Vol. 51 • No. 12

December 2008

Microwave Journal

www.mwjournal.com

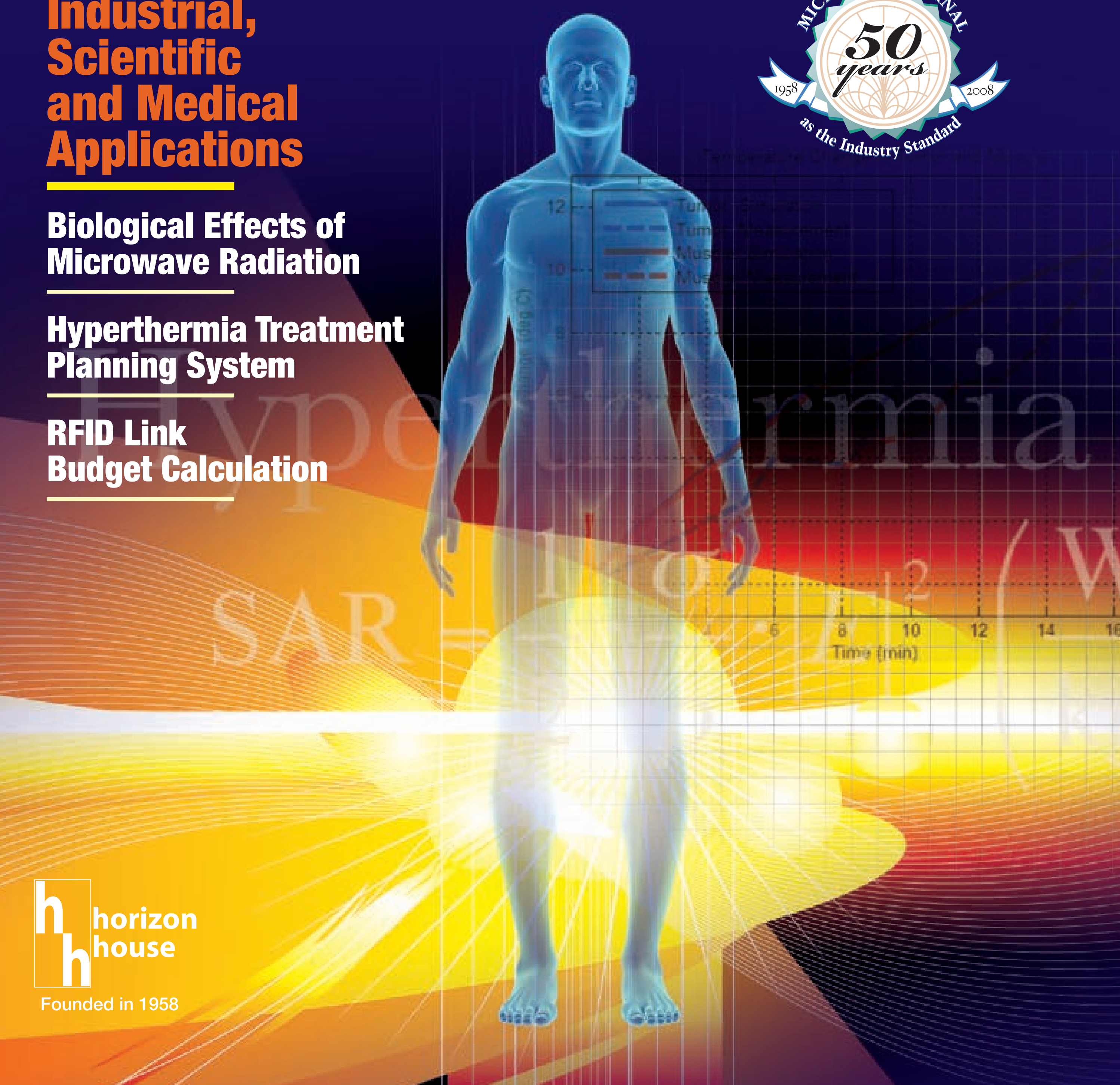
MICROWAVE JOURNAL 50 years 1958 2008 as the Industry Standard

Industrial, Scientific and Medical Applications

Biological Effects of Microwave Radiation

Hyperthermia Treatment Planning System

RFID Link Budget Calculation



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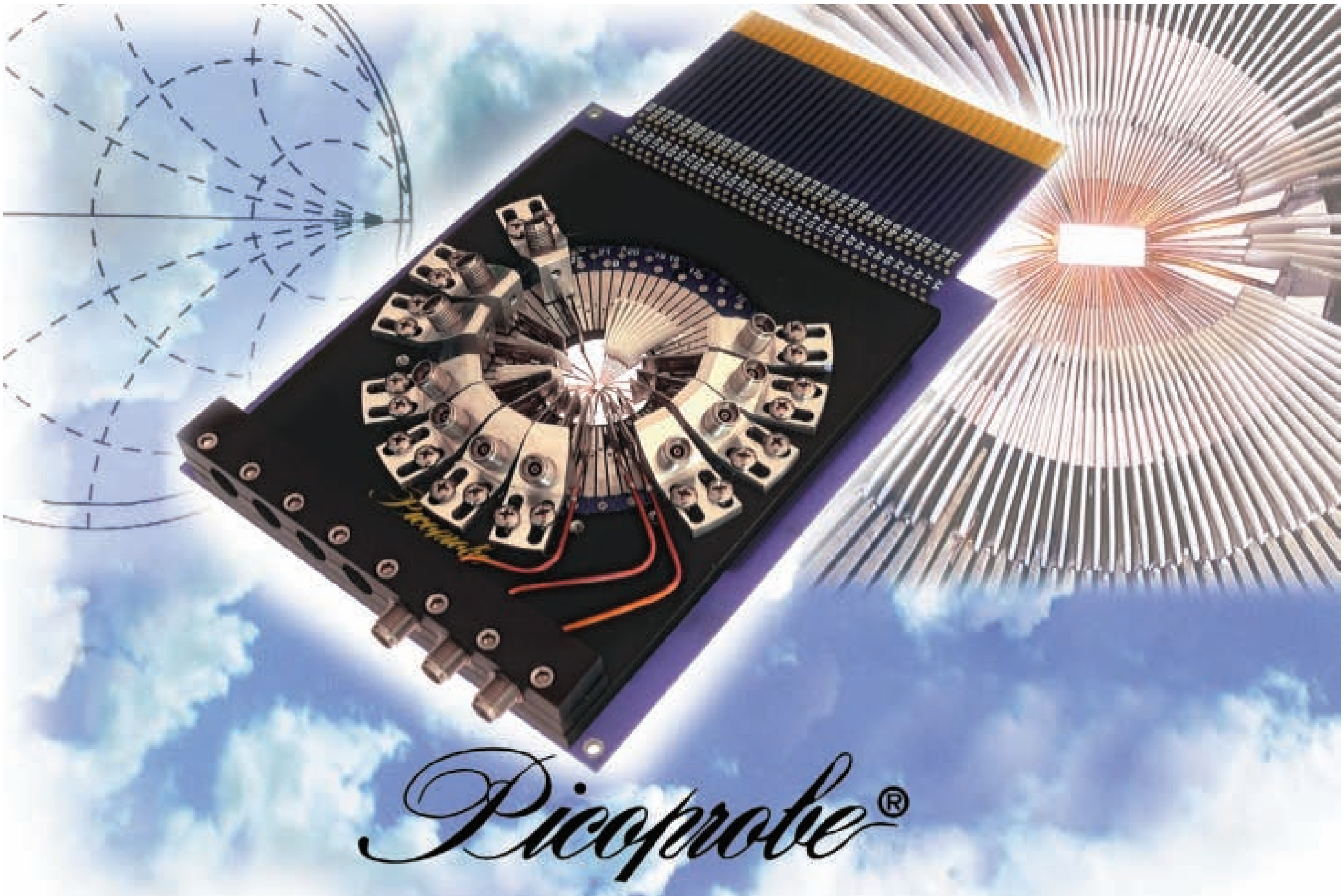

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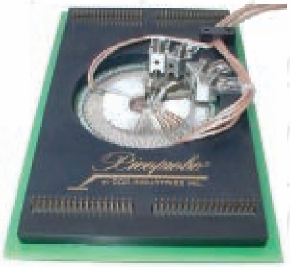

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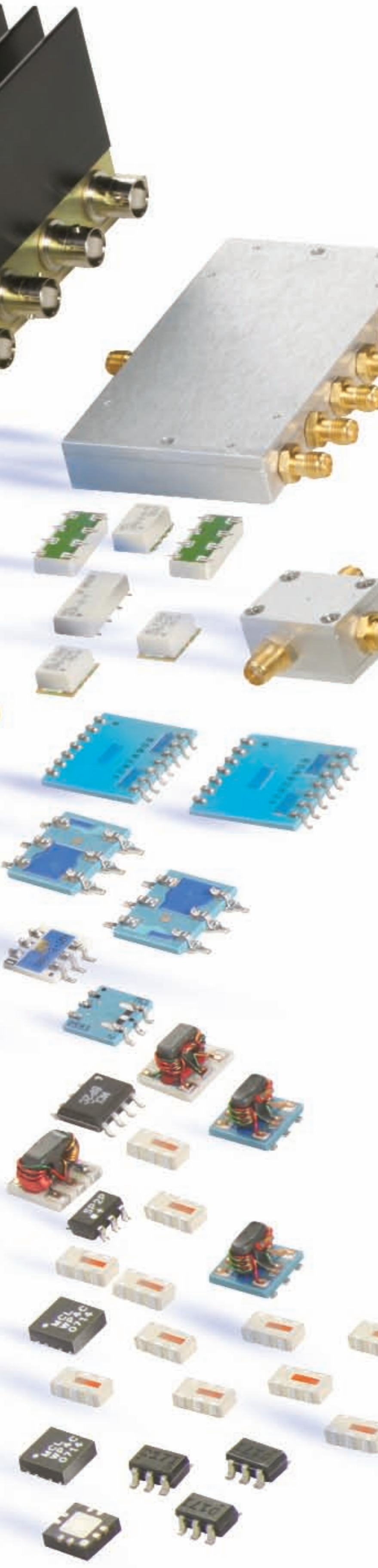

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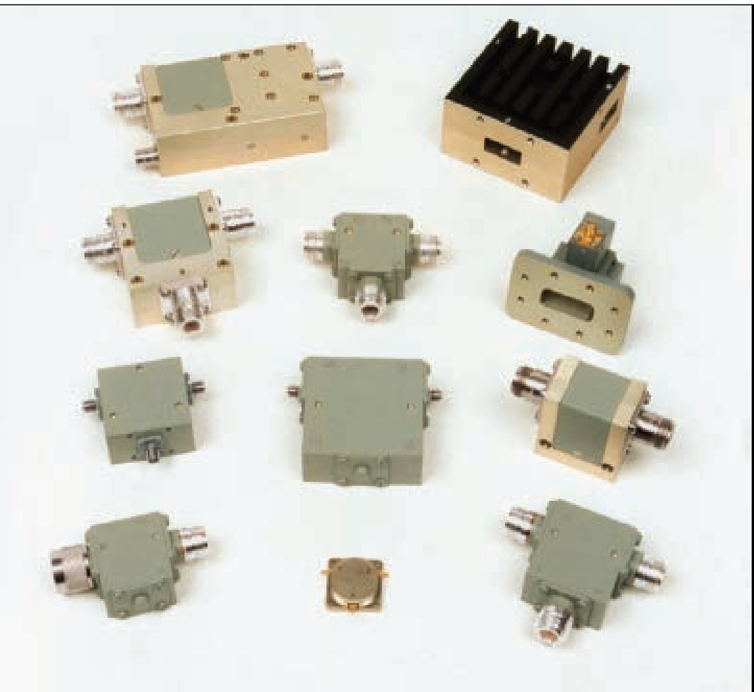

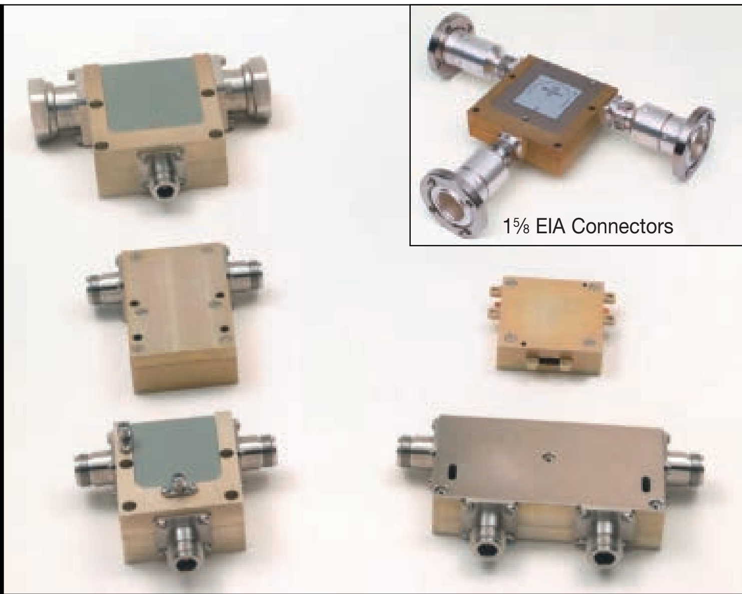

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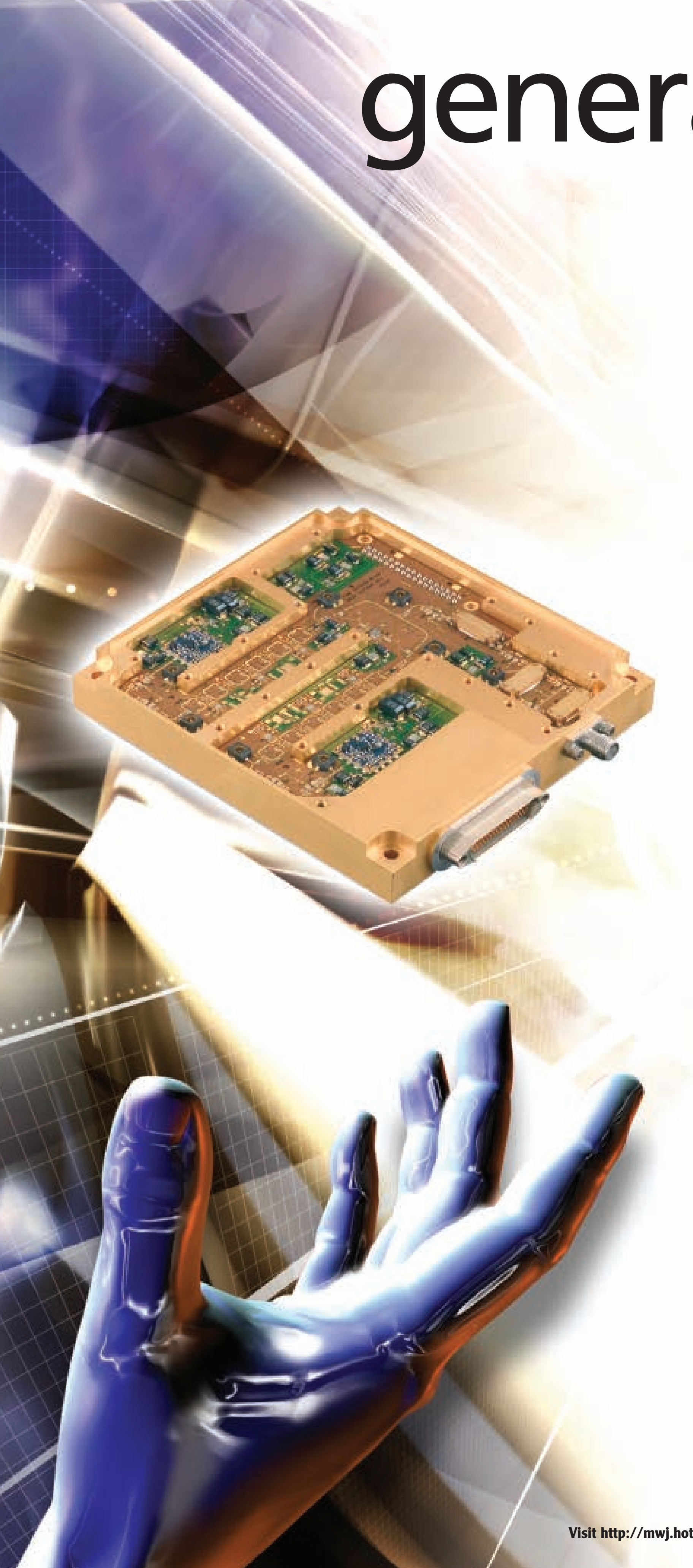

