
Brookfield, CT (203) 775-1234,
www.ajtuckco.com.

RS No. 312



▲ Microwave Amplifier Brochure

This brochure, entitled "SuperPower Amps," provides a detailed overview of the company's microwave amplifiers for EMC and wireless testing. The brochure contains information on the many "Gigs Galore" microwave offerings from AR, along with specifications on the ST, T and S series amps that comprise these offerings.

AR Worldwide,
RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.

RS No. 313

▲ Product Catalog

This 300-page catalog presents standard products and customized solutions in IF/RF and microwave frequencies. Besides an expanded line of control products, the catalog adds multifunction assemblies and five categories of amplifiers including low noise, driver, high power, narrow and broad bandwidth, and 27 MHz to 20 GHz – highlighting the transition the company is undergoing to meet increasing customer needs.

Daico Industries Inc.,
Carson, CA (310) 507-3242,
www.daico.com.

RS No. 314

▲ Product Catalog

This product catalog details the company's design and production of a complete line of voltage-controlled oscillators in a variety of packages that cover the frequency range of 5 MHz to 11 GHz. The intra-company design standards set the military grade product line carry over to the commercial product line providing a rugged unit capable of withstanding vibration, shock, temperature and other environmental extremes.

Emhiser Micro-Tech,
Verdi, NV (775) 345-0461,
www.emhiser.com/vco.

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MMBC12G8	12.8*	5	50	**–120 dBc/Hz @ 100 kHz offset**
MMBC13G05	13.05*	5	50	**–120 dBc/Hz @ 100 kHz offset**

*Other frequencies on request available. Please contact factory.

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MMCC411	**5 – 10***	5	70	–90 dBc/Hz @ 100 kHz offset
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Catalog Update

▲ Short Form Catalog

This short form catalog highlights the company's miniature frequency synthesizers, phase-locked sources, LOs, signal sources, phase-locked oscillators and DRO replacement products. This complete line of high performance standard and custom-designed frequency sources is for military and commercial wireless communications applications.
EM Research Inc.,
Verdi, NV (775) 345-2411,
www.emresearch.com.

RS No. 316

▲ Filter Catalog

This catalog includes the company's complete line of RF and microwave filter products. Also featured are integrated filter assemblies that include switched filters and filter amplifiers. Other RF products included are phase comparators, manual and digital phase shifters, voltage-controlled phase shifters, voltage-controlled attenuators and broadband mixers.
Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 317

▲ RF/Microwave Products

This brochure provides the company's high reliability RF and microwave PIN and limiter diodes, tuning and multiplier varactors, noise diodes, Schottky-barrier diodes, MNS chip capacitors and solid-state control modules. With high volume wafer fabrication now in place to meet the competitive needs of the company's commercial customer base, the Lowell facility can deliver more cost-effective components faster.
Microsemi Microwave Products,
Lowell, MA (978) 442-5600,
www.microsemi.com.

RS No. 318

▲ Product Catalog

This catalog features a sampling of the company's RF and microwave filters and components that cover the frequency range from 5 Hz to 50 GHz. These high quality designs include surface-mount, waveguide, stripline/microstrip, lumped element and cavity/coaxial topologies. Filter types and accessories include bandpass, bandstop, combiners, couplers, diplexers, high pass, low pass and adapters.
Microwave Filter Co. Inc.,
East Syracuse, NY (800) 448-1666,
www.microwavefilter.com.

RS No. 319

▲ Short Form Product Catalog

This catalog details the company's design, development and supply of monolithic microwave integrated circuits for microwave and millimeter-wave wireless communications applications. The MMICs are developed utilizing state-of-the-art semiconductor processes and design high levels of integration on a single chip. A MMIC product matrix that contains a snapshot view of its current product line and a product selection guide are also included.
Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.

RS No. 320

▲ Amplifier Product Catalog

This 74-page AFS series amplifier product catalog includes technical specifications and typical test data of the company's wide array of low noise and high power amplifiers. In addition, the catalog covers many special amplifier designs such as surface-mount, variable gain, dual output, temperature-compensated, cryogenic, high intercept, limiting and pulse modulated power gated designs.
MITEQ Inc.,
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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.
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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

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39 ☐ Synthesized Signal Sources
40 ☐ Spectrum Analyzers
41 ☐ Network Analyzers
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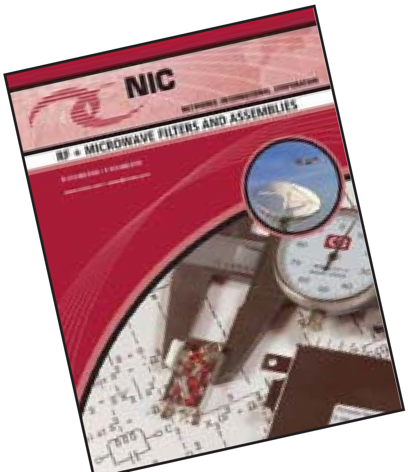
CATALOG UPDATE



▲ Products and Capabilities Brochure

This products and capabilities brochure is designed for advanced RF communications. Products include: lumped component, ceramic and crystal filters, switched filter banks, phase shifters, multiplexers and diplexers, TCXOs and VCTCXOs, and space qualified products. Advanced environmental testing capabilities and filter design considerations are also included.

Networks International Corp., Overland Park, KS (913) 685-3400, www.nickc.com.

RS No. 322

▲ Product Selection Guide

This product selection guide provides in-depth specifications and package information for over 600 of the company's products. The power amplifiers, front-end modules, direct conversion transceivers and complete system solutions are at the heart of multimedia handsets, cellular base stations and wireless networking platforms.

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

RS No. 323

▲ Components and Systems Catalog

This 92-page RF and microwave components and systems catalog features products from the recently acquired companies of FSY Microwave and Salisbury Engineering. The catalog provides users with assistance in RF filter topology selection as well as product features, specifications, applications, schematics and outline drawings.

Spectrum Microwave Inc., Palm Bay, FL (321) 727-1838, www.specwave.com.

RS No. 324

▲ Cable Assembly Selection Guide

This selection guide will assist readers in choosing the best microwave coaxial cable assembly with the best combination of components and price for a specific purpose. It is separated into four parts: general design criteria, cable types and specifications, connector types and specifications, and cable assembly data. This information can then be used with specific requirements to submit a request for quotation.

SSI Cable Corp., Shelton, WA (360) 426-5719, www.ssicable.com.

RS No. 325

▲ Capabilities Brochure

This brochure from Crane Aerospace & Electronics STC Microwave Systems covers components and subsystems that range from RF/IF to millimeter-wave. It features high performance products designed and manufactured for military/defense, aerospace and industrial applications. Products include up/down converters, switch matrices, DVLAs, oscillators and attenuators. Existing products or custom design are available.

STC Microwave Systems, Chandler, AZ (480) 961-6269, www.craneae.com/stcms.

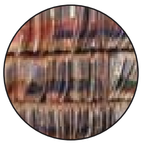
RS No. 326

▲ High Performance Solutions

This newly updated catalog covers high performance microwave interconnect solutions to 50 GHz for defense and aerospace applications: phase stable, low loss and miniature flexible assemblies; semi-rigid cable and assemblies; capabilities; custom applications and solutions; and case studies. Product selection grids, performance graphs, tables, charts, tutorials, photos, and ordering and service information are also included.

Storm Products-Microwave Group, Woodridge, IL (630) 754-3300, www.stormproducts.com.

RS No. 327



CATALOG UPDATE

▲ Radar Technologies

This brochure includes information relating to the company's wide capability in components and subsystems for radar technologies, including ferrite phase shifters and switches, differential phase shift circulators, isolators and power splitters, latching circulators, ferrite components, rotary switches and SAW pulse compression subsystems.

Thales-MESL Ltd., Edinburgh, Scotland +44 131 333 2000, www.thales-mesl.com.

RS No. 328

▲ Capabilities Brochure

This brochure provides an overview of the company's thin film capabilities and features the UltraBridge,™ UltraCapacitor™ and UltraInductor™ solutions. The design guide assists a reader in choosing the proper substrate material for a high power circuit, or the right conductor or resistor film that will help avoid wire bonding problems.

UltraSource Inc., Hollis, NH (800) 742-9410, www.ultrasource.com.

RS No. 329

▲ RF Semiconductor Selection Guide

This short form catalog features the company's amplifiers, mixers, RF integrated circuits, RFID reader modules and chipsets that are used to transmit, receive and process signals to enable current and next generation wireless and wireline services. Product descriptions and outline drawings are also included.

WJ Communications Inc., San Jose, CA (800) 951-4401, www.wj.com.

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***Johanson Manufacturing**
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NEW WAVES: Military and Government Electronics

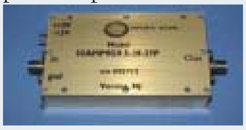
Microwave Downconverter

The model PN9276 is a 40 GHz microwave downconverter that provides the combination of high bandwidth with low noise performance. This model is designed for radar, commercial wireless, satellite terrestrial microwave links and calibration labs. This downconverter plugs into any PN9000 phase noise analyzer or PN9500 wideband jitter and phase noise analyzer. The PN9276 allows phase noise measurements up to 200 MHz offset as a result of its intermediate frequency range. Price: $57,750.
Aeroflex Inc.,
Plainview, NY (516) 694-6700,
www.aeroflex.com.