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  - *Input Noise Temperature Measurement*
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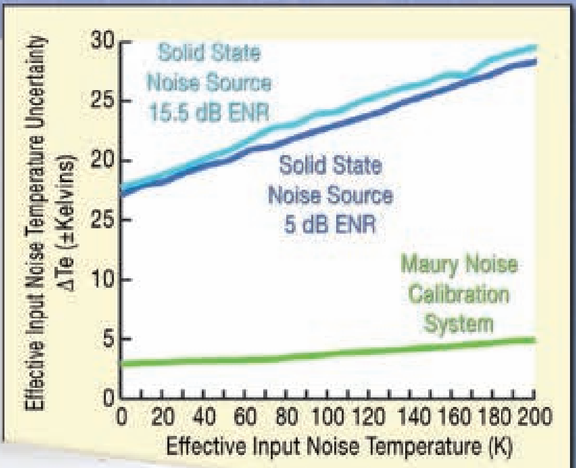

*Each NCS consists of two (one hot and one cold) or three (one hot, one ambient and one cold) thermal noise sources whose outputs can be easily switched into a common calibrated output port. The output switch makes operation of the NCS in a noise performance measurement as simple as using a solid state noise generator **— without the associated accuracy penalty**.*

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NOTE FROM THE EDITOR

COVER FEATURE: THEN AND NOW

TECHNICAL FEATURES

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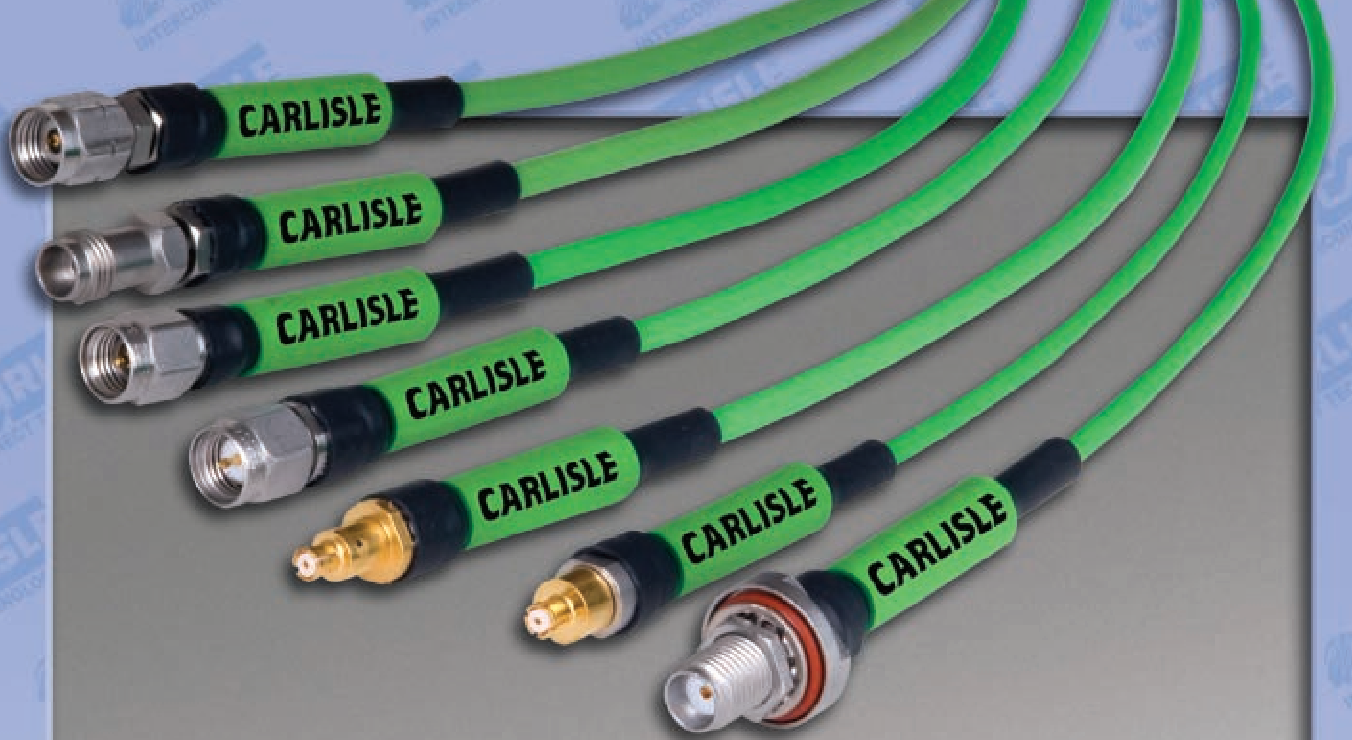

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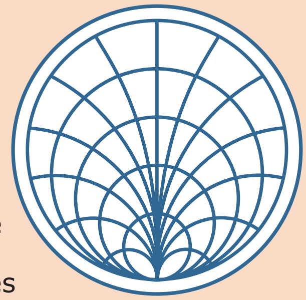

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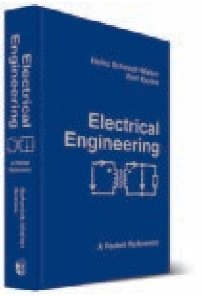
Multi-Technology Devices
Laurent Desclos, Ethertronics Inc.

Integer-N PLL Local Oscillator for Satellite Telecommand Receiver
M. Mohiyuddin, R. Kumar M, J. Mathew and P. K. Pandey, ISRO Satellite Centre

Expert Advice

Pierre Piel is the lead RF application engineer for the RF Power Emerging Markets group at **Freescale Semiconductor.** He has more than eight years experience in RF power design and application engineering. Pierre talks about the opportunities for microwave devices in industrial, scientific and medical applications.



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The *Microwave Journal* blog is where our editors park their thoughts on the news items affecting our industry. We provide quick snapshots of what is happening in the microwave world - the serious and the amusing. Will microwaves ease 4G backhaul? What's the latest in IMD measurements? Do engineers make good presidents?

http://microwavejournal.blogspot.com

Executive Interview

MWJ talks to **Bryan Ingram,** vice president and general manager of the **Wireless Semiconductor Division (WSD)** for **Avago Technologies,** about the largest independent semiconductor company in the world, the wireless infrastructure market and the company's fixation on micro-miniaturization.

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150-70	dc-18.0	0-70/10	
150-70-1	dc-18.0	0-70/10	
151-11	dc-4.0	0-11/1	
152-90-3	dc-26.5	0-90/10	
150T-11	dc-18.0	0-11/1	◆
150T-15	dc-18.0	0-15/1	◆
150T-31	dc-18.0	0-31/1	◆
150T-62	dc-18.0	0-62/2	◆
150T-70	dc-18.0	0-70/10	◆
150T-75	dc-18.0	0-75/5	◆
150T-110	dc-18.0	0-110/10	◆
151T-110	dc-4.0	0-110/10	◆
152T-55	dc-26.5	0-55/5	◆
153-70	dc-40	0-70/10	New
153-110	dc-40	0-110/10	New

Model	Frequency Range (GHz)	Attenuation Range (dB)	Notes
3200-1	dc-2.0	0-127/1	
3200-2	dc-2.0	0-63.75/.25	
3200-1E-2	dc-3.0	0-127/1	
3200-2E-2	dc-3.0	0-63.75/.25	
3201-1	dc-2.0	0-31/1	
3201-2	dc-2.0	0-120/10	
3206-1	dc-2.0	0-63/1	
3200T-1	dc-2.0	0-127/1	◆
3206T-1	dc-2.0	0-63/1	◆
3250T-63	dc-1.0	0-63/1	◆ X
3406-55	dc-6.0	0-55/1	New
3408-55.75	dc-6.0	0-55.75/0.25	New
3408-103	dc-6.0	0-103/1	New
4216-63	0.8-3.0	0-63/1	
4218-127	0.8-3.0	0-127/1	
4238-103	.01-2.5	0-103/1	

Notes: ◆ SmartStep® Control Circuitry, X = 75 Ohm Model
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JOURNALISM IN TRANSITIONAL TIMES

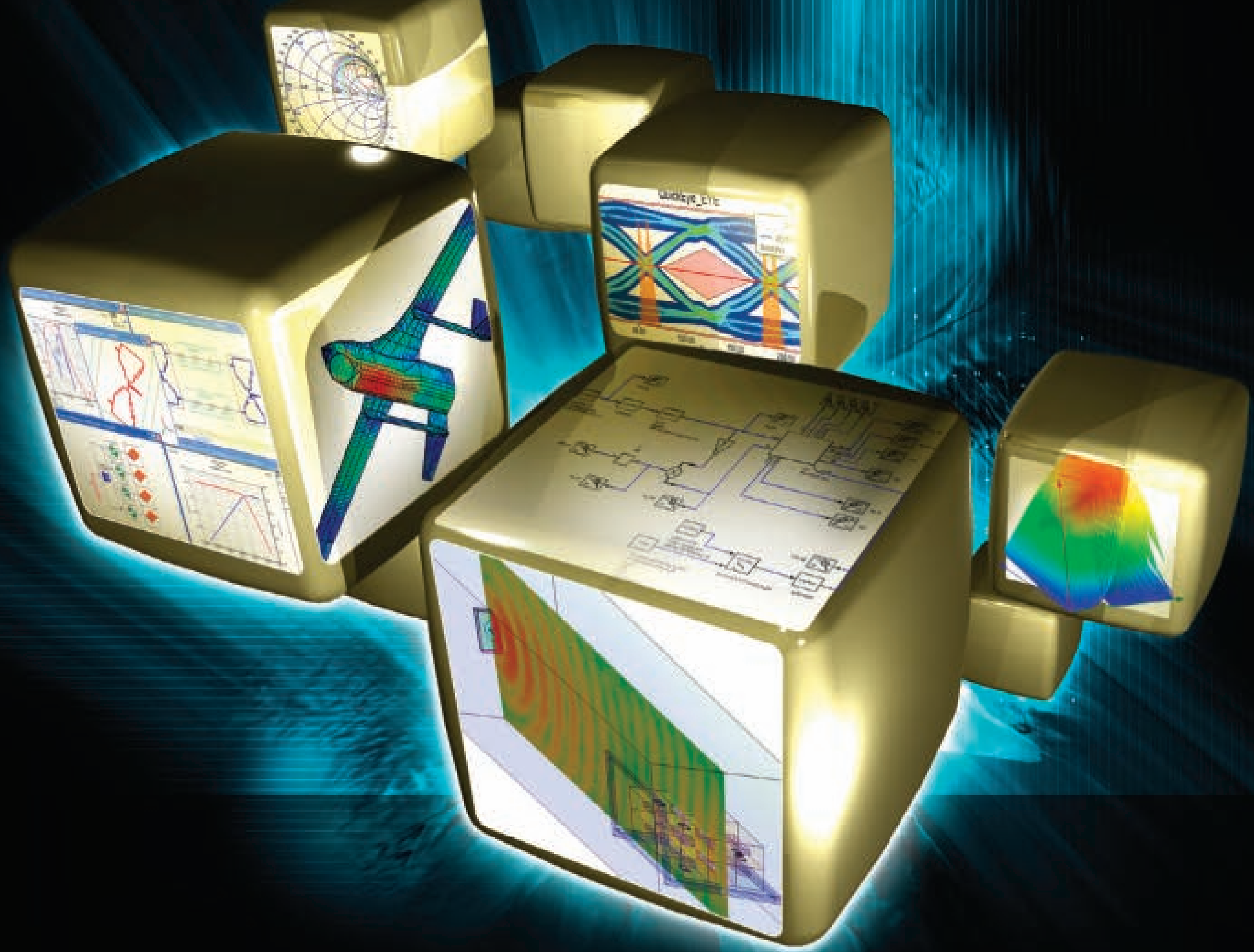
DAVID VYE, *Microwave Journal* Editor

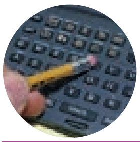
This issue concludes our celebration of 50 years serving the microwave industry. We hope you have enjoyed this yearlong look at our shared history—the reprints of past articles and special retrospective reports, as well as the projections of the future by all our guest contributors.

Without a doubt, 2008 was a transformational year for the entire world—politically, economically and socially. Last January, few could have predicted what would transpire over the next 12 months, except for those with the right information. Certain commodities traders undoubtedly saw data suggesting insufficient oil reserves for the upcoming high demand summer months and on speculation drove the price of gas to a point that shocked the rest of us. Certain insiders saw a presidential campaign so well organized that it would beat the odds despite the barriers of race, relative inexperience and an unfamiliar name. I have yet to hear of anyone who truly foresaw the extent of the current financial market meltdown; perhaps some things, like complex, unregulated securities and human greed, are beyond prediction.

Change is inevitable, yet knowledge turns the surprising into the predictable. Evolutionary change is a slow and deliberate process that transforms the vision of a certain future into the reality of the present. Even disruptive change, characterized by an abrupt event, is usually preceded by a long, slow effort occurring under the radar of the general public. At this year's WiMAX World in Chicago, IL, a very heated discussion between the merits of WiMAX versus LTE was held during the executive summit. LTE was championed as evolutionary change by its proponents, while WiMAX was positioned as disruptive change. People tend to like evolutionary change. It is smooth and gradual and easy to digest. Yet disruptive change is often responsible for putting technical advancement on a new growth path that leads to even greater opportunity. Both forms of change are critical to the advancement of our profession and next year we will turn the editorial microscope on the evolutionary and the disruptive.

Meanwhile, this past year was filled with evolutionary change at the *Journal*. Our editors Harlan Howe and Frank Bashore, former publisher Howard Ellowitz and associate publisher Ed "The Colonel" Johnson all retired, while technical editor Patrick Hindle joined our staff. (Note: Frank and Harlan remain active members of our editorial review board). Our long-running "Ask Harlan" feature was transformed into the "Expert Advice" column, replacing Harlan's expertise with that of a guest expert each month and 15,000 visitors to our site read what they had to say. Roughly 20,000 engineers and managers joined us for our monthly RF/MW training webinars with Besser Associates. Thousands of you came to our IMS and EuMW online show daily web site and read our blog, downloaded our podcasts and checked out the videos shot from the exhibition hall with companies participating in our Virtual Trade Booths. Next year, you can expect more enhancements to both our print and online mediums. In an ever-changing world, we intend to utilize all available means to keep our readers informed and aware. After all, surprises should be reserved for parties—like when turning 60. ■





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DECEMBER

ASIA PACIFIC MICROWAVE CONFERENCE (APMC 2008)
December 16–19, 2008 • Hong Kong, China
December 19–20, 2008 • Macau, China
www.apmc2008.org

JANUARY

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January 18–22, 2009 • San Diego, CA
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MOBILE WORLD CONGRESS
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www.mobileworldcongress.com

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www.satellite2009.com

APRIL

CTIA WITH RF, MICROWAVE AND M2M ZONES
April 1–3, 2009 • Las Vegas, NV
www.ctiawireless.com

IEEE WIRELESS AND MICROWAVE TECHNOLOGY CONFERENCE (WAMICON 2009)
April 20–21, 2009 • Clearwater, FL
www.wamicon.org

JUNE

IEEE RADIO FREQUENCY INTEGRATED CIRCUITS SYMPOSIUM (RFIC 2009)
June 7–9, 2009 • Boston, MA
www.rfic2009.org

IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM (IMS 2009)
June 7–12, 2009 • Boston, MA
www.ims2009.org

AUGUST

IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY (EMC 2009)
August 17–21, 2009 • Austin, TX
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■ **Topics:** The CST user group meeting offers an informal and enlightening environment where developers and researchers using CST's leading-edge simulation tools, CST STUDIO SUITE™ and CST MICROSTRIPES™, can present and discuss their work to a wide audience of interested parties.
■ **Site:** Darmstadt, Germany
■ **Dates:** March 16–18, 2009
■ **Contact:** For more information, visit www.cst.com.

Modern Wireless Data Communications

■ **Topics:** This course is tailored to end users, technology planners, decision makers and implementers who need an understanding of both how wireless works and what the technology can do. The information starts at an introductory level and progresses into coverage of the more technical material at an intermediate depth. You will gain a thorough and intuitive understanding of the subject matter, without delving into the complex underlying mathematics or theory. For more information, visit http://epdweb.engr.wisc.edu/.
■ **Site:** Madison, WI
■ **Dates:** April 20–22, 2009
■ **Contact:** University of Wisconsin-Madison, Department of Engineering Professional Development, 432 North Lake Street, Madison, WI 53706 (800) 462-0876.

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■ **Topics:** Fairchild's power experts bring you the latest in design techniques for optimizing system power. This one-day event provides insight into analog, discrete and optoelectric solutions. The registration fee includes lunch and a copy of all presentations and white papers. For more information, visit www.fairchildsemi.com.
■ **Site:** For location information, please visit url.
■ **Dates:** For date information, please visit url.
■ **Contact:** Fairchild Semiconductor Corp., 82 Running Hill Road, South Portland, ME 04106 (207) 775-8100.

Semiconductor Devices for IC Design

■ **Topics:** This course provides an in-depth and comprehensive understanding of the basic characteristics of semiconductor devices plus their second-order effects and device modeling that enable a circuit designer to cope with ever-increasing bandwidths of state-of-the-art designs. This course is intended for working professionals who are interested in understanding semiconductor devices and their modeling for integrated-circuit design. Many topics in BJT and MOS are covered.
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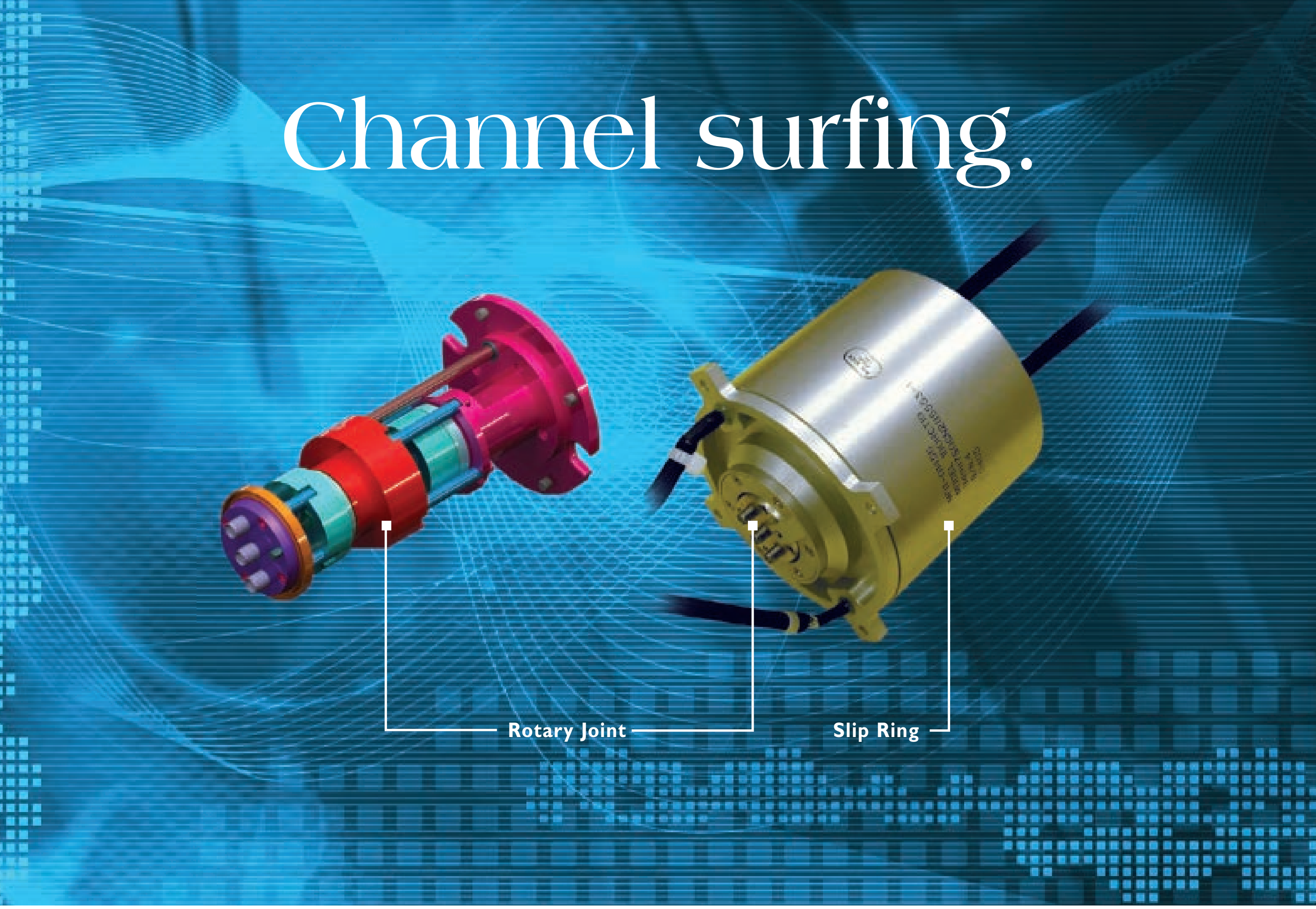

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SYMPOSIUM ON THE BIOLOGICAL EFFECTS AND HEALTH IMPLICATIONS OF MICROWAVE RADIATION

A REVIVAL OF THE MICROWAVE-BIOLOGY FIELD?

DR. JOHN M. OSEPCHUK

In the ten years preceding the last Tri-Service Symposium (1960) on the "Biological Effects of Microwaves," a considerable community of researchers participated in the study of interaction of microwaves with biological systems, particularly animals and man. Military standards were confirmed at 10 mw/cm² maximum permissible exposure levels based on the conclusion that all significant effects were thermal in nature.

There has been little activity in this field until this year. If the recent symposium held in Richmond, Va. on Sept. 17 - 19 is any indicator, however, there is a revival of interest despite little new knowledge. This conference was sponsored by the Bureau of Radiological Health (BRH of the Department of HEW) and the Medical College of Virginia partly with the aim of providing new information for BRH in its new safety standards work in the field of microwaves.

The registered attendance at the Symposium is described in Table I. Most of the researchers and authors were those who were active in the Tri-Service Symposia. The new element in this field is the large and dominant interest played by HEW-related groups following the granting of authority to HEW for setting radiation-safety standards over a broad spectrum of electronic products.

After hearing papers for two days on "biological effects" a panel was asked the third day if it was premature to consider lowering the US-accepted 10 mw/cm² standard. The majority of experts on the panel and in the audience responded that it was premature for reasons of adequacy of present standards or lack of new knowledge. The minority who supported immediate reduction of the standard based their arguments on the possibility of subtle non-thermal effects as reported by the Soviets. In fact most of this group were relatively new in non-ionizing radiation and evidently feel from long experience in the ionizing radiation field that a reluctant acknowledgement of the correctness of Soviet standards is sure to come. These, in brief, permit whole body exposure of 10 μw/cm² for a whole working day, 100 μw/cm² for two hours daily, and 1 mw/cm² for 15 - 20 minutes per day.

The content of the symposia ranged from speculation on the unknown to a review of previous work substantiating present U. S. standards. Dr. Cleary of the Medical College of Virginia posed many questions on understanding of thermal effects, frequency "specificity", peak power effects, central nervous system effects, multiple-source effects, cumulative effects, effects due to the microwave B field, measurement techniques, and mechanisms of non-thermal effects. An authoritative review by Dr. Schwan (Penn. U.) of previous work concluded that most significant effects are thermal and there is no evidence for "non-thermal" effects at levels below those at which thermal effects are significant. His review of absorption coefficients of a human body suggested that absorbed power density at most is equal to incident power density and that any "hot spots" are not likely to be dramatic. Dr. Schwan proposed a consideration of current density as a more general exposure parameter than power density and estimated maximum safe levels of around 3 mA/cm² as equivalent to present U. S. standards.

Dr. Hanlon of HEW called for more research and standards work, and said "pure science must come to grips with applied politics." He also cautioned that it is clear that technology is emphasizing new electronic products for individuals and home use and "has not been assiduous in insuring safety of these devices under *any* conditions of operation."

A review of microwave cataracts by Dr. Russell Carpenter was followed by a report by Dr. Zaret who has observed 42 of the 44 recorded microwave cataracts, mostly since 1964. A group from Temple University and Ark Electronics reported on studies of radiation effects of either E or B fields at low frequencies around 5 to 30 MHz. Their conclusions are that thresholds for biological hazards in near fields at these frequencies are at much higher field intensities than the values which correspond to 10 mw/cm². A proposed formula for reduction of the radiation protection guide level of 10 mw/cm² for high temperature and/or humidity was presented by W. W. Mumford of Bell Labs. This would drop the guide level from 10 to 1

TABLE I

Attendees at Symposium on the Biological Effects and Health Implications Of Microwave Radiation

September 17-19, 1969, Richmond, Virginia

	Attendees	(Speakers)	
Government			
HEW related groups	69	(6)	
State, County, and City health depts.	12		
Military (incl. NASA)	35	(4)	
Other Fed. Agencies (AEC, FAA, FTC, NBS)	9	(4)	
	—		Total 125 (14)
Industry			
Oven manufacturers	21	(2)	
Other industry	44	(2)	
	—		Total 65 (4)
Public			
Universities	52	(20)	
Independent and non-profit institutions	20	(4)	
Medical*	7		
Insurance companies	2		
Labor Unions	1		
	—		Total 82 (24)
Registered Attendees			Grand Total** 272

** Since general attendance ranged up towards 400 it is concluded that there were as much as 100 other non-registered attendees such as HEW personnel or students during the Symposium.

* Note also that a large proportion of attendees under "university" or "military" are in medically related professions.

36 the microwave jour

mw/cm² as the THI index varied from 70 to 80. Dr. Sol Michaelson (University of Rochester) reviewed the research on thermal effects which underlies the 10 mw/cm² standard with the conclusion that there is no evidence to suggest that it is still not sound.

A day of reviewing non-thermal effects ranged from a review of Soviet work by Christopher Dodge, of the U. S. Navy, to a report by Tanner et al. of National Research Council (Canada) of the disturbing effects of microwaves on birds in the range of 10-60 mw/cm². Other papers included a review of the radar "hearing" effect by Frey (Random line) and a review of mutation and other effects in elementary organisms due to exposure to fields in the HF range (5-30 MHz) by Dr. Heller (N. E. Institute).

A paper by the invited Dr. Karel Marha (Czechoslovakia) was greeted with special interest. His review included a description of microwave oven radiation-safety standards for workers. The standard called for measurements a foot or more away from an oven at likely positions of gonads or eyes. The standard involves a dose-like formula which permits the equivalent of 10 mw/cm² at 2.0″ from an oven for 1/2 hour daily although requiring lower levels for longer exposure. This was seen as an example of a standard that quotes a low level — i.e., 25 μw/cm² for long term exposure but with time and space factors included is equivalent to existing oven standards of 10 mw/cm² at 2.0″ for short exposures of 30 minutes or less.

Discussions on instrumentation clearly showed no real knowledge of Soviet instrumentation other than the conclusion that it is all designed for far field measurement. Papers by Dr. Wacker and Dr. Bowman of NBS indicated the many difficulties in a rigorous development of a probe for near fields of the type near microwave ovens. Dr. G. Voss of Univ. of Alberta (and also IMPI) editorialized during his paper on leakage suppression techniques for an immediate acceptance by industry of a 1 mw/cm² standard based on technical feasibility and moral responsibility. Most industry members present were not convinced by his presentation, and instead pointed out additional safety factors resulting from the rapid decay of fields near an oven and limited time exposure.

During the symposium in the evenings another important meeting

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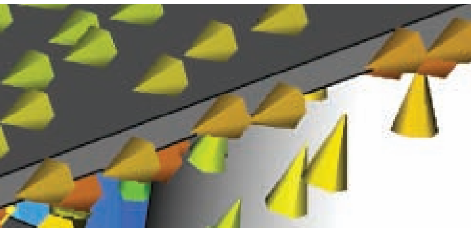

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TOWARDS THE VALIDATION OF A COMMERCIAL HYPERTHERMIA TREATMENT PLANNING SYSTEM

Recent developments have reinvigorated clinical investigations of hyperthermia (HT) as a viable adjuvant treatment in the fight against cancer. Researchers are placing a greater emphasis on multi-modal approaches that include mild temperatures (40° to 43°C) and standard therapies like radiation and chemotherapy, than on achieving higher temperature treatments (43° to 45°C), which were pursued in the past. The emergence of robust computer simulation tools for accurate hyperthermia treatment planning has aided this resurgence by helping improve the quality of heating. This article outlines a recent collaborative study at Duke University to demonstrate the capabilities of a new suite of 3D electromagnetic and thermodynamic simulation tools for treatment planning of external hyperthermia treatments with a radio frequency (RF) phased-array heat applicator. Following a brief introduction to the rationale for moderate temperature hyperthermia and current methodology for heating tissue at depth in the body, the article will present a new approach for improved heating based on treatment planning with electromagnetic simulation software tools. Procedures, benefits and a comparison of simulated heating patterns with those measured in two clinical hyperthermia treatments of advanced fibrous histiocytoma (soft-tissue sarcoma) tumors will be presented.

HISTORICAL BACKGROUND

Modern interest in hyperthermia began in the second half of the 19th century with a serendipitous clinical observation that some patients with externally visible tumors who experienced even moderate systemic temperature rise from a separate, severe illness experienced remissions of their tumors.[1] Although intriguing, subsequent studies of fever induced therapy gave way around the turn of the century to a more intense interest in the oncological potential of the then newly discovered Roentgen Rays (X-rays). By the 1970s,

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CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-25FT-SMSM+	SMA	25	11.7	27	139.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
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CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-10FT-NMNM+	N-Type	10	4.7	27	156.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
		Female to Male			
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CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95
ARMORED CABLES		Male to Male			
APC-6FT-NM-NM+	N-Type	6	3.0	27	181.95
APC-10FT-NM-NM+	N-Type	10	4.8	27	208.95
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frustrated with the limited success of radiation therapy for some resistant tumors, researchers returned to studies of the cell killing potential of heat as an adjuvant therapy to enhance the effects of radiation.[2] By 1984, hyperthermia was an approved medical treatment for superficial tumors that could be heated with the equipment available at that time.

NEW BIOLOGICAL AND CLINICAL RATIONALE

Bolstered by research in the 1980s emphasizing the cell killing potential of heat, researchers focused on high temperature hyperthermia (> 43°C) treatments intended to induce cell death. Unfortunately, this approach was limited by a number of biological, technological and commercial factors. As a result, interest in hyperthermia suffered a setback in the mid-1990s.[3] Fears of thermotolerance, for example, limited the number of heat fractions to about two per week. Thermotolerance in surviving cells increases with temperature; however, its effect is now known to be limited in tissues treated with mild-temperature HT. Heating tissue above 43°C also causes vascular damage, thereby inducing hypoxia, whereas the presence of oxygen is critical to the effectiveness of both radiation- and chemo-therapies. It is now understood that mild HT leads to increased blood perfusion and pO2 (reoxygenation) of fast-growing hypoxic tumors that have outgrown their local blood supply, thus enhancing radio- and chemo-sensitization. Furthermore, because of the threat of vascular damage and hypoxia, heat was often applied after radiation, which can reduce the effectiveness of the HT in terms of reoxygenation. Finally, studies have shown that mild HT results in the denaturation (unfolding) and eventual aggregation of nuclear proteins, processes that interfere with mitosis, DNA transcription and DNA repair. A noted absence of detrimental clinical effects of thermotolerance and overwhelming evidence of positive effects from tissue reoxygenation and increased denaturation/aggregation potential are the key biological factors encouraging scientists to rethink adjuvant mild hyperthermia.

ACCOMPANYING TECHNOLOGICAL AND COMMERCIAL CONSIDERATIONS

A typical course of clinical hyperthermia treatments consists of four to eight heating sessions, spread over a period of several weeks. The first hour of a two-hour session is used for patient preparation, such as placement of thermal monitoring probes in and around the tumor volume and the placement of the RF applicator around the tumor region. After the patient is prepared, power is supplied to the applicator's antenna(s) and the tumor is heated by radiated electromagnetic energy.[4] Though the principles of tumor heating are widely understood, the technology to focus heat into a desired tumor volume at depth in the body has lagged behind the theory, especially for deep-seated malignant tumors. For regional hyperthermia of deep-seated tumors, electromagnetic annular phased-array applicators (including smaller sized mini-annular phased-array (MAPA) applicators that fit around one extremity) have been developed for the frequency range of 75 to 150 MHz.[5-7] To focus the heat into the tumor site, researchers have found that the driving phases and amplitudes of the MAPA must be carefully controlled.