RS No. 216

High Power Amplifier

The model 50AMP9G9.5-30-37P is a high power amplifier ideal for wireless, defense and satellite communications. This model operates in a frequency range of 9 to 9.5 GHz and offers a P1dB of at least 37 dBm and gain of 30 dB. Input voltage is ±12 V and current draw is 3.5 A. Noise figure is 7 dB. The amplifier is supplied with an SMA(f) input and output connector. This model has a small profile at less than two inches by four inches including connectors and is less than one inch in height.



Amplical Corp.,
Verona, NJ (201) 919-2088,
www.amplical.com.

RS No. 217

Directional Coupler

The model 1821 is a directional coupler that operates in a frequency range of 1 to 18 GHz. This model features coupling of 10 ±0.5 dB, directivity of 16 dB minimum and maximum VSWR (any port) of 1.35. The coupler offers an insertion loss (includes coupled power) of 1.3 dB maximum, power rating (input) of 20 W average, 3 kW peak and standard connectors that include SMA female, optional SMA male or N female. Unit may be manufactured to meet military specifications. Weight: 4.4 ounces. Delivery: stock to 30 days.
Krytar,
Sunnyvale, CA (408) 734-5999,
www.krytar.com.

RS No. 220

High Power Directional Coupler

The model CD2-122-142-40-2K is a high power directional coupler designed for long range search radar in the 1.2 to 1.4 GHz band. The coupler can handle 2 kW average power and 20 kW pulse power. There are two forward and two reverse coupled ports at 40 dB ±0.5 dB down from the main thru-line. The coupler has an insertion loss of < 0.15 dB and the VSWR is < 1.15 with a minimum directivity of 20 dB at each port. The input and output connectors are EIA 7-16 and the coupled ports shown are SMA female. The coupler can be adapted with many other connector types to suit different applications.

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

RS No. 221

Fast Switching Power Amplifiers

The model 5303039D and model 5303068A operate in the 20 to 2000 MHz frequency range at greater than 50 W RF output power at P_{sat}, and can quickly be switched off to enhance system sensitivity in the receive mode. As a result, these modules are ideal for wideband communications and EW applications, with duplex receive and transmit functions. These modules can be switched within 2 μs to be within 20 dB of KTB in conjunction with no input signal. These models can also be hot switched. Delivery: six weeks.
Ophir RF,
Los Angeles, CA (310) 306-5556,
www.ophirrf.com.

RS No. 222

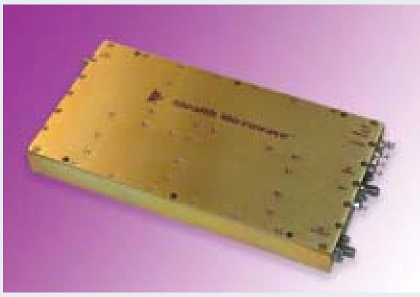
Hybrid Oscillator

The HT700 and HVT700 hybrid oscillators combine the high performance of discrete oscillators with the tight stability of integrated compensation. The HT700 operates in a frequency range from 1 to 100 MHz and is available with a variety of output waveforms. The HT700 can hold a stability of ±0.5 ppm over extended temperature ranges of –40° to +85°C. These oscillators are suitable for a variety of GPS applications including avionics and military. Communications applications include satellite and voice data, microwave and voice data, and radio base stations.

Rakon Ltd.,
Auckland, New Zealand +64 9 573 5554,
www.rakon.com.

RS No. 223

Ultra Linear RF Amplifier



The model SM4450-43L is a GaAs FET amplifier designed for various military and commercial applications demanding high performance. The unit operates from 4.4 to 5 GHz with a P1dB of +43 dBm and OIP_3 of +62 dBm. Small-signal gain is 55 dB with a flatness of ±0.5 dB across the band. Standard features include a single +12 VDC supply, thermal protection with auto reset and over/reverse voltage protection. Size: 7.5" × 3.97" × 0.79".
Stealth Microwave Inc.,
Trenton, NJ
(888) 772-7791,
www.stealthmicrowave.com.

RS No. 224

Crystal Oscillator

The model 9210B is a military oven-controlled crystal oscillator (OCXO) designed for ground tactical and airborne applications where good frequency stability and phase noise are required under severe environments. This model is based around a third-overtone SC cut crystal. The standard 9210B oscillator is available in either 5 or 10 MHz output configurations, both of which provide good frequency stability and phase noise performance in static or dynamic environments. The 9210B is capable of operation in vibration environments exceeding 30 G rms. Size: 2" × 2" × 1.25". Price: $1,795.00.
Symmetricom Inc.,
San Jose, CA
(978) 927-8220,
www.symmetricom.com.

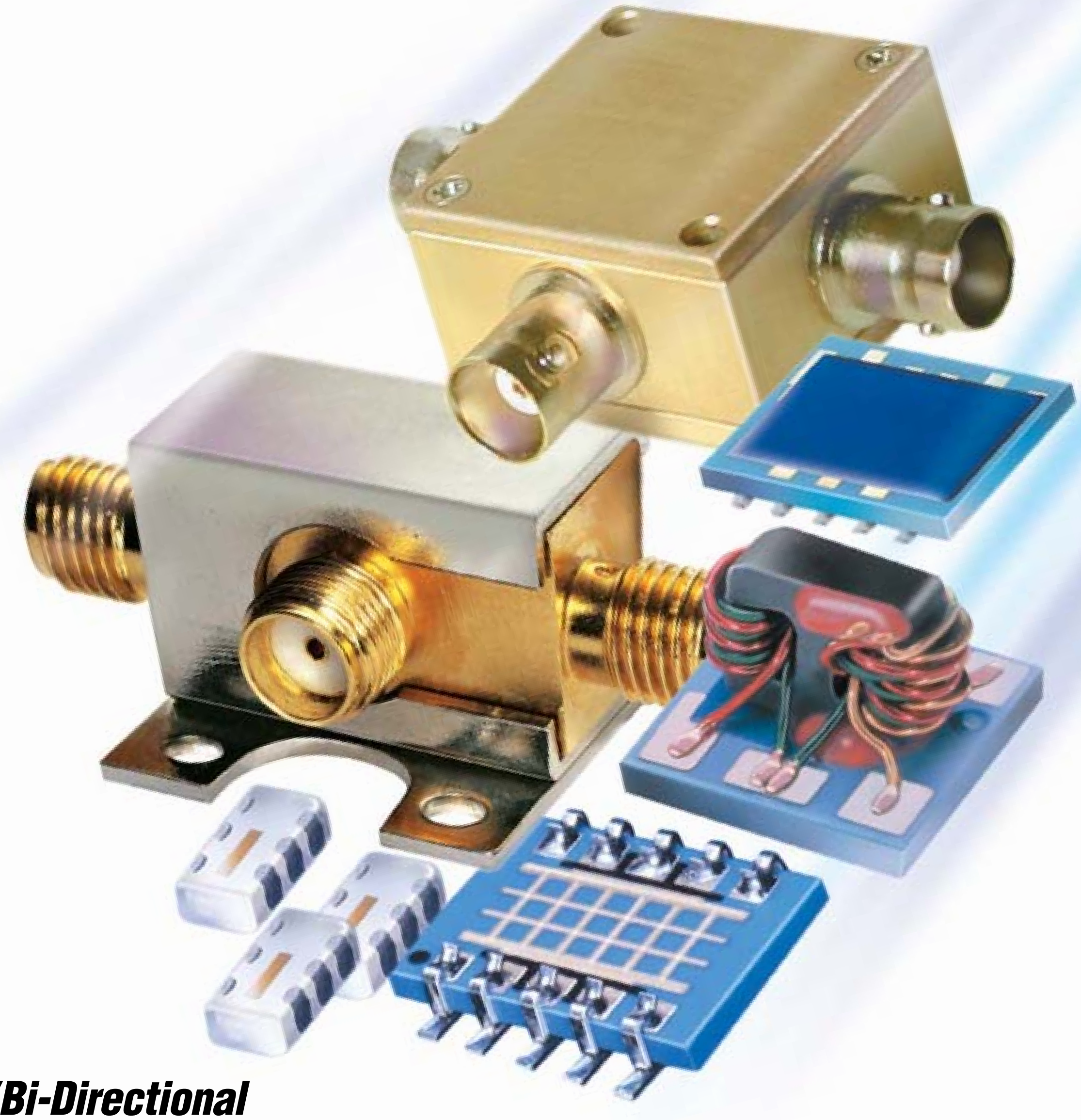
RS No. 225

Broadband Bias Tees

The VBN-CS series of miniature broadband coaxial bias tees is designed for applications in commercial and military frequency bands. The VBN-CS series 50 Ω bias tees are offered in five distinct models covering popular frequency bands. The VBN-CS110 operates from 100 to 1000 MHz, the VBN-CS120 from 100 to 2000 MHz, the VBN-CS130 from 100 to 3000 MHz, the VBN-CS810 from 800 to 1000 MHz and the VBN-CS172 from 1700 to 2000 MHz. All models exhibit low insertion loss of 0.4 dB typical, high RF-DC isolation of 40 dB typical and a typical VSWR of 1.20.