Equipment considerations also damaged initial perceptions of hyperthermia and have significantly slowed acceptance of this clinical modality. Limited adjustability of applicator power deposition patterns led to poor control of heating, which has restricted the number of locations to which HT could be reliably applied. Even for multiple antenna arrays, inflexible and klunky controls made beam focusing and steering slow and imprecise. Delivering the required power to the target also presented a challenge. The absence of robust computer simulations often left clinicians to deal with superficial "hot spots"—in some cases leading to undesirable blisters or burns on the skin surface (air-dermis interface). The absence of noninvasive thermometry forced HT technicians to rely on a very limited number of implanted temperature probes. Insurance controlled cost codes and restrictive reimbursement rates have also played a role in encouraging OEMs to forego develop-

ment plans. Happily, many of these technical challenges have been addressed in the last 10 years and promising solutions are emerging.

THE DUKE STUDY: EQUIPMENT, METHODS AND RESULTS

Power Delivery System

In ***Figure 1***, a schematic overview of the RF power delivery system is presented. A Lucite cylinder with a single ring of eight dipole antennas connected in parallel pairs sits directly over a soft tissue sarcoma of the lower leg, as shown in ***Figure 2***. During treatment of Cases I and II, the applicator was positioned below the patient's knee. Filters and matching feed network were designed to deliver up to 50 W per dipole pair at a frequency of 140 MHz. Frequency selection is a trade-off between beam size and penetration depth. Higher frequencies have smaller beam widths and shorter penetration depths. A water bolus was used to reduce concomitant hot spots and to improve the radiation efficiency of the electrically short dipoles. Water is an ideal waveguide medium for two reasons. First, its electrical properties are closely matched to that of human dermis so the applied energy can be transmitted through to the tumor. Impedance mismatches and changes of wavelength at dielectric interfaces cause reflections and hot spots. Second, water has a high heat capacity and is therefore an excellent thermal coolant of the skin surface.

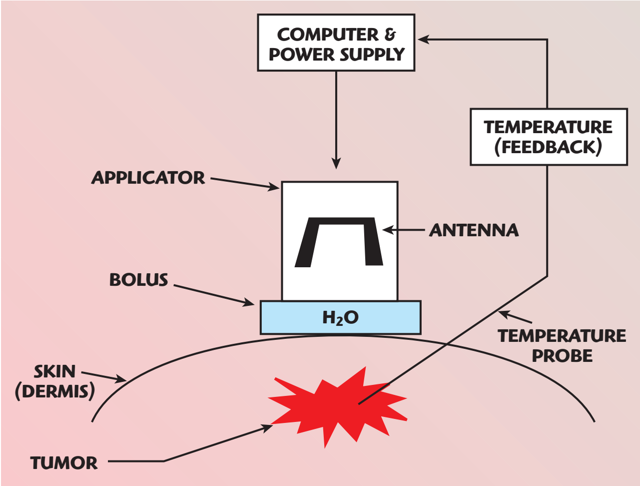


Fig. 1 Schematic of the power delivery system.

Fig. 2 Applicator in situ.

Measuring Temperature to Confirm Simulation Results

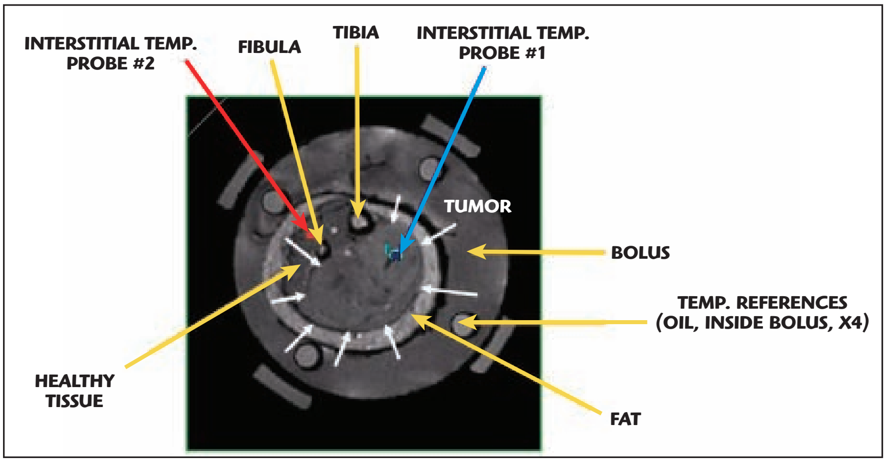
Information about each structure and target volume of a patient can be obtained by utilizing computed tomography (CT) or other medical imaging modalities, as shown in ***Figure 3***. The sarcoma tumor, located in the patient's lower leg, is surrounded by a water bolus inside a 26 cm diameter, four-antenna phased-array applicator. The patient is supine. The tumor region is indicated by white arrows. In this study, two interstitial temperature probes were inserted into the tumor and surrounding healthy tissue. These local probes were used to confirm the simulation results.

Simulation Methods and Procedures

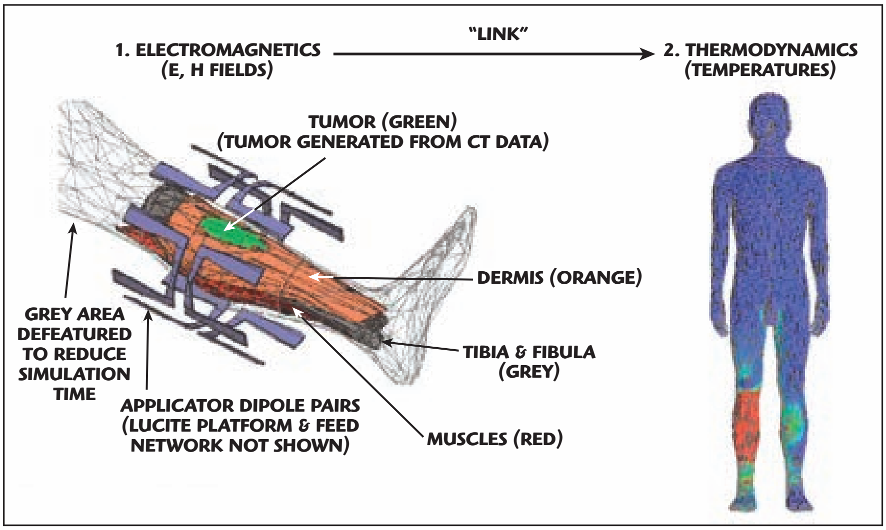
Due to the recent advent of accurate 3D electromagnetic and thermal simulation software programs, pre-treatment planning of complex heterogeneous tissue regions is now possible. First, the antenna array and tissue properties are entered into the EM solver with appropriate geometry, and specific absorption rate (SAR) distributions are calculated. These SAR distributions can then be automatically fed into a bio-heat transfer equation-based thermal solver to produce expected 3D temperature distributions in the tissue. The simulation strategy is:

Step 1: Use 3D FEM simulator (HFSS) to solve for EM fields in the volume of interest.

Step 2: Insert the EM field inputs



▲ *Fig. 3 Cross-sectional view of sarcoma tumor.*



▲ *Fig. 4 Summary of simulation strategy.*

from HFSS into the 3D FEM thermodynamic simulator (ePhysics) to produce temperature distribution from bio-heat transfer equation calculations in the volume of interest with assumed perfusion values that bracket the expected range in tumor and normal tissues.

Although exact temperature maps are not possible, due to uncertain tissue perfusion which varies spatially and temporally during treatment, these SAR and estimated temperature maps help clinicians pre-plan dosage and avoid patient hot-spots. They allow technicians to determine appropriate field amplitude and phasing, which are used to control beam steering. Simulations also help engineers test new applicator designs and provide educational training aids for pretreatment planning optimization of optional heating configurations and approaches.

In this study, an electromagnetic and thermodynamic co-simulation approach using accurate tissue properties and anatomy from a complete human body model was correlated against direct measurements. The effective energy exchange between the power delivery system and the tumor is determined in two steps. First, a 3D, finite element electromagnetic simulator is used to predict the electric field in the tissue region of interest (that is the leg). The solved electric field data are converted to SAR inputs according to the following equation:

$$SAR = \frac{1}{2} \cdot \frac{\sigma}{\rho} \cdot |E|^2 \quad \left(\frac{W}{kg}\right) \qquad (1)$$

where σ is the tissue electrical conductivity, ρ is the tissue density and E is the electric field. In the second step, the SAR data from the electromagnetic simulator is then "linked" to a thermodynamic simulator and the bio-heat transfer equation is solved for changes in temperature (ΔT):

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$$\rho \cdot c \cdot \frac{\partial T}{\partial t} = \kappa \cdot \nabla^2 T - \rho \cdot \rho_b \cdot c_b \cdot F \cdot \left(T - T_b\right) + \rho \cdot SAR \qquad (2)$$

where T is the temperature (°C), t is the time (s), r is the tissue density (kg/m^3), κ is the thermal conductivity (W/(m · K)), c is the tissue specific heat (J/(kg · K)), F is the blood flow rate or perfusion ($m^3/(kg \cdot s)$) and the subscript "b" refers to blood. This energy balance (Equation 2) relates the rise in temperature over time at a given region of interest to the heat inputs (power deposition or SAR) and heat losses from thermal conduction and convection (blood perfusion). As will be shown in the test case results below, the blood perfusion factor represents the greatest source of uncertainty. Several initial simulations were run to bracket the expected range of tumor perfusion. ***Figure 4*** summarizes the overall simulation strategy.

PROCEDURES

Step 1: Producing the EM Model and Simulation

The applicator with paired dipole antennas and tuning stub feed network was first drawn in a mechanical CAD program. The drawing file was translated and imported into the electromagnetic simulator. The amplitude and phase inputs to each dipole were adjusted for optimum tumor focus. Next, a recently released 300-component human body model was called by the EM simulator. To reduce simulation time, all non-essential distal body components such as head or arms were de-featured (turned off). A model of the sarcoma bearing leg was created starting from a "generic patient" computed tomography (CT) database into which the tumor volume was inserted at the appropriate location. The electrical properties were entered for each component of the model and the EM simulation initiated. The FEM-based EM simulator first produces a tetrahedral mesh for each model component using an adaptive meshing algorithm. This algorithm automatically adds more tetrahedra to regions experiencing large changes in the electric and magnetic field quantities being solved. Once the mesh is complete, the field solver solves Maxwell's equations for each tetrahedron. The solved 3D EM field model is then linked ("data-linked") to the 3D thermodynamic solver. Data linking allows changes in the EM model, for example amplitudes and phases fed to the dipole pairs, to be automatically updated in the 3D FEM thermodynamic model. The resulting field quantities are then used to produce the SAR inputs in the thermodynamic simulator.

Step 2: Simulation of the Thermodynamic Model

The thermodynamic simulator uses the same 3D applicator-body model as the EM simulator. A mesh is produced and the temperature changes within each tetrahedron are derived as a function of time. To complete the thermodynamic model, material properties, including mass density, thermal conductivity and specific heat, for each component were entered. These data were derived from a literature search and are summarized in ***Appen-***

dix A.[8,9] When a range of values appeared in the literature, an average value derived from the range was used. In addition, the bolus was assumed to form a constant temperature thermal sink. Based on bolus dimensions and the volumetric flow rate of water within the bolus, an interface (forced convection boundary) temperature of 24°C was assumed.

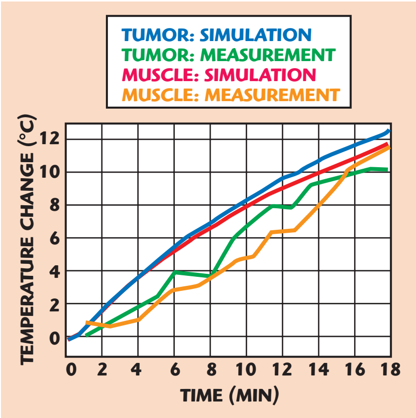
Baseline blood perfusion values were derived from a literature search and are summarized in the table.[10] To provide a more realistic model of variable tissue perfusion during heat treatments, a temperature dependent perfusion model was created. This model was based on perfusion data of a dog's prostate taken from the *CRC Handbook of Thermal Engineering*. According to the model, the perfusion factor F, in Equation 2, was multiplied by a temperature dependent factor ranging from 1 to 1.52. This temperature dependent perfusion model was used to account for the clinical observation that perfusion increases in response to gentle heating. In addition, the perfusion value for the skin layer was assumed to increase by a factor of five when the skin is warmed. However, due to the overall mass of the skin, this additional perfusion had little effect on the simulation results.

RESULTS

Case I

The first case was used as a baseline to determine the correlation between measurement and simulation. As shown previously, two in situ probes were used. The first was located centrally within the tumor and the second was placed in healthy tissue to the left of the tibia. During the first 18 minutes of treatment, the four dipole pairs were driven with equal amplitudes and phases at 140 MHz. This phasing resulted in a beam that was focused centrally in the roughly cylindrical volume of interest and heated the surrounding tissue almost equally,[5] except as modified by heterogeneous electrical and thermal tissue properties. Both the healthy tissue and malignant tissue were heated.

The temperature data for the in situ probes is compared to the simulation results in ***Figure 5***. Here, the perfusion values shown in the table and the temperature dependent model were used in the simulation. A high correlation between simulation and measurement was found for both the tumor and the healthy tissue. These results were encouraging and the investigators were able to proceed to a subsequent, more complex clinical trial.



▲ *Fig. 5 Case I: Temperature changes in tumor and muscle.*

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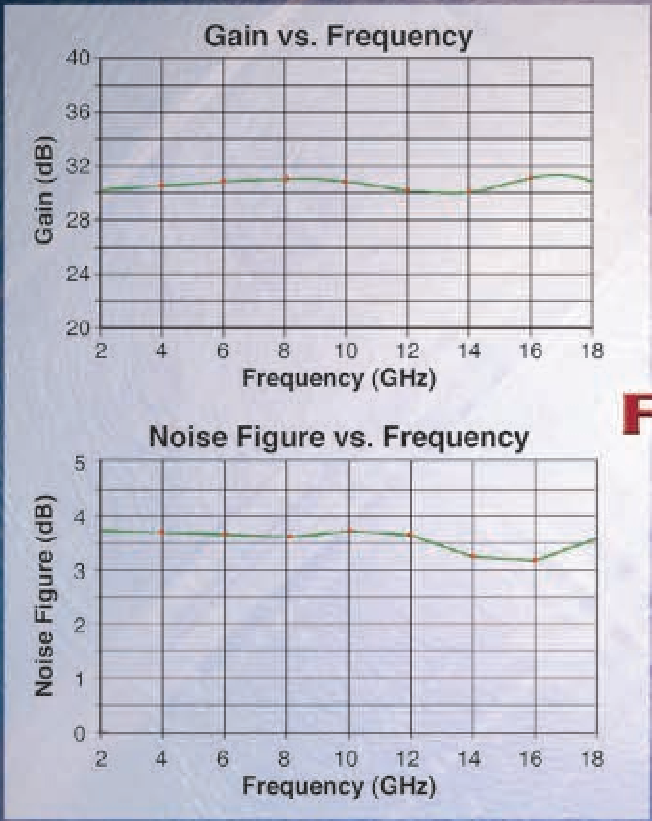

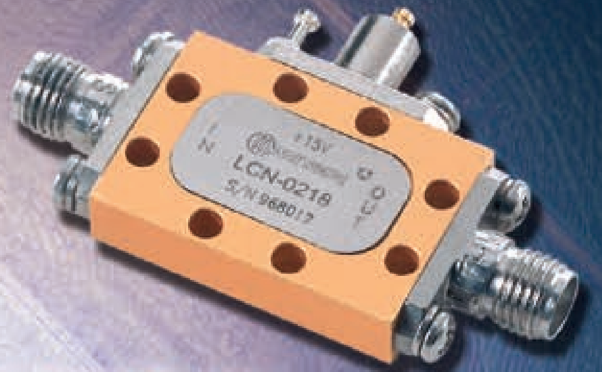

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Case II

In the second clinical study, an attempt was made to maintain a constant temperature rise in the tumor by adjusting the total input power to the dipole pairs during the treatment. As before, the four dipole pairs were driven with equal power and phase. For the first two minutes, 30 W were applied to each of the four dipole pairs. From minutes two to five, 20 W were applied, and so on as indicated in ***Figure 6***. After the treatment, the applied power changes were simulated. As shown, there is fairly tight correlation between measurement and simulation for the first 10 minutes. Thereafter, for approximately five minutes, the curves begin to diverge. Eventually, at approximately 15 minutes, trends realign, but with a two degree separation.

After studying the data and their sensitivity to various parameters, it was postulated that the effect of perfusion was still being underestimated—even with the temperature dependent model. Subsequent simulation studies were performed to confirm this view.

Since the sensitivity study strongly hinted that the perfusion values were too low, and since there was not enough information to include detailed modeling of complex arteries and veins during this trial, an iterative series of simulations was conducted with increasing perfusion factors. A marked improvement in the correlation in Case II was observed using a perfusion value that was double the initial value. Both cases were re-simulated with the new perfusion factors and compared to the measured results. As shown in ***Figure 7***, both cases demonstrated a marked improvement in the correlation of simulated and measured data.

DISCUSSION

A number of investigative pathways are renewing interest in adjuvant mild hyperthermia in the fight against cancer. Critical among these is the development of simulation tools that allow clinicians the opportunity to optimize the heat dosage and prevent patient hot spots. Inspired by the goal that one day researchers will be able to accurately predict the temperature distribution before a clinical hyperthermia treatment for each patient, much effort has been done in the area of computer modeling and simulation.[1] As argued in *THE LANCET Oncology* (August, 2002), "The potential to control power distributions in vivo has been significantly improved... by the development of planning systems and other modeling tools." These simulation tools are also being used to design new applicators and train the next generation of medical researchers.

To achieve these goals, two steps are required. The first step is to determine the E-field distribution in heterogeneous tissue, which, when coupled with respective tissue properties, determines the power deposited per unit volume or mass (SAR). Secondly, using the knowledge of spatial and time dependent SAR distribution, coupled with the thermal properties, one can predict the transient and steady state temperature distributions. Ideally, one needs accurate patient specific anatomic and physiologic tissue models and complete understanding of the electrical and thermal properties of malignant and surrounding healthy tissue. Clearly, a very complex model is required. However, some of the critical information is not completely known, such as blood per-

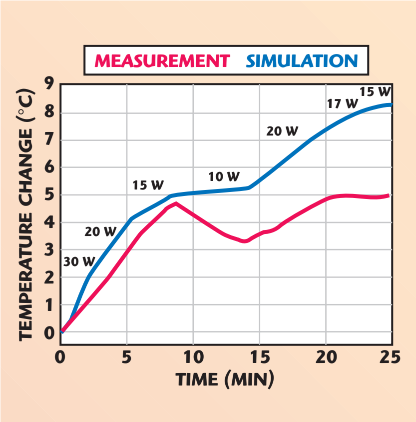

Fig. 6 Case II: 25 minutes with variable power, equal phases.

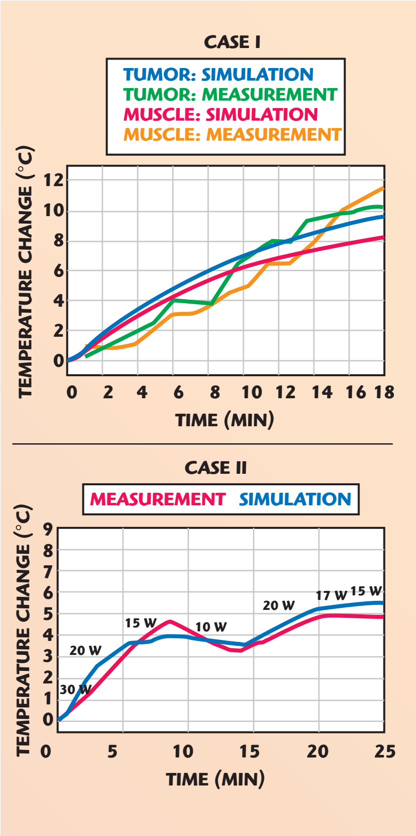

Fig. 7 The effect of perfusion.

fusion. Studies on blood perfusion in tumors show that the value varies significantly with tissue type, as well as temperature and other physiologic conditions.[11] But no specific value for human tumor can be identified accurately in advance. Of all these factors, the effect of local tissue temperature on muscle perfusion is the easiest to study. Research in this area has been done by different groups. The information used herein for the temperature dependence of blood perfusion is from the *CRC Handbook of Thermal Engineering*. This reference provides a few perfusion multipliers for dogs' prostate over a range of temperatures. In this study, the initial perfusion increased 17 percent when temperature exceeded 39.6°C and 52 percent when temperature reached 41.7°C.

CONCLUSION

In this study, a novel coupled electromagnetic and thermal simulation procedure is described that combines 3D FEM electromagnetic and thermodynamic simulators with an advanced human body model that incorporates accurate anatomic geometry and corresponding tissue properties. An assumption of temperature dependent blood perfusion has been investigated. Two clinical hyperthermia treatments of an advanced soft tissue sarcoma of the leg are simulated and results compared to simulations. The comparison of simulated and measured thermal data are shown to have a high degree of correlation if blood perfusion is considered, proving the importance of perfusion modeling for clinical applications. ■

ACKNOWLEDGMENTS

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APPENDIX A

MATERIAL PROPERTIES USED IN THE THERMODYNAMIC SIMULATION

	Mass Density [kg/m³]	Thermal Conductivity [W/(m°C)]	Specific Heat [J/(kg°C)]	Perfusion [kg/m³/s]
Muscle	1047	0.45	3550	0.44
Bone	1990	0.29	970	0.4
Marrow	1040	0.45	3550	0.44 (not found, assumed same as muscle)
Skin	1125	0.31	3000	0.39
Tumor	1047	0.55	3560	0.3 (not found, assumed a little less than other organs)
Rest (high water content but includes some fat)	1020	0.4	3200	Assumed same as muscle

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Northrop Grumman Receives Two Contracts for AN/APN Radar Program

Northrop Grumman Corp. has been awarded two separate contracts from the US Air Force Warner Robins Air Logistics Center to provide navigation and weather radars and logistical support for the US Air Force, Air Force Reserves and Air National Guard. The Northrop Grumman AN/APN-241 provides high resolution ground maps, predictive windshear, accurate low level navigation, unprecedented safety-of-flight measures and critical situational awareness, enabling precision aerial drops. The radar contract is valued at $33.4 M, while the contract for continued logistical support is valued at $9.9 M.

"These two contract awards are evidence of the continued confidence the Air Force has in our products and services as we continue to support the warfighter," said Guido Sottosanti, Jr., program manager of the AN/APN-241 at Northrop Grumman. Manufacturing of the radars will take place at company facilities in Norwalk and Baltimore. Deliveries are expected to be completed in 2011.

AN/APN-241 radars have been delivered and installed in over 200 C-130Hs for the US Air Force, Air Force Reserves and Air National Guard. Northrop Grumman has delivered 700 equivalent shipsets of AN/APN-241 hardware in support of C130s and C27s operating around the world today.

Raytheon Awarded $422 M Contract for Standard Missile-2 Production

The US Naval Sea Systems Command awarded Raytheon Co. a $422 M production contract for Standard Missile-2 Block IIIA and Block IIIB missiles. Raytheon will provide SM-2 missiles to the US Navy, Taiwan, the Republic of Korea and Japan. The SM-2 employs dual-mode infrared and radio frequency guidance to defeat target countermeasures. The SM-2 has demonstrated success against supersonic, sea-skimming missiles during high-G (gravity force) maneuvers.

"The flexibility and reliability of the SM-2 are unmatched and it has the longest range of any naval air defense in the world," said Ron Shields, Raytheon Missile Systems Standard Missile program director. "That is why navies around the world continue to select it as their missile of choice for fleet air defense coverage." SM-2 has been the US Navy's primary surface-to-air fleet defense weapon for more than three decades. It is capable of engaging anti-ship cruise missiles, fixed-wing aircraft and helicopters. The latest versions of the missile feature improved guidance software. "The SM-2 continues to evolve to meet the needs of the US Navy and allied navies," said Kirk Johnson, the US Navy's Standard Missile program manager. "This weapon system will help us counter the expanding array of threats the US Navy faces in the world today."

Lockheed Martin Team Completes GPS III Integrated Baseline Review

The Lockheed Martin team developing the next generation Global Positioning System (GPS) spacecraft, known as GPS III, has successfully completed on-schedule an Integrated Baseline Review (IBR) with the US Air Force, an important program milestone that precedes the Preliminary Design Review. GPS III will improve position, navigation and timing services for the warfighter and civil users worldwide, and provide advanced anti-jam capabilities yielding superior system security, accuracy and reliability.

The successful IBR consisted of a comprehensive review of the entire program and established a reliable baseline in relation to the program cost, schedule and technical requirements. In completing the IBR on schedule, the Lockheed Martin GPS III team, which includes ITT, Clifton, NJ, and General Dynamics Advanced Information Systems, Gilbert, AZ, is on track to complete the space vehicle Preliminary Design Review in the second quarter 2009.

"Working shoulder to shoulder with our customer, this in-depth review demonstrated that we have a solid technical baseline and a high confidence schedule in place to achieve mission success on this critical program," said Don DeGryse, Lockheed Martin's vice president of Navigation Systems. "Additionally, the review further strengthened our partnership with the Air Force. This strong partnership is an essential attribute to successful program execution and will ultimately lead to success on GPS III."

The team is working under a $1.4 B Development and Production contract awarded in May 2008 by the Global Positioning System Wing, Space and Missile Systems Center, Los Angeles Air Force Base, CA, to produce the first two GPS IIIA satellites, with first launch projected for 2014. The contract also includes options for up to ten additional spacecraft.

Honeywell Announces a New Family of 3-D Weather Radar

Honeywell announced it is developing a family of business aviation radars, IntuVue, that offers flight crews the ability to detect and avoid previously unforeseen turbulence, windshears and dangerous storm activity so they can make more informed route decisions, thereby increasing passenger comfort and safety while decreasing weather-related costs due to diversions, injuries and aircraft damages. The first application of IntuVue in business aviation is the Gulfstream 650, and derivative IntuVue radars will be retrofittable and available in the next two years as future upgrades to existing fielded Honeywell Primus® radars. Nearly 180,000 business jet flights are delayed due to weather each year. Honeywell IntuVue advanced weather radar technology enables pilots to see and avoid turbulence sooner to improve passenger safety and reduce operating costs. The volumetric scanning and 3-D display technology automatically shows the weather along the flight plan, while also allowing pilots to see all the weather in front and behind the aircraft.

"Weather related delays cost the business jet industry over $340 M each year," said Robert Wilson, Honeywell's Business and General Aviation President. "With Honeywell's IntuVue weather radar as standard equipment, operators can expect to significantly reduce operating costs while making air travel more comfortable and secure. Operators using IntuVue radar in commercial aircraft are experiencing 50 percent fewer turbulence-related incidents, compared to existing business and general aviation radars."

IntuVue is the first radar to offer predictive windshear detection and alerting for aircraft with smaller antenna sizes. This is made possible due to advanced signal processing and an innovative 45° polarized antenna that more effectively rejects false signals from the ground. IntuVue is the first and only fully automatic weather radar system certified to the FAA's Enhanced Turbulence Detection Minimum Operation Performance Standard, enabling pilots to see and avoid turbulence sooner. IntuVue is the only commercial radar utilizing pulse compression for greater accuracy at longer range, a technology used previously only in military radars. This technology enables improved in-flight decisions by providing tools to view storms in three dimensions at up to 320 nautical miles ahead of the aircraft, with no loss of resolution, which allows optimum rerouting around or through weather that can help reduce fuel burn up to 11 percent. Compared to legacy radar systems, IntuVue's slim design and high reliability reduces operating costs by 53 percent, reduces weight by 25 percent and reduces maintenance cost by 30 percent.

The IntuVue model RDR4000 is standard equipment on the Airbus A380 and will also be standard on the A350 when it enters service. The radar is also certified and flying on the B777, B737NG, C-17, KHI C-X and C-130, and will be available in 2010 on the A320, 330 and 340. ■


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20 - 150 MHz, minimum	≥ 40 dB @ 200 MHz & ≥ 50 dB @ 300 - 600 MHz
20 - 220 MHz, minimum	≥ 40 dB @ 300 MHz & ≥ 50 dB @ 450 - 900 MHz
20 - 335 MHz, minimum	≥ 40 dB @ 440 MHz & ≥ 50 dB @ 660 - 1400 MHz
20 - 500 MHz, minimum	≥ 35 dB @ 670 MHz & ≥ 50 dB @ 1005 - 2000 MHz
20 - 700 MHz, minimum	≥ 40 dB @ 980 MHz & ≥ 50 dB @ 1470 - 2000 MHz
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20 - 1400 MHz, minimum	≥ 40 dB @ 2000 MHz & ≥ 50 dB @ 3000 - 4200 MHz
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CASAGRAS is an EU Framework 7 project aimed at promoting international collaboration on RFID standardisation with particular reference to the emerging Internet of Things (IoT). Its partners represent the UK, Korea, Japan, China, the US, Germany and France. It is one of the most important RFID projects ever funded by the European Commission with its brief to make recommendations and to propose standards and best practice that can be agreed and applied worldwide.

CASAGRAS will consider how best to meet the global challenges and maximize the opportunities. It will examine global standards, regulatory and other issues concerning RFID, and provide a framework of foundation studies to assist the international community to accommodate the issues concerning RFID and the Internet of Things.

European Consortium Starts First Public Trial of NFC

StoLPaN, the pan-European consortium driving adoption of Near Field Communication (NFC), has announced details of the first public trial of NFC that will integrate this emerging contactless technology in the Dolomite skiing resorts of North East Italy. Tourists visiting selected hotels will be provided with NFC-enabled mobile phones and smart cards that can be used securely in multiple environments in their resort for applications that use different devices and connection technologies including NFC, SMS and barcodes.

The trial will include the delivery of up-to-date ski and weather reports to phones when devices are waved past NFC-enabled active posters, and integration of NFC with SMS and barcode-based infrastructures in bars, restaurants and shops to offer customer loyalty schemes. For example, a coupon picked up from a smart poster offering discounts at a local restaurant might be redeemed through the NFC phone using a SMS or barcode system later that evening.

The trial, organized by StoLPaN, is being managed by research company Ennova Research, and relies on the support of Cattid of the University of Rome, the Regione Veneto local government and AFF Hungary. The trial will use different types of NFC-enabled phones, contactless point of sales terminals from Ingenico, NFC and MIFARE technology by NXP Semiconductors, the service platform by Ennova Research and the security levels by the University of Technology of Graz.

Thales Alenia Space España Supplies Kopernikus

Thales Alenia Space España has been chosen to supply the X-band communication subsystems and the S-band telemetry, tracking and command (TT&C) transponders for the first three Sentinel observation satellites in the European Space Agency's Kopernikus programme, which was formerly known as Global Monitoring for Environment and Security (GMES). The Sentinel satellites are being developed as part of the Space Component of the Kopernikus programme, which is being co-funded by the European Commission.

As prime contractor for the X-band communication subsystem, Thales Alenia Space España leads a consortium including the Thales Alenia Space France and Belgian companies. They are responsible for the specification, design, assembly, integration, and testing and delivery of this assembly for the Sentinel 1, 2 and 3 satellite families, as well as for the three recurrent ones.

Thales Alenia Space's Spanish subsidiary will also develop, manufacture and supply the S-band TT&C transponders for the three Sentinel satellites. The X-band subsystem transmits high data volumes from observation satellites in low Earth orbit to ground stations. The downlink data rate, based on an innovative arrangement of two frequency-multiplexed RF channels, exceeds 600 Mbps. The S-band TT&C transponders allow Earth stations to control and communicate with the satellite.

Comarch Constructs WiMAX Network in Montenegro

The last phase of a WiMAX project at Promonte, the prime GSM mobile service provider in Montenegro, has been completed by Comarch. The project introduces global activity taken within Telenor Group's 'Internet to the people', taking advantage of the combination of the latest technologies like 3GHSPA, WiMAX and WiFi. The project focused on three areas: construction of the WiMAX transport network, installation of access to WiFi infrastructure and core equipment (OSS/BSS systems, routing and switching). The construction of the WiMAX network included delivery and installation of WiMAX base stations in seven major cities.