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

RS No. 226



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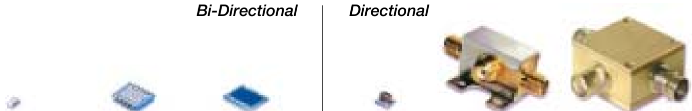

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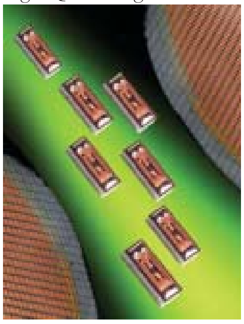
COMPONENTS

Thin Film Inductor

This thin film inductor in the 0402 size offers high Q and tight tolerances with high current handling capability as well as repeatability. With its land grid array packaging and miniature size, the inductor provides both high frequency performance and rugged construction for reliable automatic assembly in applications such as mobile communications, satellite TV receivers, GPS, vehicle location systems, wireless LANs, filters and matching networks. The L0402 offers an inductance range of 0.82 to 6.8 nH. Price: $0.10 to $0.30. Delivery: stock to six weeks.



AVX Corp.,
Myrtle Beach, SC (843) 448-9411,
www.avx.com.

RS No. 218

Partial Wrap Termination Resistors

These partial wrap termination resistors offer an exposed solder fillet that is designed to facilitate visual inspection for the termination joint of the flip chip resistor. The flip chip resistor delivers high frequency performance to 40 GHz. Ohmic values range from 10 Ω to 2kΩ. The partial wrap around termination is available in platinum silver as well as PtAg plus a solder coating of 62/36/2 (SAC-alloy). These resistors are an ideal choice for high frequency radio communications, microwave and radar applications. Price: $0.40 to $0.65 (1000).

International Manufacturing Services Inc.,
Portsmouth, RI (401) 683-9700,
www.ims-resistors.com.

RS No. 219

High Power Bias/Monitor Tees

These high power bias/monitor tees operate at a frequency range of 100 to 8000 MHz. The tees feature high DC current, high RF power, broadband performance, low insertion loss and low VSWR. Applications include high power device characterization, high power amplifier development and high power/high current in-line amplifier bias. Size: 1" × 1" × 2" (excluding connections).

Antelope Valley Microwave Inc.,
Lancaster, CA (661) 726-9903,
www.avmicrowave.com.

RS No. 227

5 W Fixed Attenuator

The model series 352-009-XXX is comprised of 50 Ω fixed attenuators that offer attenuation values from 1 to 30 dB covering the DC to 6 GHz frequency range and 5 W average power rating. The package measures 2.46" × 0.63" for 1 to 20 dB values and 2.86" × 0.63" for 21 to 30 dB values. The connector configuration is N male/N female. This series is an economical solution and most dB values are available from stock.

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

RS No. 228

Solid-state Switch Matrix

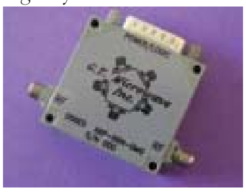
This CANBUS-based solid-state switch matrix with RS-422 control interface performs from 3.4 to 4.2 GHz and is available in full fan-out configurations from 32 × 32 to 32 × 64. The model 5096 switch matrix consists of two input modules, four output modules and one controller module. This matrix is designed for signal routing applications and can also be utilized as a building block for numerous ATE applications.

Dow-Key Microwave,
Ventura, CA (805) 650-0260,
www.dowkey.com.

RS No. 229

PIN Diode Attenuator

The model A6P-69N-0MG is a multi-octave digitally controlled miniature PIN diode attenuator that operates from 2 to 18 GHz with a 64 dB dynamic range in 0.25 dB steps. Across the entire band, VSWR is less than 2.1, insertion loss is less than 4.5 dB and it is capable of handling +13 dBm CW, 1 W maximum. With 8-bit binary, TTL compatible logic, the switching speed is less than 1.5 µs from any state to any state. Size: 1.7" × 1.8" × 0.75".



G.T. Microwave Inc.,
Randolph, NJ (973) 361-5700,
www.gtmicrowave.com.

RS No. 230

PIN Diode Limiter

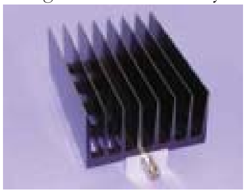
The model LP2018 is a passive 2 to 18 GHz PIN diode limiter that offers a built-in return with fast response and short recovery time of 10 to 20 ns typical. This limiter has low insertion loss of 1.8 dB, with protection in high power environments for 1 W CW and 100 W peak input (1 µs) power handling capability. The unit is hermetically sealed.

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

RS No. 231

High Power Attenuators

The 50FHDQ series of high power attenuators is designed for a variety of high power test applications. Models range from the 50FHDQ-XXX-300-3N (300 W, DC to 3 GHz, with N M/F connectors) to the 50FHDQ-XXX-500-3N (500 W, DC to 3 GHz, with N M/F). TNC and 7/16 DIN connectors are also available.



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

RS No. 232

Suspended Substrate Filter

The model 11SB10-3100/T2000-O/O is a filter that utilizes suspended substrate technology to realize low insertion loss and tight stopbands. This filter realizes insertion loss less than 1 dB at 3100 MHz and a 3 dB relative bandwidth of 2 GHz. Extremely tight shape factors of 1.02 on the low side and 1.05 on the high side make this a selective filter. The filter can be sealed for use in harsh environments as needed.

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

RS No. 233

Digital Phase Shifter

The model DP-2-4-425-50-PX is a digital phase shifter that covers 400 to 450 MHz. Typical specifications include a 6 dB maximum insertion loss, 1.5 VSWR, phase accuracy at 425 MHz ±2.8°, +5 V DC at 25 mA, 1 µs maximum switching speed and an operating temperature of –40° to +85°C. Size: 2 × 1 × 0.210 inch low profile package.

Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 234

Electromechanical Switches

These electromechanical switches utilize a non-molded cavity design that achieves a high

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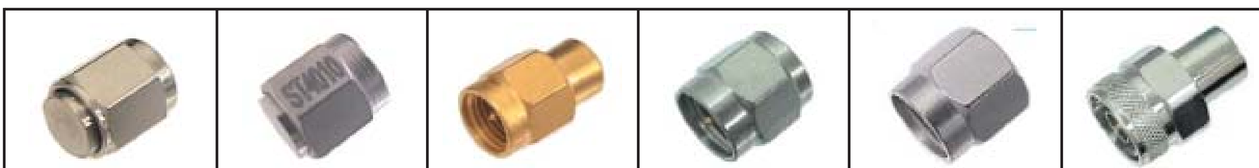
TERMINATIONS 0-50GHZ



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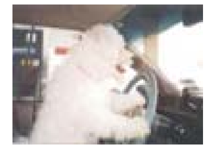

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NEW PRODUCTS

performance. These switches are available in a variety of mechanical and electrical configurations tailored to meet a system's requirements. This SPDT switch offers a miniature design with SMA connectors and is available up to 18 GHz. Options available include latching or failsafe actuator, suppression diodes and indicators. Delivery: one to two weeks ARO.

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

RS No. 235

Two Diplexers

The first waveguide diplexer covers a frequency range from 7.9 to 8.5 GHz and measures 177 × 30 × 30 mm. The filter's bandwidth is 42 MHz and the duplex space is 120 MHz. The second waveguide diplexer covers a frequency range from 7.1 to 7.8 GHz. The filter's bandwidth is 56 MHz, the duplex space is 154 MHz and its physical dimensions are 177 × 30 × 30 mm. Both diplexers have an insertion loss of ≤ 1.5 dB and a high Tx/Rx isolation of ≥ 70 dB.

Microwavefilters srl,
Pioltello, Italy +39-02-92162703,
www.microwavefilters.it.

RS No. 236

Type-N Attenuators

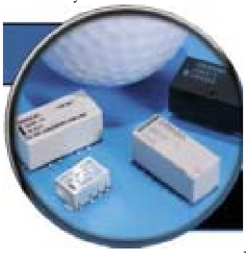
These type-N UNAT fixed attenuators offer a selection of thirteen different attenuation values ranging from 1 to 20 dB, good return loss and flat attenuation over the broad DC to 6000 MHz band. The UNAT fixed attenuators offer a unique unibody construction that endures rigorous applications and wide temperature extremes ranging from –40° to +100°C. Patent pending. Price: from $15.95 (1–9).

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

RS No. 237

HF Relays

The models G6K-RF, G6Z, G6Y and G6W are HF relays that feature small size and low power consumption.



The G6Z, G6Y and G6W have a low power consumption of 200 mW and the G6K-RF has a power consumption of 100 mW. In addition, each relay features good isolation and insertion loss characteristics. At 1 GHz, the isolation for the G6K-RF is 20 to 30 dB minimum. Size: G6Z: 9.5 × 8.6 × 20 mm; G6W: 9.2 × 9.4 × 20 mm; G6K-RF: 5.4 × 6.9 × 10.3 mm. Price: G6Y and G6Z: $1.50 (10,000); G6K-RF: $10.00 (10,000); G6W: $50.00 (10,000).