The range of the network was further extended by building WiFi access infrastructure in main tourist locations (hotel areas, busy squares, etc). In the areas not covered by WiMAX technology, access will be ensured using integrated WiFi over UMTS. The last stage of the project includes installation of OSS/BSS systems and core routing/switching equipment.

Promonte imposed a strict three-month schedule. However, through close cooperation between Comarch's engineers, Telenor R&I experts and Promonte's professional staff, Comarch took just two and a half months to build the network infrastructure and integrated BSS systems, which has enabled the launch of the first Internet services in Montenegro's major cities (Podgorica and the largest holiday resorts on the coast) by using WiMAX technology.

Quartet to Develop HSUPA Platform

NTT DOCOMO Inc., Renesas Technology Corp., Fujitsu Ltd. and Sharp Corp. have announced a plan to jointly develop the SH-Mobile G4 single-chip LSI device, and a platform incorporating it, to support the HSPA1/HSDPA2/W-CDMA and GSM/GPRS/EDGE (2G) mobile telephony standards. Development of the platform is targeted for completion by the fourth quarter of fiscal 2009 (January-March 2010).

The new SH-Mobile G4 will be fabricated with 45 nm process technology to enable highly integrated functions and extra-fast processing. It will provide enhanced functionality and improved performance. In addition to HSDPA cat.8 for extra-fast downlink speeds (maximum 7.2 Mbps), the SH-Mobile G4 will support HSUPA to boost uplink speeds to a maximum of 5.7 Mbps, almost 15 times faster than the conventional 384 kbps speeds.

In 2004 NTT DOCOMO and Renesas began joint development work on the SH-Mobile G series of single-chip LSI devices, which integrate a baseband processor that supports dual-mode communication and an application processor. The SH-Mobile G4 will be the fourth product to emerge from this collaboration.

This joint development work has since progressed to now include handset manufacturers such as Fujitsu and Sharp. Each platform has a SH-Mobile G series product as the core component and includes a basic software suite (OS, middleware and drivers) and a reference chipset in a single package. By using the new platforms, mobile phone manufacturers can eliminate the need to develop basic functions independently, significantly reducing development time and costs. Renesas plans to provide the platform to the worldwide mobile phone market, in addition to customers in Japan. ■

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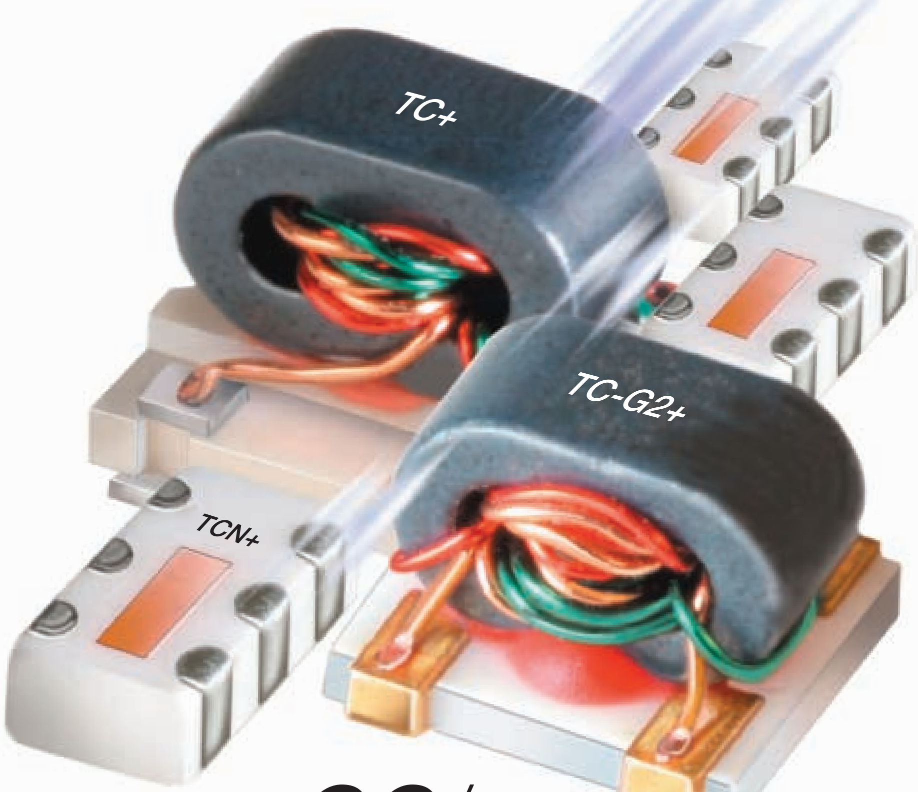

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Multi-mode WiMAX/LTE Chips to Hit Markets in 2009

2009 will see the introduction of a new class of wireless communications chip that features dual-mode support for both WiMAX and LTE, according to ABI Research. The thrust of demand for such chips comes from those wireless device makers seeking to reduce the number of their SKUs; they will welcome the economies of scale that come from creating devices that support both 4G standards.

"Some mobile operators are showing interest in dual-mode chipsets," says ABI Research principal analyst Philip Solis, "and they are backing it with cash. Vodafone, for example, has a foot in both WiMAX and LTE camps. They will use LTE in industrialized regions and WiMAX in developing nations. In Japan, KDDI may deploy LTE on its own, but as an investor (along with Intel and others) in WiMAX operator UQ Communications, KDDI has an interest in both standards."

These chips are destined for any and all mobile devices, although given that most of the early usage of both LTE and WiMAX will be for data transmission, USB modems, laptops, netbooks and MIDs are likely to be the first products to include the dual-mode chips. "Because WiMAX networks will be deployed sooner than LTE, for competitive reasons these dual-mode chips are generally being created by WiMAX chip vendors, particularly the smaller, more agile ones," Solis adds.

ABI Research's study "The WiMAX Chipset Market" examines chipset vendors' activities and products. Forecasts include shipments and revenue by a variety of segmentations including device CPE, mobile devices by type, region, main frequency band and 802.16e/16m. It forms part of the firm's Wireless Semiconductors Research Service, which also includes other Research Reports, ABI Insights, an ABI Vendor Matrix and analysis inquiry support.

After Sparkling 2007, Cell Base Station Sales Down Steeply in 2008

After a fantastic 2007 for worldwide base station shipments, results for this year look pretty weak, reports In-Stat. In 2007, many new 3G networks were rolled out around the world and GSM subscriber growth was occurring at a fast clip, driven by millions of new subscribers in India, Africa and China, the high-tech market research firm says. However, those trends will not prevent total worldwide base station shipments from dropping sharply this year compared to 2007.

"New 3G networks are continuing to be deployed and some operators like T-mobile are deploying entirely new WCDMA-type networks," says Allen Nogee, In-Stat analyst. "However, the worldwide economy has been faltering, subscriber GSM growth—even in fast-growing developing areas—is starting to slow and wireless broadband use, while growing, is not growing fast enough for operators to spawn continued base station growth."

Recent research by In-Stat found the following:

- Cellular demand in China and India will keep sales of GSM base stations strong for many years.
- WCDMA base station shipments will exceed those of GSM-type base stations in 2011.
- 2009 will see a sharp rise in the number of TD-SCDMA base stations shipped.

The research, "Worldwide Cellular Base Station Forecast Driven by Data," covers the worldwide market for cellular base stations. It provides forecasts for base station deployments by region and by air link through 2012. It includes analysis of trends in the marketplace, including femtocells and TC-SCDMA. Profiles of manufacturers are also provided.

The Wireless Home Office (Finally) Approaches

After a long wait, the first stage of what will become the "wireless home office" is arriving. Some home office ultra-wideband (UWB) products are now hitting retailers' shelves and more are expected by the end of the year. These are mainly in the wireless USB category, the first major market application for UWB, utilizing wireless USB embedded in devices such as laptop computers, wireless docking stations for those computers and wireless external hard drives.

"The wireless USB docking station seems to be hitting a sweet spot," says ABI Research senior analyst Douglas McEuen. "A number of the more capable laptop models now include native wireless USB. This represents an important step towards creation of the true wireless home office."

Dell and Lenovo are leaders in UWB-enabled laptops; wireless USB stations are available from Kensington and Toshiba, and Imation is expected to release a wireless USB external hard disk drive range by year's end. Wireless USB products will be more expensive than their wired predecessors, but McEuen feels that as production efficiencies evolve, the differential will soon shrink to the point that wireless solutions are competitive on both price and capabilities.

"This generation of products comes closer to achieving the data rates that UWB was hyped as offering," notes McEuen, "and this is the first true opportunity for consumers to get their hands on UWB products and see them in action."

The ABI Research study "Ultra-wideband Connectivity" analyzes critical UWB market conditions, from market drivers and obstacles to global regulations and standards. Key market semiconductor vendors are profiled and the study concludes with an in-depth market forecast that tracks both positive and negative forces numerically. It forms part of two ABI Research Services: Home Networking and Short-Range Wireless, which also include other Research Reports, Research Briefs, Market Data, an Online Database, ABI Insights, ABI Vendor Matrices and analyst inquiry support.

95 Million Cellular M2M Modules to Ship in 2013

Continued strong growth in M2M (machine-to-machine) communications markets will see about 95 million cellular M2M modules shipping in 2013, according to ABI Research. Of shipments to the three main segments—telematics, telemetry and wireless local loop—about 34 million devices are expected to be for telematics and 39 million for telemetry.

According to senior analyst Sam Lucero, "Until about 2011, the major market growth will be found in the telemetry segment, since it encompasses a broad range of applications, including smart metering, POS terminals and remote monitoring and control applications. After 2011, we expect to see a spike in telematics applications. These exist now, but from 2011 will be driven more quickly by mandates such as Europe's eCall initiative, which will see cellular connections in every vehicle, and in North America by a much stronger competitive reaction to OnStar: virtually of the major automakers will come out with OEM telematics programs. Commercial telematics also set for strong growth as fleet managers use telematics to reduce fuel costs and increase overall operational efficiency."

Average selling prices are expected to decline across all air interface standards through about 2010, after which they should level out. Will current global and economic uncertainties negatively affect this market? There is no immediate indication of this, although, says Lucero, "A few companies have told ABI Research that the economy uncertainty will have a direct impact; we are in the process of surveying selected stakeholders to evaluate whether our forecasts will need to be refined."

However, one here-and-now pain point in the market is the ability to develop applications easily and cost-effectively. Module makers such as Wavecom are involved, as are stand-alone software vendors such as Sensor Logic and equipment players such as Digi International. It is not clear yet whether application developers will settle on one or another preferred type of ecosystem partner. ABI Research's "Cellular M2M Markets" study discusses these market forces, analyzes cellular M2M module vendor strategic responses, provides 2006/2007 vendor market share data and forecasts cellular M2M module growth from 2008 through 2013. It forms part of three ABI Research Services: M2M, Consumer Mobility and Mobile Devices. ■

Broadband Amplifiers by AML Communications

To Order Call: (805)388-1345 ext. 203

Model	Frequency (GHz)	Gain (dB)	Flatness (dB) max	NF (dB) max	P1dB (dBm) min	VSWR (In/Out)	DC Current @ +12/+15VDC
Broadband Low Noise Amplifiers							
AML016L2802	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
AML48L3001	4.0 – 8.0	30	±1.0	1.2	+10	1.8:1	150
AML412L3002	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
AML1226L3301	12.0 – 26.5	33	±2.0	2.8	+8	2.5:1	200
Broadband Medium Power Amplifiers							
AML0016P2001	0.01 – 6.0	21	±1.25	3.2*	+23*	2.0:1	480
AML26P3001-2W	2.0 – 6.0	28	±2.5	6	+33	1.8:1	1500
AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
AML618P3502-2W	6.0 – 18.0	35	±2.5	4	+33	2.0:1	1850
Narrow Band Low Noise Amplifiers							
AML23L2801	2.8 – 3.1	28	±0.75	0.7	+10	1.8:1	150
AML1414L2401	14.0 – 14.5	24	±0.75	1.5	+10	1.5:1	130
AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

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

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

High Dynamic Range Amplifiers

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

*Above 500MHz.

Power Amplifiers by Microwave Power

To Order Call: (408)727-6666 ext. 42

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Gain (dB)	DC Current(A) @ +12V or +15V
Broadband Microwave Power Amplifiers						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
Millimeter-Wave Power Amplifiers						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

High-Power Rack Mount Amplifiers

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Pac (kW)	Height (in)
C071077-52	7.1 - 7.7	52.5	170	51.5	1.8	10.25
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	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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INDUSTRY NEWS

■ In Strategy Analytics' annual ranking of the world's top GaAs device manufacturers, **RFMD**, **Skyworks** and **TriQuint** remained at the helm of the Gallium Arsenide (GaAs) industry in 2007, driving annual growth of 17 percent year-on-year. Overall, the GaAs device market was worth $3.6 B in 2007 with the top three companies accounting for 50 percent of the market. Other North American companies, including **Avago Technologies** and **M/A-COM**, accounted for seven out of the top ten GaAs device manufacturers on a global basis. Strategy Analytics expects that North American companies will continue to dominate the landscape in 2008 and beyond.

■ **Agilent Technologies Inc.** and **Aeroflex Microelectronic Solutions** announced a strategic alliance to deliver industry-leading RF and microwave components and Multi-chip Module solutions for aerospace, satellite and military applications using Agilent's monolithic microwave integrated circuits (MMIC).

■ **Anite**, a leader in testing technology for the wireless industry, and **Renesas Design France** (RDF), a provider of advanced wireless technologies and platforms, announced a strategic partnership in the field of Wireless Conformance testing. RDF has selected Anite's SAT(H) software test platform, a unique host test solution for 2G/3G Protocol Stack software, for the validation of the RDF 2G/3G dual-mode Protocol Stack. The partnership will also see Anite using the RDF protocol stack as a reference design to accelerate the development of the conformance test cases required for the industry certification of wireless devices.

■ **RF Micro Devices** (RFMD), a leader in the design and manufacture of high performance semiconductor components, announced the opening of a customer support center in Bangalore, India. The new customer support center in Bangalore highlights RFMD's large presence in Asia and underscores the company's commitment to one of the world's fastest growing markets for RF semiconductor components. RFMD's Bangalore customer support center houses applications engineering, customer service, sales management and technical sales.

■ **AWR**, a leader in high frequency electronic design automation (EDA), announced that its Finnish R&D facility will conduct research within the European Integrated Circuit/Electromagnetic Simulation and Design Technologies for Advanced Radio Systems-on-chip (ICESTARS) project. ICESTARS strives to enable the development of low-cost wireless chips that can operate at frequencies up to 100 GHz. The ICESTARS project is funded by the European Commission within its Seventh Research Framework Programme (FP7) and is led by NXP Semiconductors.

■ **Innovations for High Performance Microelectronics** (IHP), Frankfurt, Germany, announced the availability of a leading-edge ADS process design kit (PDK) for IHP's 0.25 μm SiGe process (SG25H3). The PDK for IHP's SG25H3 process technology is the result of collaboration between IHP and **Agilent Technologies' EEsof** EDA division to accelerate customers' time-to-market by offering an accurate and productive work environment for MMIC design solutions.

■ **Keithley Instruments Inc.**, a leader in solutions for emerging measurement needs, announced that **ip.access**, a developer of femtocell and picocell solutions, has purchased Keithley's award-winning radio frequency (RF) test solutions. ip.access has selected Keithley's Series 2800 RF Vector Signal Analyzers and Series 2900 RF Vector Generators as the solution for its production testing of WCDMA femtocell base stations.

■ Forty years ago, **EMS Technologies Inc.** opened its doors as a technology engineering company in Norcross, GA. The company recently culminated its month-long 40th anniversary observances in a special meeting with EMS Technologies staff. Anniversary festivities kicked off with a groundbreaking ceremony for EMS's Defense and Space Systems' 30,000 square-foot building expansion.

■ **Nearfield Systems Inc.** (NSI) celebrates the company's 20th anniversary. NSI was founded in September 1988 when partners Greg Hindman and Dan Slater formed their company to address the industry's need for turn-key near-field antenna measurement systems. Hindman and Slater demonstrated their first product, a portable planar near-field scanner system, at the 1989 AMTA Symposium in Monterey, CA, where they also presented three technical papers on antenna measurements. Since its formation, NSI has been very active in the antenna measurement community and has delivered more than 400 near-field and far-field measurement systems throughout the world.

■ Raytheon Missile Systems Tucson recently presented supplier awards to companies that routinely demonstrated excellence in product quality and on-time delivery over the last 12 months with a 95 percent rating. **SV Microwave** is proud to be one of the 18 companies that received the Raytheon Missile System's Excellence Award out of over 500 suppliers.

■ **W.L. Gore & Associates Inc.**, a developer and manufacturer of high performance cable assemblies, has joined the Ethernet Alliance, an industry group dedicated to the promotion of Ethernet technologies. Gore will specifically play a key role in the advancement of developing Ethernet copper cable interconnect technologies. Currently this includes GORE™ SFP+ and QSFP Copper Cable Assemblies.

CONTRACT

■ Agilent Technologies Inc. announced that its wholly owned subsidiary, **NetworkFab**, has been awarded a five-year, $45 M Small Business Innovative Research (SBIR)

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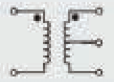
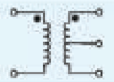
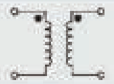
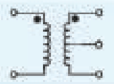
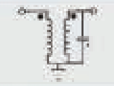
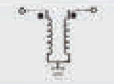
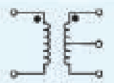
Model #	Z Ratio (50:Z)	Frequency (MHz)	Schematic
TM1-1	1:1	0.4 - 500	
TM4-0	1:4	0.2 - 350	
TM1-0	1:1	0.30 - 1000	
TM2-1	1:2	1 - 600	
TM4-GT	4:1	5 - 1000	
TM8-GT	8:1	5 - 1000	
TM2-GT	2:1	5 - 1500	
TM1-6	1:1	5 - 3000	
TM1-8	1:1	800 - 4000	
TM4-1	1:4	10 -1000	
TM4-4	1:4	10 - 2500	
TM1-2	1:1	20 - 1200	

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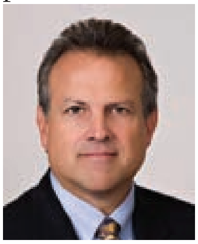
Phase III Contract with the US Army Communications-Electronics Research, Development and Engineering Center's Intelligence and Information Warfare Directorate at Fort Monmouth, NJ. This contract is for Wideband Sensor Systems with hyperfast Direction Finding (DF) and integrated Signals Intelligence (SIGINT) search, identification and collection of tactical targets.

NEW MARKET ENTRY

■ **ANADIGICS Inc.** announced its AWB7220 power amplifier (PA), the first in the company's new line of products targeted at the 3G and 4G femtocell markets. ANADIGICS' new AWB7220 PA is a highly isolated, fully matched, multi-chip module (MCM) designed and engineered specifically for use in femtocell and customer premises equipment (CPE) worldwide.

PERSONNEL

■ SMITHS Group plc has appointed **Ralph L. Phillips** president of Smiths Interconnect. Phillips, who had been acting president since May, has been appointed following a search process that included external and internal candidates. Smiths Interconnect designs and manufactures specialized electronic and RF products primarily for the global wireless telecommunications, aerospace and defense markets. It is headquartered in the US with approximately 3,100 employees in the United States, United Kingdom, France, Germany, Italy, China, Costa Rica and Mexico. Smiths Interconnect is expanding geographically and broadening its technology offering. As part of this strategy, it recently acquired Shanghai-based Allrizon and Brisbane-based Triasx Pty Ltd. that design and manufacture radio frequency filters and related products.



▲ Ralph L. Phillips

■ Remcom Inc. recently announced a change in corporate leadership as **Raymond Luebbers** retires from the position of CEO and president and **Stephen Fast**, former executive vice president, assumes the role as his successor. After serving as Remcom's founding president for nearly 15 years, Luebbers will remain in service to the company as a senior executive consultant, continuing to provide his widely recognized electromagnetic research expertise to Remcom and its customers. Fast has been an integral part of Remcom's growth since 2002, leading the Government Service Division for the company.

■ Park Electrochemical Corp. announced the appointment of **Thomas A. Pursch** as president of Nelco Products Inc., Park's printed circuit materials business unit located in Fullerton, CA. Pursch had been vice president and general manager of Amphenol Printed Circuits in Nashua, NH since 2005 and vice president and general manager of Teradyne Inc. in Nashua since 2002.

■ **Monteith G. Heaton** has recently joined Asylum Research as executive vice president of marketing and business development for Asylum's line of atomic force and scanning probe microscopes (AFM/SPM). Heaton joins Asylum with over 25 years of marketing, sales, business and technical management experience, most recently as VP sales and marketing for Innovative Micro Technology (IMT), where he was instrumental in building IMT into one of the world's leading MEMS foundries.

■ Giga-tronics announced two new appointments to strengthen and enhance its international business. John Regazzi, president and CEO of Giga-tronics, announced that **John Dixon** has joined the company as director of sales for European, Middle Eastern and African (EMEA) markets, and **Zhao Peng** has joined the company as director of sales for China and Hong Kong. Dixon previously held senior positions at Racal Instruments, Ubinetics Ltd. and more recently Comarco Wireless Test Solutions. Zhao will be responsible for building strong customer relations, creating new opportunities, and facilitating overall business with agents in Hong Kong and Macau, as well as mainland China. Previously, Zhao held the positions of sales manager at Beijing Stone Instruments Co. Ltd., ROOTS Communication Equipment and Electronic Scientific Engineering Ltd.

■ MFG Galileo Composites, a specialist in the design and manufacturing of custom composite radomes and reflectors, is expanding its management team with the appointment of **Todd Finney** as director of new business development. Finney will be responsible for pursuing new business wins for the company as well as supporting existing customers worldwide. Finney brings 16 years of experience in advanced composites, most notably in his prior role as director of military programs for Applied Aerodynamics based in Dallas, TX. Most recently (2004-2008) he served as the regional sales manager for McNally Industries focused on business development within the Department of Defense and tier two defense communities.

▲ Todd Finney

■ Crane Aerospace & Electronics, a segment of Crane Co., has named **Tim Jors** as business unit leader – Standard Power. In this capacity, Jors will be responsible for product management, new business development, strategic planning, management of business relationships with key customers as well as Standard Power Solutions profit and loss. Jors brings to the group over 25 years of progressive experience in supply chain, materials management and operations. Jors joined Crane Aerospace & Electronics in 2005 as vice president of supply chain for the Electronics Group.

▲ Tim Jors

REP APPOINTMENTS

■ **Mouser Electronics Inc.** announced it has inked a distribution agreement with **Tektronix**, a worldwide provider of test, measurement and monitoring instrumentation.

Mouser's Tektronix portfolio includes high quality oscilloscopes, arbitrary/function generators and other essentials for engineers' design benches.

■ **KOR Electronics**, a systems leader in exploiting the digital RF domain, announced it has signed a marketing partnership agreement with **Val Jackson & Associates Inc.**, Port Angeles, WA, to enhance its coverage to customers in the Pacific Northwest region. For further information, contact: Val Jackson & Associates Inc., 818 N. Barr Road, Port Angeles, WA 98362, ph: (360) 452-7308, or visit: www.valjacksonassoc.com.

■ **Richardson Electronics Ltd.** announced the addition of an innovative product line from **W.L. Gore & Associates**. Richardson will now sell Gore's high-tech line of surface mountable EMI shielding materials including GORE-SHIELD® Supersoft SMT EMI Gaskets and Grounding Pads, and the new GORE™ snapSHOT® Board-Level EMI Shield. To view W.L. Gore products on Richardson's web site, visit: www.rell.com/gore.

■ **Sprague-Goodman Electronics Inc.,** Westbury, NY, a manufacturer of trimmer capacitors, transformers, fixed and variable inductors and tuning tools, has added **C&D Electronics**, Holyoke, MA, to its list of franchised distributors. In addition to its Holyoke, MA headquarters, C&D has branch offices on Long Island, NY, and in the Dallas/Ft. Worth area of Texas. For more information, contact: C&D Electronics, 28 Appleton Street, Holyoke, MA 01040, ph: (413) 493-1200, fax: (413) 493-1212, e-mail: info@cdindustries.com or visit: www.cdindustries.com.

■ **Pletronics Inc.** has appointed **Migvan Technologies & Engineering Ltd.** (MTE), Petach Tikva, Israel, as its representative/stocking distributor for Israel. MTE will assume sales and customer service support for Pletronics current business in Israel and promote the company's broad line of high-end oscillators and crystals to the Israeli electronics industry. MTE represents a select line of top electronic component manufacturers to industrial, military and high tech companies as well as educational institutions in Israel.

■ **Renaissance Electronics Corp.** is pleased to announce the appointment of a new representative company to serve and further develop its customer base in France, Germany and Spain. The primary territory that **BFI** serves is France, Germany and Spain. The customer base for ferrite, base station, switches, components and subsystems in these regions is well balanced. For more information, please contact sales at (978) 772-7774.

■ **Digi-Key Corp.** announced that it has expanded its line of **Tyco Electronics** Raychem Circuit Protection Products to include the PolyZen family of polymer-protected Zener diodes. The PolyZen devices are featured in Digi-Key's print and on-line catalogs and are available for purchase directly from Digi-Key.

LINK BUDGET CALCULATION FOR UHF RFID SYSTEMS

This article provides the basic concepts necessary to perform a link budget analysis of passive UHF RFID systems. Unlike conventional wireless communication systems, there are two intrinsic characteristics that determine the link budget in UHF RFID systems: the required power to turn on the tag's IC chip and the phase noise of the TX leakage occurring in the reader's circulator. The former is the major factor limiting the link budget in the forward link, whereas the latter mainly restricts the link budget in the reverse link. In this article, the link budget calculations are performed with respect to the interrogation range. As an example of a link budget calculation, stationary RFID reader and mobile RFID reader results are compared.

Radio frequency identification (RFID) is an automatic identification method that relies on storing and remotely retrieving data using devices known as RFID tags or transponders. RFID systems with a variety of radio frequencies and techniques have been introduced.[1] Among them, the ultra-high frequency (UHF) band passive RFID system has drawn a great deal of attention because of its numerous benefits, such as cost, size and increased interrogation range. In particular, the interrogation range of the UHF RFID system is comparatively large, due to the use of a traveling electromagnetic (EM) wave to transfer power and data. The increased interrogation range makes it possible for RFID to revolutionize various commercial applications, such as supply chain management.[1,2] Moreover, the interrogation range has been considered as the most important feature representing the performance of a UHF RFID system.

The interrogation range is similar to cell coverage in wireless communication systems. In general, there are many factors involved in limiting the interrogation range. Among these, three major factors are the power required to turn on a tag's integrated circuit (IC) chip, the reader receiver's sensitivity and the wave propagation environment. Propagation environment is an extrinsic parameter affecting the interrogation range, whereas the power to turn on a tag's chip and the reader receiver's sensitivity are considered as intrinsic parameters. These two intrinsic parameters are closely related to the powers of signal and noise in RFID links. Therefore, this power relationship can be easily calculated using the link budget, which is the wireless communication system designer's primary tool for estimating the cell coverage.

Similarly, the link budget analysis is also applicable to an RFID case. However, a UHF RFID system differs from conventional wireless communication systems in the link budget analysis. This is because the tag has no internal power supply and the reader must supply

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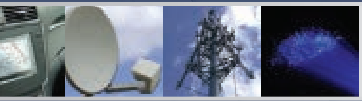

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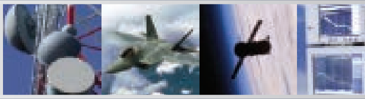

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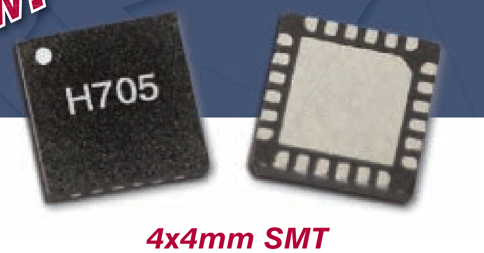

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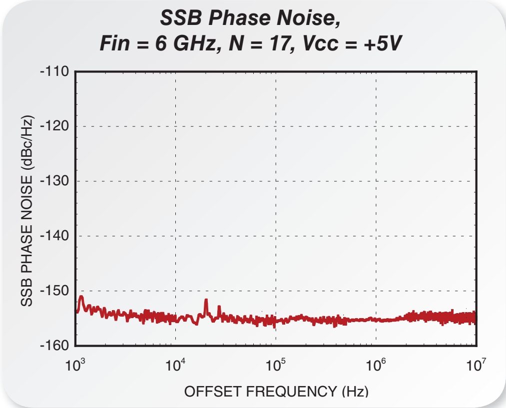

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	DC - 18	Divide-by-4	-15 to +10	-4	-150	+5V @ 96mA	LP3	**HMC493LP3E**
	10 - 26	Divide-by-4	-15 to +10	-4	-150	+5V @ 96mA	LC3	**HMC447LC3**
	DC - 7	Divide-by-5	-12 to +12	-1	-153	+5V @ 80mA	MS8G	**HMC438MS8GE**
	DC - 18	Divide-by-8	-15 to +10	-4	-150	+5V @ 105mA	LP3	**HMC494LP3E**
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	0.5 - 18	Divide-by-4	-15 to +10	-4	-150	+5V @ 93mA	C-1 / SMA	**HMC-C006**
	0.5 - 8	Divide-by-5	-15 to +10	-1	-155	+5V @ 80mA	C-1 / SMA	**HMC-C039**
	0.5 - 18	Divide-by-8	-15 to +10	-4	-150	+5V @ 98mA	C-1 / SMA	**HMC-C007**
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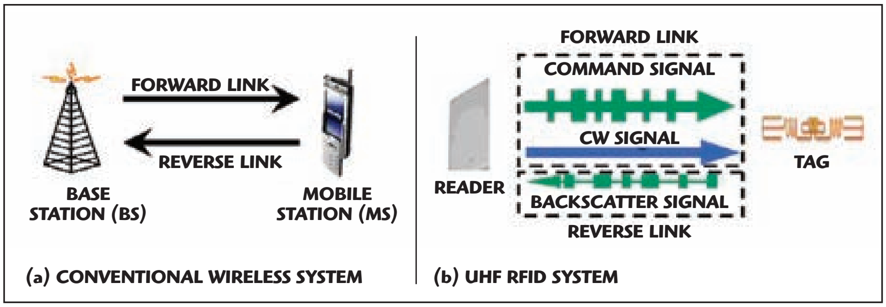


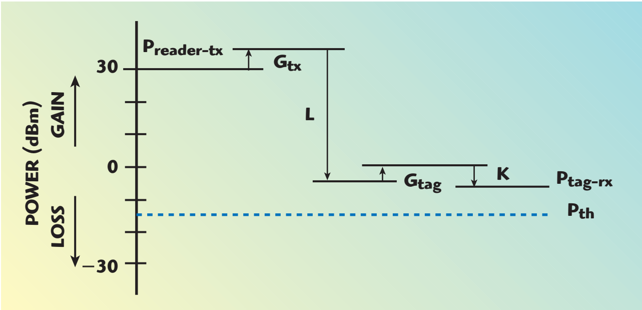
▲ *Fig. 1 Comparison between a conventional system and a UHF RFID system.*

the power. Consequently, the link budget is mainly dependent on the threshold power necessary to power up the tag.[3-5] Another major difference is that the phase noise of the transmission (TX) leakage at the reader's circulator has greater influence on the system noise than the thermal noise at the reader's receiver.[6-8] In this article, link budget calculations, considering the intrinsic characteristics of UHF RFID systems, are presented to provide guidance regarding system design and deployment.

RFID RADIO LINKS

It is well known that a communication link encompasses the entire communications path from the transmitter, through the propagation channel and up to the receiver. In a typical wireless communication system, illustrated in ***Figure 1***, there are forward and reverse links. The forward link is the communication link from a base station (BS) to a mobile station (MS), whereas the reverse link is the opposite communication link, from MS to BS. Because BS and MS can simultaneously transmit data to each other through the forward and reverse links, a conventional communication link is called full duplex. In addition, conventional wireless systems usually maintain a link balance between forward and reverse links, where the power levels of the two links have little difference. Therefore, the forward link coverage is almost the same as that of the reverse link, although the transmit power and sensitivity of both links are a little different.