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

RS No. 238

RF CMOS Switch

The model PE4283 SPDT is a reflective switch that has been developed for the convergence

market and generic RF applications. Featuring ultra-low power consumption, high compression point and good ESD tolerance, this new device offers

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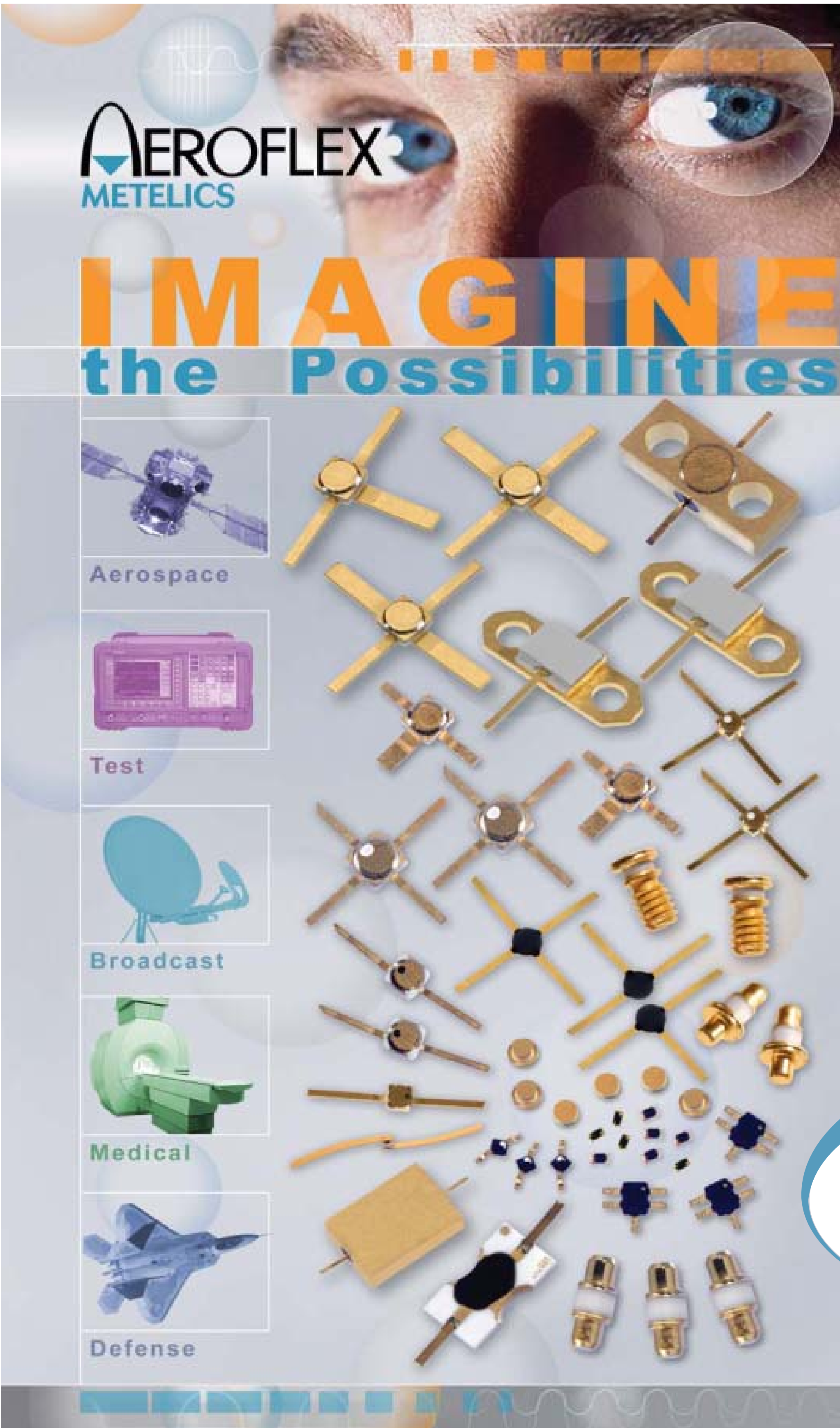

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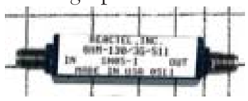
a unique combination of versatile features, high performance and competitive price for emerging applications in the WLAN, ISM, BT and other short range radio markets. This model offers less than 1 dB of insertion loss from DC to 4 GHz, 2 kV ESD tolerance and isolation of 34 dB at 1 GHz. Price: $0.25 (10,000).
Peregrine Semiconductor Corp., San Diego, CA (800) 737-6937, www.psemi.com.

RS No. 239

Wideband High Pass Filter



The part number 6HM-130/3G-S11 is a miniature high pass filter with an extended passband. This high performance unit offers a nominal 1 dB passband of 130 MHz to 3 GHz while maintaining less than 1 dB of insertion loss for 95 percent of the passband. Passband can be further extended to meet specific requirements.
Reactel Inc., Gaithersburg, MD (301) 519-3660, www.reactel.com.

RS No. 240

High Power Transmitter Combiner

This high power transmitter combiner is designed for base station systems that include GSM, DCS, PCS and UMTS. These combiners offer low operation temperature and stability for maximum reliability and energy efficiency. The combiner features high isolation, low operating temperatures, two separately fused fan banks for redundancy, long life span, standard 19" – 2U rack size and is available in various channel combining configurations.
Renaissance Electronics Corp., Harvard, MA (978) 772-7774, www.rec-usa.com.

RS No. 241

Octave Band Divider

This application specific series of economical power dividers/combiners is designed for signal routing within building wireless distribution applications. The two-way divider operates between 1500 to 3000 MHz. Electrical performance offers typical insertion loss of 0.25 dB, isolation of 23 dB typical, VSWR of 1.25 typical, phase unbalance of 2° maximum and amplitude unbalance of 0.3 dB maximum. Forward power handling is 20 W CW. Size: 2" × 2" × 1", plus connectors.
Response Microwave Inc., Framingham, MA (978) 456-9184, www.responsemicrowave.com.

RS No. 242

Multi-position Coaxial Switches

These miniature terminated multi-position coaxial switches (3 to 6 position) provide reliability, long life and good electrical performance. The switch features low current and a significantly reduced height suitable for high density packaging applications. The SP-3T thru SP-6T operate at a frequency range of DC to 18 GHz. These switches offer RF cold switching of 2 W average, 50 Ω impedance and a failsafe or latching operating mode.
RLC Electronics Inc., Mount Kisco, NY (914) 241-1334, www.rlcelectronics.com.

RS No. 243

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New Products

Chip Resistors

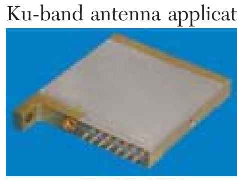
These high reliability chip resistors meet the visual inspection requirements of MIL-PRF-38534 and are ideal for use in hybrid applications requiring exclusive characteristics. The resistors offer tolerances from 0.1 percent, power ratings from 20 to 2000 mW temperature coefficients of resistance as low as 25 ppm, and voltage ratings from 15 to 200 V. The operating range for these resistors is from –55° to +125°C. Size: 0202: 0.020" × 0.020"; 2512: 0.250" × 0.125". Price: < $1.00.

State of the Art Inc.,
State College, PA (800) 458-3401,
www.resistor.com.

RS No. 244

Ku-band Switch Assembly

The model MFS 134 is a switch assembly for Ku-band antenna applications. This model operates in the Ku-band with typical electrical specifications that include a noise figure of 6 dB maximum at 25°C, gain at 14.875 GHz of 5.2 dB ± 0.5 dB at 25°C, output port isolation (all ports on) of 18 dB minimum and a switching speed of 20 nanoseconds typical. Size: 1.45" × 1.7" × 0.220". Weight: 35 grams maximum.



TRAK Microwave Corp.,
Tampa, FL (813) 901-7200,
www.trak.com.

RS No. 245

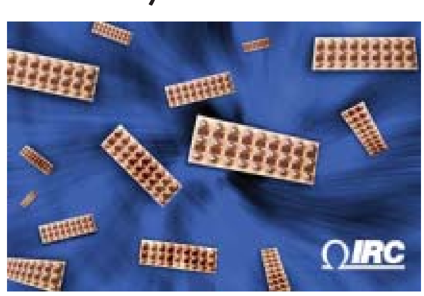
Two-way Power Divider

The model WPD-50/2N is a 50 Ω, two-way broadband Wilkinson power divider that operates in the 800 to 2700 MHz frequency range and offers a minimum of 20 dB (25 dB typical) of port-to-port isolation with an insertion loss of 0.5 dB nominal above the theoretical split. This model features N female connectors on all ports and is well suited for applications including antenna sharing, in-building systems, test and verifications labs and integrated test modules.

Trilithic Inc.,
Indianapolis, IN (800) 344-2412,
www.trilithic.com.

RS No. 246

Grid Array Network



The CHC series is an 18-resistor ball grid array network designed to maximize signal integrity in high speed digital circuit designs by combining nine Thevenin pairs in a network schematic. These chipscale networks are available in a wide range of standard and custom resistance values. The devices also feature absolute TCRs to ±100 ppm/°C and standard tolerances to ±1 percent with operating temperatures from 0° to +70°C. Price: $0.99 (10,000). Delivery: 10 weeks.

TT electronics,
IRC Advanced Film Division,
Corpus Christi, TX (361) 992-7900,
www.irctt.com.

RS No. 247

High Linearity Mixer

The model MH205A is a passive GaAs MESFET mixer that provides high dynamic range performance and is available in a Pb-free SOIC-8 package. This device uses patented techniques to realize +35 dBm input IP3 at an LO drive level of +17 dBm when used in a simple application circuit in an upconverting or downconverting high side LO configuration. This single monolithic integrated circuit does not require any external baluns or bias elements and operates over a frequency of 800 to 960 MHz. Price: $2.25 (10,000).

WJ Communications Inc.,
San Jose, CA (408) 577-6200,
www.wj.com.

RS No. 248

AMPLIFIERS

Hermetically Sealed DLVA

The model LVD-218-50 option HERM is a hermetically sealed 50 dB detector log video amplifier (DLVA). This amplifier operates over the frequency range of 2 to 18 GHz. The DLVA offers true DC coupling, with a logging range of –40 to 0 dBm minimum, with a pulse response of 50 ns in a recovery time of 250 ns. This DLVA employs planar diode detectors and integrated video circuitry for high speed performance and good reliability.

American Microwave Corp.,
Frederick, MD (301) 662-4700,
www.americanmicrowavecorp.com.

RS No. 249

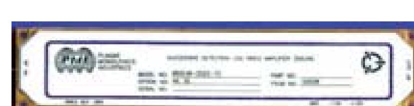
Gain Block MMIC Amplifier

The model HMC474MP86 is a general-purpose SiGe HBT gain block MMIC SMT amplifier that covers DC to 6 GHz. This Micro-P packaged amplifier can be used as a cascadable 50 Ω RF/IF gain stage with 15.5 dB gain and up to +11 dBm saturated output power. The HMC474MP86 delivers an output IP3 of +22 dBm at 850 MHz, while operating from a single positive supply as low as +3 V, and consuming only 25 mA.

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

RS No. 250

SDLVA



The model MSDLVA-2020-70 options 48 and SE SDLVAs operate from 4 to 8 GHz (other frequencies are available). This unit has high speed and utilizes GaAs technology in a compact size. It offers a dynamic range of 80 dB, VSWR of 1.6 typical and TSS of –73 dBm typi-

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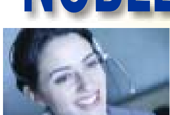
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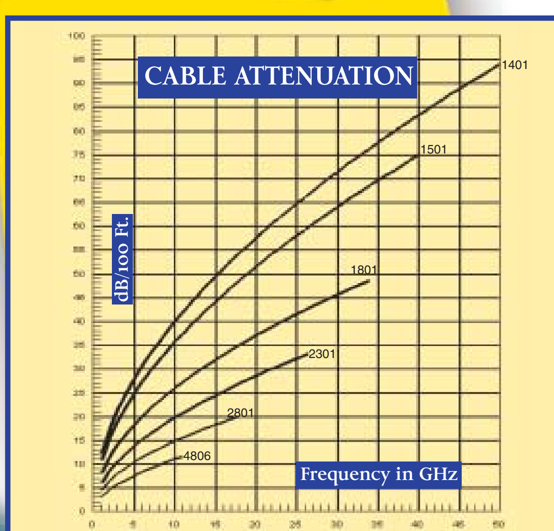

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cal. The logging range is –65 to +15 dBm. Frequency flatness is ±1 dB typical. Size: 4.6" × 0.98" × 0.24".
Planar Monolithics Industries,
Frederick, MD (301) 631-1579,
www.planarmonolithicsindustries.com.
RS No. 251

Power Amplifiers

The model QPN-94042730-01 and model QPN-94043025-02 are W-band power amplifiers that operate in a frequency range from 92 to 96 GHz and offer 25 dB gain minimum. Two saturated output power levels are offered: QPN-94042730-01 at 27 dBm and QPN-94043025-02 at 30 dBm. DC requirements are +5 V at 2.0 A for 0.5 W output and 4.0 A for the 1 W output. Package sizes are 2.0" × 1.4" × 1.0" for 0.5 W and 2.2" × 1.7" × 1.4" for 1 W, with WR-10 inputs and outputs. Fast pulse modulation is available.
QuinStar Technology Inc.,
Torrance, CA (310) 320-1111,
www.quinstar.com.
RS No. 268

Quad-band Polar Modulator

The model RF3178 is a low profile quad-band polar modulator-capable transmit (Tx) module with four-port receive (Rx) capability for GSM/GPRS/EDGE Class 12 operation. The Tx module builds upon its power amplifier technology with integrated power control, PHEMT switch technology and integrated filters. The result is a compact, high performance module that simplifies transmitter design. Size: 7 × 8 × 1.4 mm.
RF Micro Devices Inc.,
Greensboro, NC (336) 664-1233,
www.rfmd.com.
RS No. 252

Power Amplifiers

The model AHP-74052030-01 and model AHP-84052030-01 are class A power amplifiers that utilize MMIC PHEMT technology and offer performance from 71 to 76 GHz and 81 to 86 GHz, known as E-band, respectively. Both amplifiers feature 30 dB small-signal gain, 20 dBm P1dB and 22 dBm P_{sat} output power nominally. The RF connectors are WR-12 waveguide with UG387/U flange. These amplifiers feature single DC power supply and normal operation is +8 to +12 V at 3.5 A for each model. Size: 4.20" × 2.68" × 6.15".
WiseWave Technologies Inc.,
Torrance, CA (310) 539-8882,
www.wisewave-inc.com.
RS No. 253

ANTENNA

High Efficiency Antenna

The model RPCR2-36-N is a high efficiency 2' diameter antenna designed for use in the 3.6 GHz point-to-point licensed communications band. The radiation pattern conforms to ETSI EN 302 078 V1.1.1 class TS3. This model operates in a frequency range from 3.4 to 3.8 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.
mWAVE Industries LLC,
Gorham, ME (207) 857-3083,
www.mwavellc.com.
RS No. 254

DEVICES

Fast Recovery Epitaxial Diode

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Advanced Power Technology,
Bend, OR (541) 382-8028,
www.advancedpower.com.
RS No. 255

Ring Quads

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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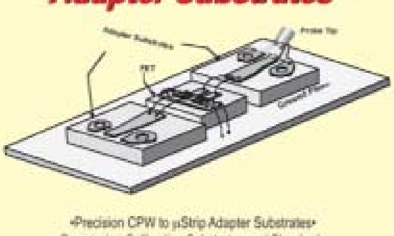

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MicroMetrics Inc.,
Londonderry, NH (603) 641-3800,
www.micrometrics.com.

RS No. 256

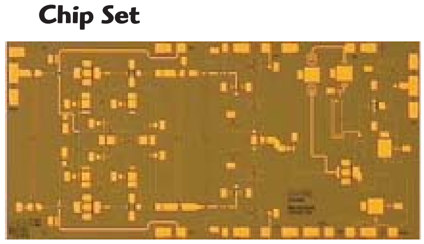
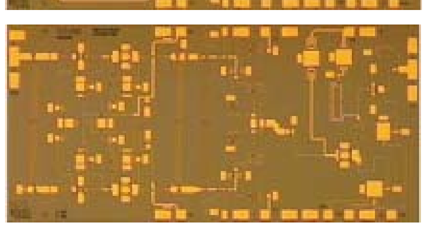
High Power PHEMT Transistors

These 10 discrete power PHEMT transistor devices utilize the 0.35 micron power PHEMT production process, offer good power, gain and efficiency performance, and are well suited for L- through Ku-band high power amplifiers. These production PHEMT devices are capable of achieving power densities greater than 1 W/mm of gate periphery. The TGF2021 family offers devices with gate peripheries ranging from 1 to 12 mm and is suited for high power amplifiers up to 12 W through X-band; the TGF2022 family of devices offers gate peripheries from 0.6 to 6 mm, sizes ideal for high power amplifiers up to 8 W through Ku-band. Delivery: stock to 12 weeks.
TriQuint Semiconductor Inc.,
Hillsboro, OR (503) 615-9000,
www.triquint.com.

RS No. 257

INTEGRATED CIRCUIT

Receiver and Transmitter Chip Set

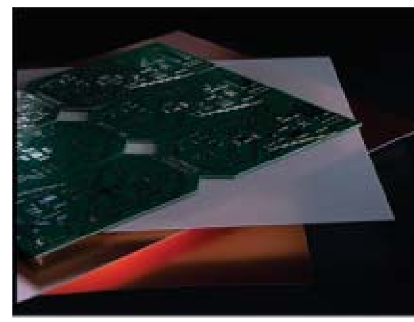



This GaAs MMIC sub-harmonically pumped receiver and transmitter chip set integrates an image reject sub-harmonic anti-parallel diode mixer, an LO buffer amplifier and a low noise amplifier for the receiver, and an output amplifier for the transmitter. The image reject mixer eliminates the need for an image bandpass filter after the amplifier to remove thermal noise at the image frequency. Using 0.15 micron gate length GaAs PHEMT device model technology, these devices cover the 18 to 25 GHz frequency bands. The receiver and transmitter pair, identified as XR1006 and XU1002 respectively, are well suited for wireless communications applications.
Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.

RS No. 258

MATERIAL

High Frequency Circuit Material

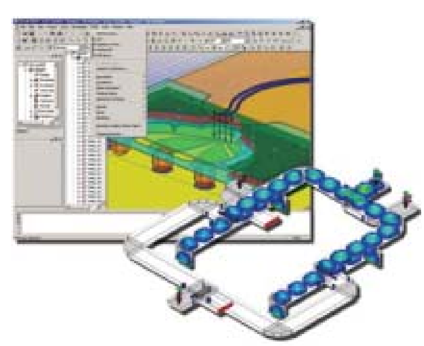


The RO4000® series of high frequency circuit material is a glass-reinforced hydrocarbon/ceramic thermoset laminate system designed for performance sensitive, high volume commercial applications. These laminates and prepregs are designed to offer good high frequency performance and low cost circuit fabrication. The result is a low loss material, which can be fabricated using standard epoxy/glass (FR4) processes.
Rogers Corp.,
Rogers, CT (860) 774-9605,
www.rogerscorporation.com.

RS No. 259

SOFTWARE

Electromagnetic Simulation Software



This recent release of Microsoft Windows® XP Professional x64 version of HFSS™ v10 of the electromagnetic field simulation software is designed for RF/microwave and high speed digital design. The migration of the electromagnetic technology to a 64-bit operating system delivers additional capacity and speed to the simulation of high performance electronic designs. Support for Windows XP Professional x64 removes the memory limitations inherent to 32-bit personal computers. HFSS users can expect to save engineering time by accessing

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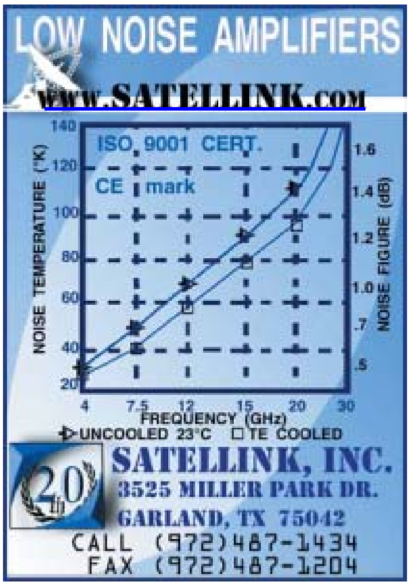

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RS No. 260

SOURCES

Frequency Multipliers

These active frequency multipliers are available in ×2, ×3, ×4 and ×5 configurations. The multipliers operate in a frequency range from 5.25 to 96 GHz. The products feature internal amplification, filtering and voltage regulation. Optional attenuation control and fault detection are also available. Output power to 2 W is available.
Phase One Microwave Inc.,
Rocklin, CA (916) 624-1445,
www.phase1microwave.com.
RS No. 261

Coaxial Resonator Oscillator

The model CRO4400A is a coaxial resonator oscillator (CRO) that utilizes voltage-controlled oscillator (VCO) technology and is geared for the point-to-multi-point radio market. This model is optimized for narrowband frequency operation and covers the 4380 to 4420 MHz frequency range within 0.5 to 4.5 VDC of control voltage and operates with an average tuning sensitivity of 16 MHz/V. The VCO offers a clean spectral signal of –105 and –128 dBc/Hz, typical, at 10 and 100 kHz from the carrier, respectively. Size: 0.50" × 0.50" × 0.22". Delivery: stock to four weeks.
Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.
RS No. 263

Temperature-controlled Crystal Oscillators

The C2260 series of temperature-controlled crystal oscillators (TCXO) is designed for use

in telecom, wireless and data communications applications. Utilizing a new generation of TCXO ICs, the C2260 series can stabilize the frequency from 6.4 MHz up to 32 MHz over a wide temperature range of –30° to +85°C to better than 0.28 ppm. The parts are fully compliant to the GR1244-Core and GR-253-Core standard. This series features temperature stability, performance and two enclosure technology advantages that include expansion coefficient and flexibility.
Vectron International,
Hudson, NH (888) 328-7661,
www.vectron.com.
RS No. 262

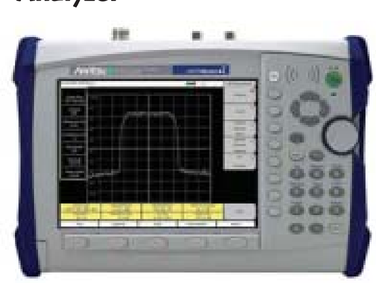
TEST EQUIPMENT

Waveform Generator

This arbitrary waveform generator (AWG) simultaneously delivers 1.25 GS/s and 10 bits of

vertical resolution for emerging communication systems, such as ultra-wideband, multiple-input multiple-output radios and advanced DSL. The model N6031A enables digital-signal-processing and systems engineers who design advanced wideband systems to rapidly create realistic orthogonal frequency division multiplexing UWB signals compliant with the multiband OFDM alliance proposal. The model N6030A and model N6031A provide up to 1 GHz of I/Q bandwidth and up to 75 dBc of spurious free dynamic range for rapidly creating realistic wideband signals. Price: $30,000.
Agilent Technologies Inc.,
Palo Alto, CA (800) 829-4444,
www.agilent.com.
RS No. 264

Ultra-portable Handheld Analyzer



The model MT8220A UMTS Master is an ultra-portable handheld Node B analyzer designed for 3G/UMTS applications. Covering the UMTS ranges of 824 to 894 MHz and 1710 to 2170 MHz, as well as 2300 to 2700 MHz, the MT8220A can conduct both RF and demodulated measurements. In addition, it functions as a spectrum analyzer with continuous frequency coverage up to 7.1 GHz, with dis-

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Model #	Frequency (MHz)	Tuning Voltage (VDC)	Typical Phase Noise @10 kHz (dBc/Hz)	Bias Voltage (VDC)
DCFO Series				
DCFO35105-5	350 to 1050	0 to 25	-112	+5
DCMO Series				
DCMO514-5	50 to 140	0.5 to 24	-105	+5
DCMO1027	100 to 270	0 to 24	-112	+5 to +12
DCMO1129	110 to 290	0.5 to 24	-112	+5 to +12
DCMO1545	150 to 450	0.5 to 24	-108	+5 to +12
DCMO1857	180 to 570	0.5 to 24	-108	+5 to +12
DCMO2476	240 to 760	0.5 to 24	-105	+5 to +12
DCMO3288-5	320 to 880	0.5 to 24	-109	+5
DCMO60170-5	600 to 1700	0 to 25	-99	+5
DCMO100230-12	1000 to 2300	0.5 to 24	-101	+12
DCMO100230-5	1000 to 2300	0.5 to 24	-98	+5
DCMO150318-5	1500 to 3200	0.5 to 20	-93	+5
DCMO150320-5	1500 to 3200	0.5 to 20	-95	+5
DCMO190410-5	1900 to 4100	0 to 15	-90	+5

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RS No. 265

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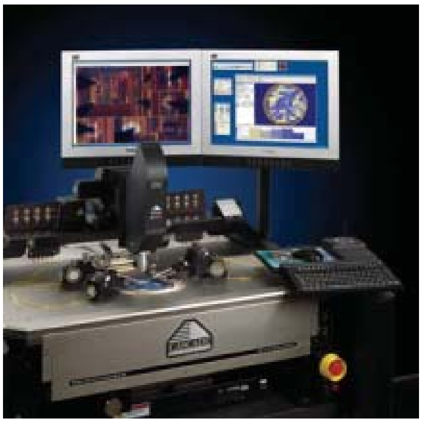

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Cascade Microtech Inc.,
Beaverton, OR
(503) 601-1000,
www.cascademicrotech.com.

RS No. 266

Arbitrary/Function Generator

The AFG3000 series of arbitrary/function generators consists of six models that shorten test time and reduce time from design to market. The series features an architecture based on a powerful "generator on a chip" ASIC and the platform's user interface is straightforward and easy to use. These models address the problem for engineers, who need to test electronic circuits with one or more signal inputs and sine waveforms at frequencies up to 240 MHz, generate arbitrary waveforms up to 2 GS/s, obtain up to 1 ppm clock stability and who desire an intuitive graphical user interface.

Tektronix Inc.,
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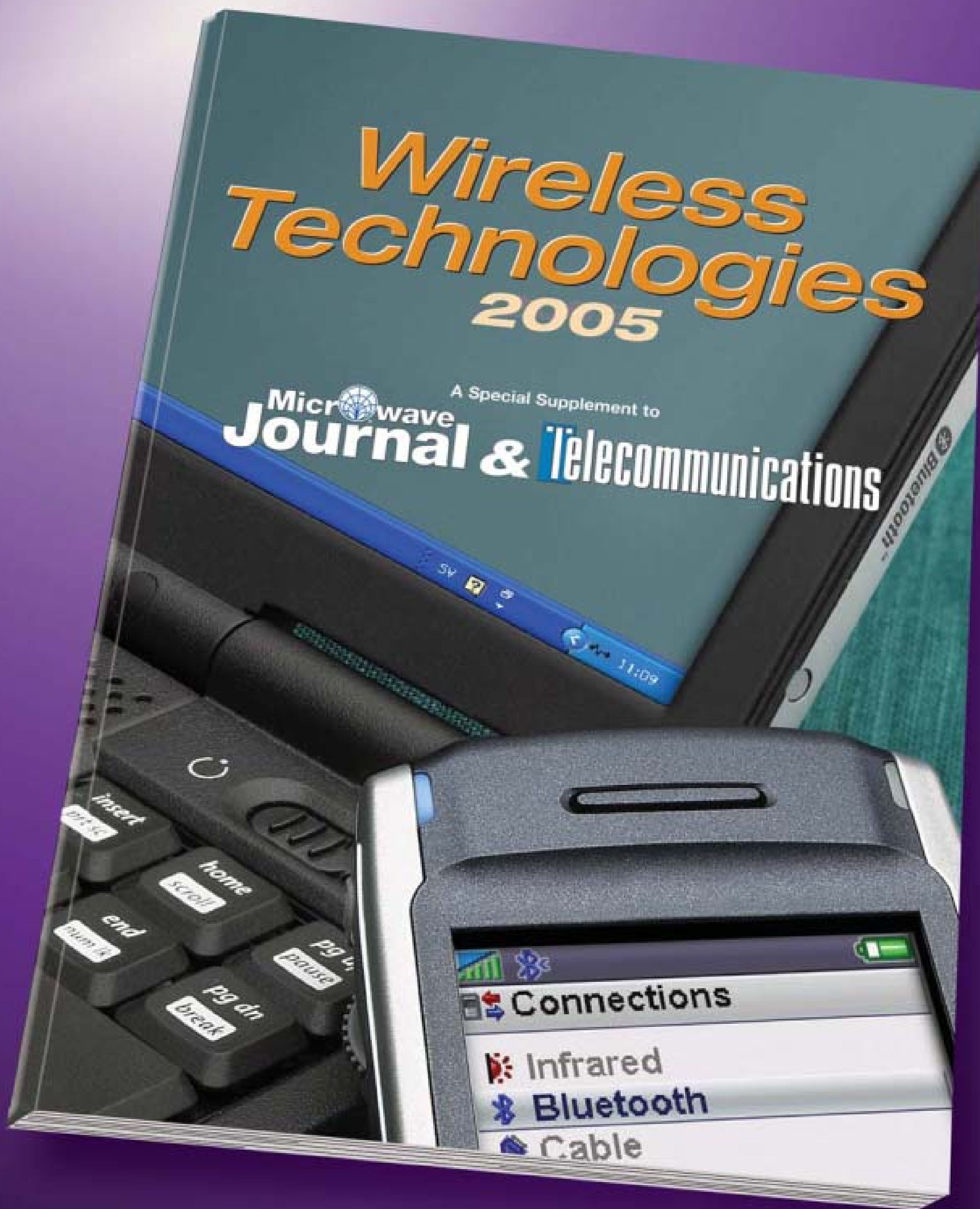

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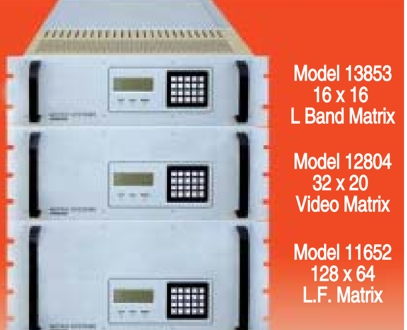

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AR Worldwide Modular RF,
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LTCC Design Guidelines

These LTCC Design Guidelines are for foundry and components. The company brings state-of-the-art packaging and circuit realization to the microwave and RF field to aid customers with LTCC designs. The company provides a complete range of services from circuit concept, mechanical and electrical modeling, to final production.
Barry Industries Inc.,
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This 300-page catalog presents standard products and customized solutions in IF/RF and microwave frequencies. Besides an expanded line of control products, the catalog adds multifunction assemblies and five categories of amplifiers – low noise, driver, high power, narrow and broad bandwidth, and 27 MHz to 20 GHz.
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This 2005/2006 catalog includes new products such as the company's complete family of WiMax antennas, new sector antennas for 3.5 GHz fixed wireless networks, new 4.9 GHz series antennas for public safety and new high frequency licensed band antennas.
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This frequency control components databook details the company's full line of RF amplifiers, low phase noise amplifiers, mixers, VCOs, DROs, limiters, limiting amps, detectors, attenuators and switches. The 900-page plus databook provides all the information needed to evaluate and choose the right frequency control components designed from recently acquired companies of Amplifonix, Magnum Microwave, Q-bit and Radian Technologies.
Spectrum Microwave Inc.,
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Folder Compilation

This folder is a compilation of material that highlights the company's quick circuit prototyping systems. The folder provides several data sheets that include a detailing of the products along with a complete overview of its Quick Circuit® system.
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This Blind Mate™ Antenna Solutions brochure describes its Blind Mate "plug-in and forget" quick release antenna mount. The Blind Mate system enables avionic and electronic warfare antennas to be quickly installed and removed from platforms without having to connect or disconnect the coaxial cable.
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Market Applications Brochure

These four market brochures display the company's capabilities in the areas of missiles and radar, C4I, electronic warfare and space. The company designs and manufactures high performance, high reliability RF and microwave devices and subsystems with hardware found on numerous military, space and commercial platforms.
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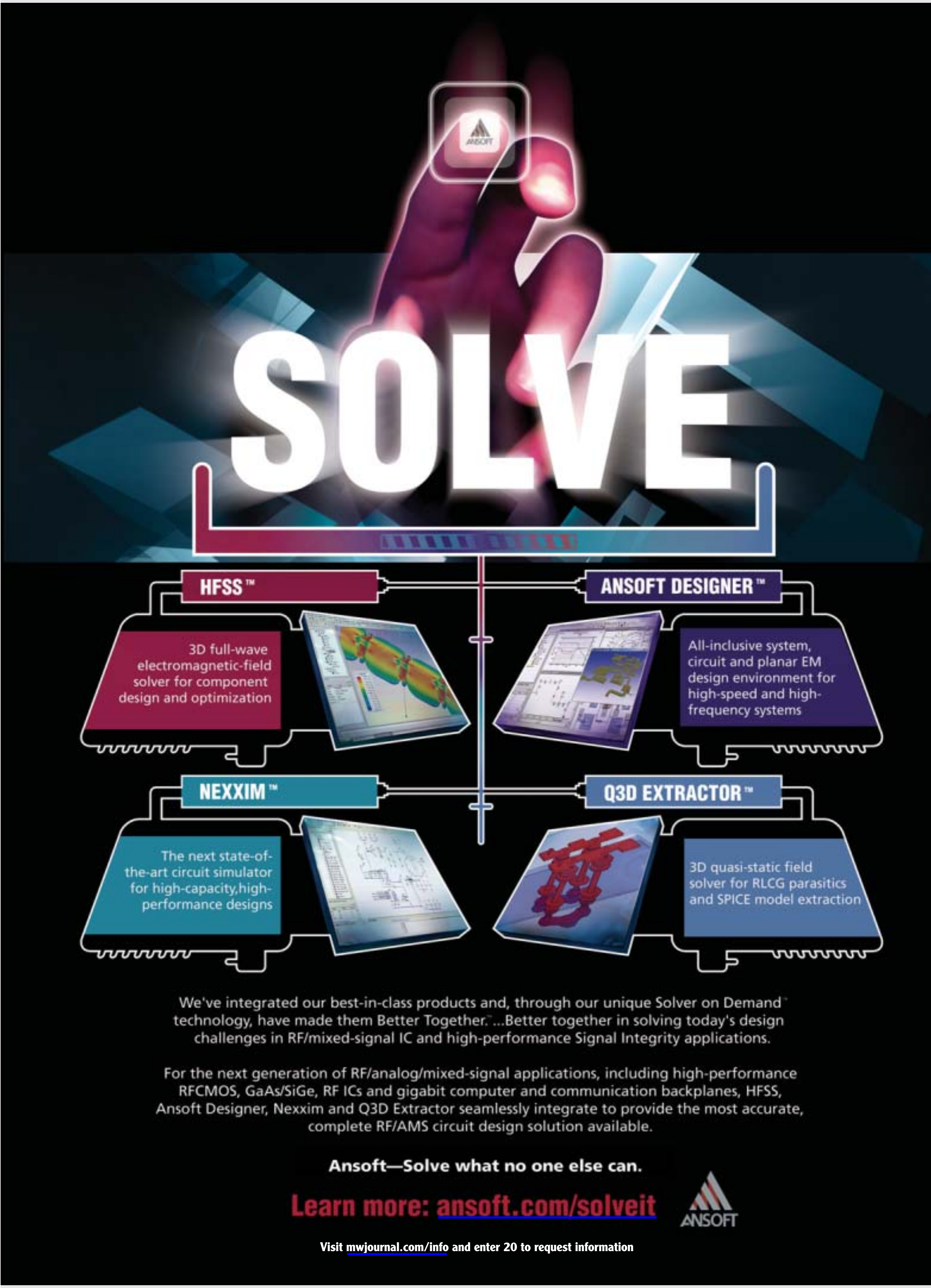

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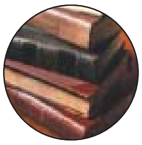

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Negative-Refraction Metamaterials: Fundamental Principles and Applications

George V. Eleftheriades and Keith G. Balmain, Eds.

Wiley-IEEE Press
433 pages; $74.95
ISBN: 0-471-60146-2

Metamaterials represent an exciting emerging research area that promises to bring about important technological and scientific advancements in diverse areas such as telecommunications, radar and defense, nanolithography with light, microelectronics, medical imaging, etc. This book includes contributions from some of the top experts in the field in an effort to document in an authoritative and understandable way the most important and most recent developments. In this book, both artificial dielectric and photonic crystal types of materials are covered. However, its scope is restricted to metamaterials that support the "unusual" electromagnetic property of negative refraction. Chapter 1 describes the fundamentals of isotropic metamaterials in which a simultaneous negative permittivity and permeability, hence a negative refracting index, can be defined. Chapter 2 builds upon these fundamentals in order to describe a range of useful microwave devices and antennas. Chapter 3 develops in a comprehensive manner the theory and experiments behind a super-resolving, negative-index, planar transmission-line lens. Chapter 4 describes numerical simulation studies of negative refraction of Gaussian beams and associated focusing phenomena. Chapter 5 exposes the theory and the unique advantages of shaped lenses made out of negative-refractive-index metamaterials. Chapter 6 introduces a new kind of transmission line metamaterial that is anisotropic and supports the formation of sharp beams called resonance cones. Chapter 7 explains how to obtain negative refraction and associated super-resolving imaging effects using dielectric photonic crystals. Chapter 8 prescribes a method for realizing negative-refractive-index metamaterials using plasmonic (metallic) nanowires. Chapter 9 deals with the unusual propagation phenomena in metallic waveguides partially filled with metamaterials. Finally, Chapter 10 introduces metamaterials in which the refractive index and the underlying group velocity are both negative.

> ***"...its scope is restricted to metamaterials that support the 'unusual' electromagnetic property of negative refraction."***

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Measurement Systems and Sensors

Waldemar Nawrocki

Artech House
336 pages; $95, £58
ISBN: 1-58053-945-9

Modern measurement systems make extensive use of computers and sensors to increase the speed and the accuracy of the desired data acquisition. This book offers a comprehensive coverage of the status of the present measurement technology. Chapter 1 starts with a description of computer-based measurement systems. Chapter 2 describes sensors and electrical circuits for temperature measurements, such as resistive sensors, thermocouples and semiconductor devices. Stress and pressure sensors are the subjects of Chapter 3. Resistance and capacitance strain gauges convert a change in dimension into an electrical signal. Piezoelectric sensors convert a force into an electric voltage. The measurement signal at the output of the sensors is an analog quantity, which must be converted into digital signals in order to be processed in computer systems. This conversion is described in Chapter 5. Chapter 6 is devoted to wired measurement systems with a serial interface, where the bits are transmitted one by one, timed by a synchronizing clock. Chapter 7 describes wireless transmission systems that are the only ones possible when the measured object is moving, is a long distance away from the measurement center or is hardly accessible. Parallel transfer of digital data offers a much higher data rate than serial transfer, but uses wired channels only. The dominant parallel interface standard is the IEEE-488 (IEC-625) standard that is described in Chapter 8. Chapter 9 considers crate and modular measurement systems, where instruments are arranged in crates, also referred to as chassis or main frames containing functional modules. Chapter 10 covers LAN-based measurement systems. These computer network-based solutions represent an important trend in the evolution of measurement systems. Chapter 11 is dedicated to DAQ boards and virtual instruments, supporting multi-channel measurements, performing different functions, and sending analog and digital activation or test signals to the measurement system.

> ***"...a comprehensive coverage of the status of the present measurement technology."***

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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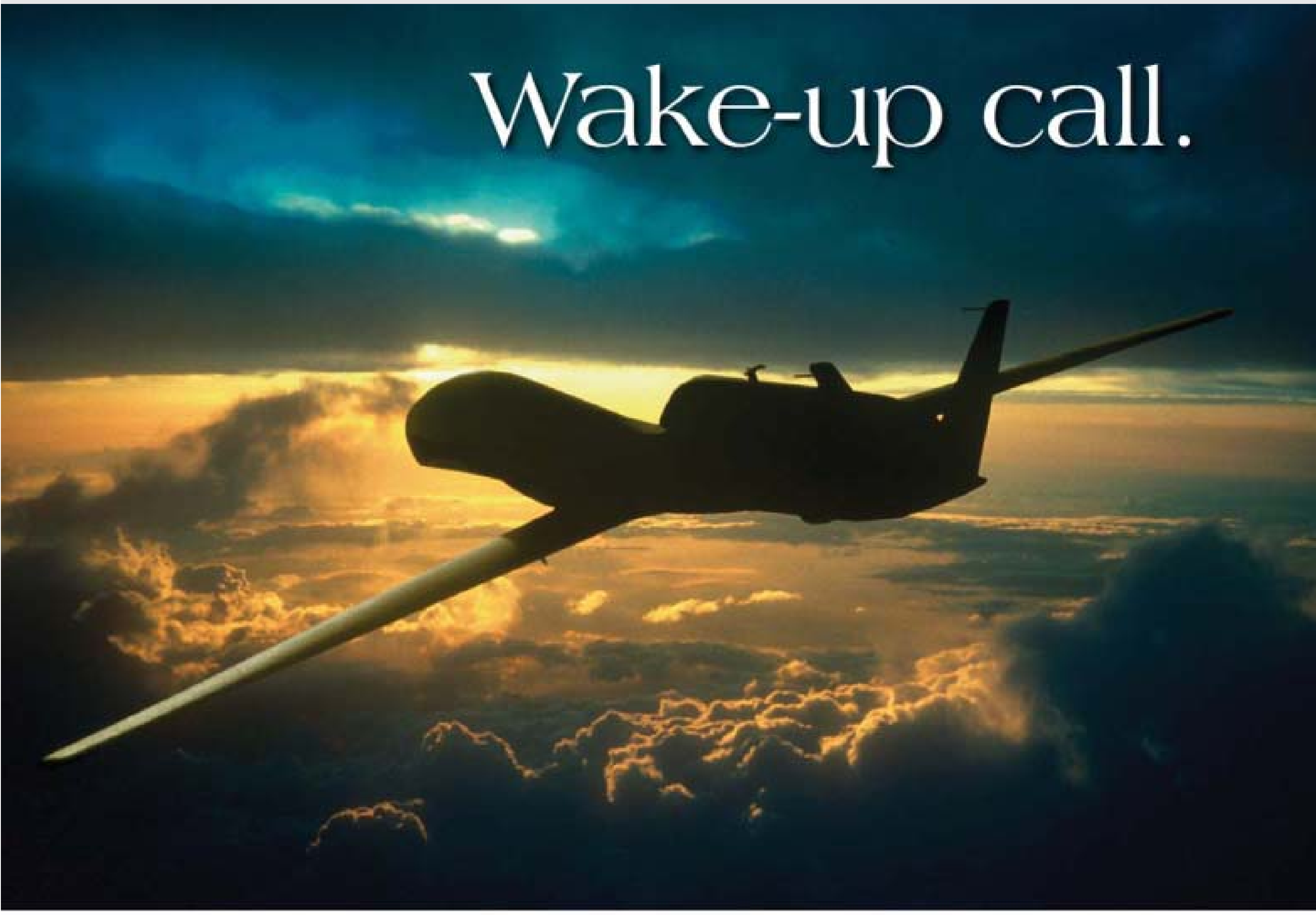

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C7148	60-600	10 ± 0.5	1.0	0.3	1.20:1	20	200	2000
C7149	60-600	20 ± 0.5	1.0	0.3	1.20:1	20	200	2000
C7113	100-1000	6 ± 0.5	1.0	0.35	1.20:1	20	200	2000
C7126	100-1000	10 ± 0.5	1.0	0.3	1.20:1	20	200	2000
C7127	100-1000	20 ± 0.5	1.0	0.2	1.20:1	20	200	2000
C7150	200-2000	6 ± 0.5	1.0	0.25	1.20:1	20	200	2000
C7058	200-2000	10 ± 0.5	1.0	0.25	1.20:1	20	200	2000
C6600	200-2000	20 ± 0.5	1.0	0.25	1.20:1	20	200	2000
C7151	300-3000	10 ± 0.5	1.0	0.35	1.20:1	20	100	1000
C7152	300-3000	20 ± 0.5	1.0	0.35	1.20:1	20	100	1000
C7153	400-4000	10 ± 0.5	1.0	0.35	1.20:1	20	100	1000
C7154	400-4000	20 ± 0.5	1.0	0.35	1.20:1	20	100	1000

*Excludes theoretical coupled power.
**Specifications subject to change.

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