On the other hand, RFID links, as illustrated, are different from conventional wireless links. A typical RFID system is composed of two components: a reader and a tag. The reader, sometimes called the interrogator, is made up of a transmitter/receiver module with one or more antennas. The tag consists of a microchip for storing data and an antenna to transmit stored data. Tags are normally categorized into active and passive types by the presence or absence of an internal power supply. Because tags have no power supply of their own in passive RFID systems, they obtain energy from the continuous wave (CW) signals transmitted by a reader. In addition, passive tags transmit their data only by backscatter modulation. In other words, the data transmission from tags to the reader is done by reflecting the wave energy back to the reader.[9] Therefore, an RFID link is half duplex: reader to tag and then tag to reader. This means that RFID links are intrinsically unbalanced. Moreover, the reverse links are highly correlated to the forward link, because the tag's transmit power is determined by the reader's transmit power.



▲ *Fig. 2 Forward link budget calculations.*

FORWARD LINK MAXIMUM ALLOWABLE LOSS

In the forward link, the forward maximum allowable loss is mainly determined by the tag characteristics. For example, let the minimum threshold power necessary to power up the chip be P_{th}. Then the forward maximum allowable loss in dB, $L_{f,\ max}$, can be calculated as

$$L_{f,max} = P_{tx} + G_{tx} + G_{tag} - \kappa - P_{th} \quad (1)$$

where

P_{tx} (dBm)=the transmit signal power fed into the reader antenna;

G_{tx} (dBi)=the reader's transmit antenna gain;

G_{tag} (dBi)=the tag antenna gain;

κ(dB)=the power loss due to backscatter modulation; and

P_{th} (dBm)=the threshold power necessary to power up the chip.

In passive RFID systems, the power induced at the tag's antenna is divided into two parts: one for the chip's power supply and the other for backscatter. The term κ refers to power loss due to backscatter modulation, which can be characterized by the tag modulation schemes: amplitude shift keying (ASK) or phase shift keying (PSK).[10] This power loss is then easily derived according to the following equation:[3]

$$\kappa = \begin{cases} -10\log_{10}\left(\dfrac{1-m^4}{(1+m)^2}\right) \text{for ASK} \\ -10\log_{10}\left(1-m^2\right) \text{for PSK} \end{cases} \quad (2)$$

where $0<m<1$ is the modulation index. The threshold power, P_{th}, is generally determined by the tag chip design architecture and the antenna matching condition. From industry experience, it is known that the RF threshold power level required to turn on a tag is 10 μW (-20 dBm) to 50 μW (-13 dBm).[3,4]

Figure 2 depicts the conceptual link budget calculation in the forward link. Upward direction arrows indicate gains, while downward direction arrows indicate losses. The tag received power, $P_{tag\text{-}rx}$, should be greater than P_{th}, to turn on the tag's IC chip. Accordingly, the maximum allowable path loss is calculated by Equation 1.

REVERSE LINK MAXIMUM ALLOWABLE LOSS

In the reverse link, the backscattered signal from the tag should be strong enough to meet the minimum

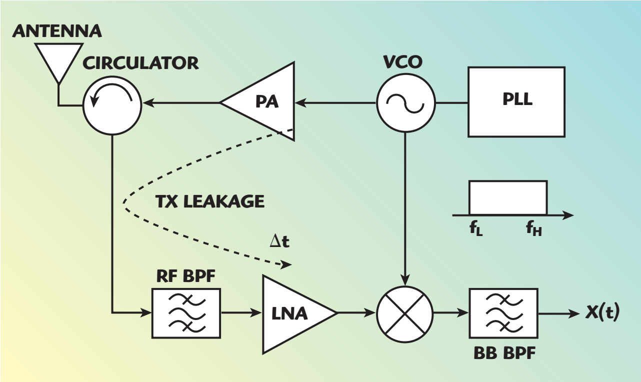


Fig. 3 UHF RFID system reader architecture.

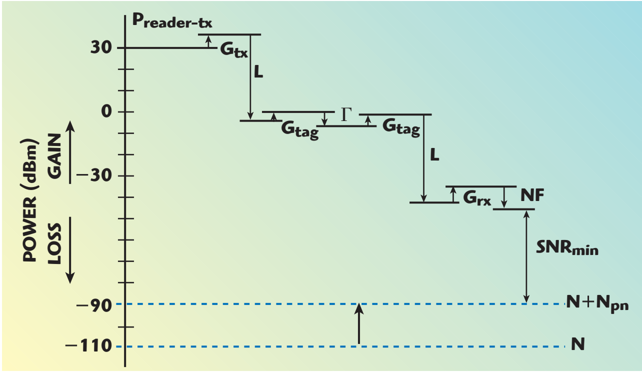


Fig. 4 Reverse link budget calculations.

signal-to-noise ratio (SNR) requirement at the reader's demodulation output. This is very similar to general wireless communication system links. However, because the CW signal always exists in a reverse link to turn the tag on, the TX leakage level plays an important role in determining the reverse link interrogation range. Fortunately, the direct current (DC) offset due to TX leakage is removed from a baseband bandpass filter. Nonetheless, the phase noise of the TX leakage on the receiving bandwidth is, unfortunately, not removed by the filter and may be much stronger than the thermal noise, to a degree that the reverse link interrogation range mainly depends on the phase noise of the TX leakage. On the other hand, in a general wireless communication system, the phase noise of the TX leakage is normally not a major problem, because duplexing techniques, such as frequency division duplexing (FDD) and time division duplexing (TDD), are applied.

To calculate the phase noise power of the TX leakage signal, the reader architecture should be given first. Consider the direct-conversion receiver architecture shown in ***Figure 3***. The reader is composed of a local oscillator (LO), a transmitter, a receiver and an antenna. The antenna can be configured in two types, two antennas or one antenna with a circulator, as shown in the figure. The circulator is a non-reciprocal three-port device, where the signals travel from the transmitter port to the antenna port or from the antenna port to the receiving port. In practice, the circulator cannot isolate the transmitter from the receiver entirely, due to the inherent leakage between its ports. Generally, TX leakage is between -20 to -50 dB.[11]

In the reverse link, the tag receives a CW signal from the reader transmit antenna, modulates it and backscatters a portion of it back to the reader receive antenna, as shown in ***Figure 4***. Using the monostatic radar equation defined by Balanis,[12] the reverse maximum allowable loss in dB, $L_{r,\,max}$, can be calculated as

$$L_{r,max} = (P_{tx} + G_{tx} + 2G_{tag} + G_{rx} - \Gamma - NF - SNR_{min} - N_{pn} - N)/2 \qquad (3)$$

where
Γ (dB) = the power reflection loss;
NF (dB) = the noise figure;
SNR_{min} (dB) = the minimal SNR to meet a given performance requirement;
N (dBm) = the thermal noise power; and
N_{pn} (dBm) = the phase noise power of TX leakage.
The power reflection loss due to the ion factor is given as

$$\Gamma = 10\log_{10}(m^2) \qquad (4)$$

for both ASK and PSK.

To calculate the reverse link budget, the minimum SNR value and the phase noise of the TX leakage power should be known. They are considered in the following sections. The minimum SNR value is obtained from the symbol error rate analysis of a system, and the phase noise of the TX leakage is obtained by integrating the power spectral density (PSD) over the passband of a baseband filter.

PHASE NOISE OF THE TX LEAKAGE

The phase noise is the degree of the LO's spectral impurity or a measure of the imperfection of the sinusoidal wave. If the PSD of a TX leakage is known, it is possible to calculate the phase noise level of the TX leakage by numerically integrating a PSD within the receiver's passband.

The LO provides two identical frequency signals: one for the transmitter and the other for the receiver. Neglecting the amplitude noise, the LO signal can be expressed as

$$X_{LO}(t) = A_{LO}\cos\left[\omega t + \theta_{LO}(t)\right] \qquad (5)$$

where
A_{LO} = the amplitude of the LO signal,
ω = the angular frequency, and
$\theta_{LO}(t)$ = the phase noise of the LO signal.

The power amplifier (PA) amplifies the LO signal to achieve a high power level. The amplified signal feeds into the reader antenna via the circulator and then radiates into the air. Simultaneously, the reader antenna also receives the backscattered signals from the tag. The circulator cannot totally isolate the transmitter from the receiver due to the inherent leakage between its ports. The TX leakage signal is delayed by Δt and is given as follows

$$X_U(t) = A_U\cos\left[\omega(t-\Delta t) + \theta_{LO}(t-\Delta t)\right] \qquad (6)$$

where

$A_U=\sqrt{2\eta R_0 P_{TX}}$ the signal amplitude

η = the TX leakage level

Δ = the round-trip delay between the TX leakage and the LO signal.

Before further discussion, it is important to recognize that $\theta_{LO}(t)$, in Equations 5 and 6, is related to the phase noise from the same LO except for a time delay.

Here, it is assumed that the baseband bandpass filter used in the reader receiver has a sharp frequency selectivity. To simplify the forthcoming analysis, the impulse response of the bandpass filter is characterized approximately with an ideal rectangular transfer function and its low-end frequency and high-end cut-off frequency are denoted as f_L and f_H, respectively. With a quadrature receiver, the TX leakage signal (Equation 6) and the LO signal (Equation 5) are mixed and the output is low-pass filtered. The resulting phase noise of the TX leakage signal will then be given as follows

$$N_{pn}=G_{rx}\int_{f_L}^{f_H}\Phi\left\{A_{LO}A_U\cos\left[\omega\Delta t+\Delta\theta(t)\right]\right\}df,$$
$$\Delta\theta(t)=\theta_{LO}(t)-\theta_{LO}(t-\Delta t) \qquad (7)$$

where G_{rx} is the transfer coefficient of the receiver, taking into consideration the total gain of the RF circuits and $\Phi\{\cdot\}$ denotes the operation of calculating the PSD of a random process, that is the Fourier transform of the autocorrelation function of a random process. If the RFID transmits only a UHF band CW signal, then the N_{pn} varies dramatically with a time delay. In the worst case, $\omega\Delta t$ takes a value of $(2n-1)\pi/2$ in Equation 7, where n is a positive integer, and the maximum phase noise of the TX leakage can be approximately expressed as

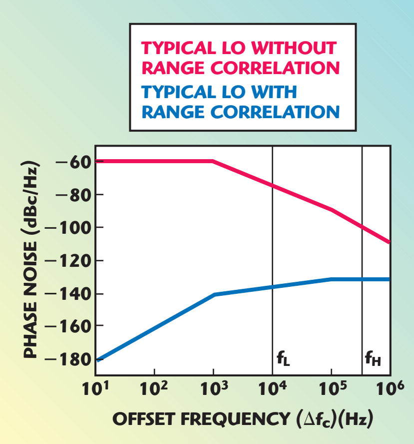
$$N_{pn}\approx G_{rx}A_{LO}^2A_U^2\int_{f_L}^{f_H}\Phi\left\{\Delta\theta(t)\right\}df \qquad (8)$$

which gives a maximum phase noise of the RFID reader.

If the same LO is used for the transmit and receive operations, the phase noise of the received signal is correlated with the LO, where the level of correlation depends on the time difference between the two signals. If the time difference is short, the corresponding effect greatly abbreviates the phase noise spectrum at the baseband. In radar applications, such as RFID, this phase-noise-reducing effect is called range correlation.[6,7] The baseband PSD at the offset frequency Δf_c with a round-trip delay of Δt is given by[6]

$$\Phi\left\{\Delta\theta(t)\right\}=\Phi\left\{\theta_{LO}(t)\right\}\cdot\left|1-\exp\left(-j4\pi\frac{r\Delta f_c}{c}\right)\right|^2=$$
$$\Phi\left\{\theta_{LO}(t)\right\}\cdot 4\sin^2\left(4\pi\frac{r\Delta f_c}{c}\right) \qquad (9)$$

Figure 5 shows an example of a typical PSD of the LO itself and the phase noise reduction effects due to the range correlation with a round-trip delay of 1 m. The typical PSD of the LO is selected considering state-of-the-art UHF RFID LO performance. The effect of the range correlation on the phase noise for different offset frequencies was estimated using Equation 8. For example, with an offset frequency of 10 Hz, the phase noise is reduced by 130 dB. The phase noise reduction is proportional to the square of the round-trip delay r and the square of the offset frequency, Δf_c. Due to the short round-trip delay (less than 1 m) between the TX leakage and the LO signals, the phase noise effects are dramatically reduced relative to the tag backscattered signal.



▲ *Fig. 5 LO phase noise vs. offset frequency.*

The phase noise reduction effect due to range correlation depends on the filter bandwidth. For a 160 kbps data rate, the measured phase noise reduction values have been shown previously.[13] The measured value is 41 dB and is almost the same as the result obtained by the authors. As shown in ***Table 1***, the TX leakage noise is much stronger than the thermal noise, to such a degree that the maximum allowable path loss mainly depends on the TX leakage level. In addition, the assumption that the phase noise of the TX leakage is dominant in determining the reverse link budget is verified. For a closed-loop phase-locked loop (PLL), the PSD of the phase noise is filtered by the transfer function of the PLL, and the phase noise effects are even smaller. Thus, this result for the open loop voltage-controlled oscillator (VCO) represents the worst case.

TABLE I

PHASE NOISE POWER REDUCTION DUE TO RANGE CORRELATION (4 W EIRP)

Data rate [kbps]	Filter BW [kHz]	Thermal noise power [dBm]	Phase noise reduction due to range correlation [dB]	TX leakage power [dBc] -20 dB isolation	TX leakage power [dBc] -50 dB isolation
40	10-80	-125.5	-51.1	-75.9	-98.9
80	10-160	-122.2	-47.1	-71.3	-94.3
160	10-320	-119.1	-42.9	-66.7	-89.7
320	10-640	-116.0	-38.6	-62.2	-85.2
640	10-1280	-112.9	-35.9	-59.3	-82.3

MINIMUM SNR

Reader sensitivity is an important parameter that defines the minimum level of the tag signal detected by a reader receiver.[14] The reader sensitivity is usually defined with respect to a certain signal-to-noise ratio (SNR) at the receiver. SNR is also obtained by a required transmission quality: bit error rate (BER) or sym-

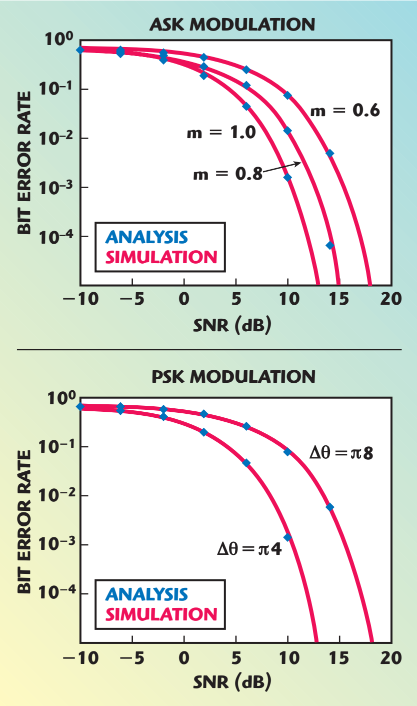


Fig. 6 Bit error rate for ASK and PSK modulation.

TABLE II

LINK BUDGET RESULTS

Parameters	Case I (Stationary Reader)	Case II (Mobile Reader)	UNITS
General Parameters			
1. Frequency	915	915	MHz
2. Data rate	160	160	kbps
3. Modulation	ASK	ASK	-
4. Modulation index, m	0.8	0.8	-
5. Reader TX power, P_{tx}	30	23	dBm
6. Reader TX antenna gain, G_{tx}	6	-3	dBi
7. Tag antenna gain, G_{tag}	2.15	2.15	dBi
8. Thermal noise power, N	-119.1	-119.1	dBm
9. Minimum SNR, SNR_{min}	12	12	dB
Forward Link Parameters			
10. Tag threshold power, P_{th}	-20	-20	dBm
11. Power supply loss due to backscattering, κ	7.39	7.39	dB
Forward link maximum allowable loss	50.76	34.76	dB
Forward link interrogation range	9.00	1.43	m
Reverse Link Parameters			
12. TX/RX Isolation	50	20	dB
13. Backscattered signal power loss, μ	1.94	1.94	dB
14. Phase noise power of TX leakage, N_{pn}	-97.5	-67.5	dBm
15. Noise figure at the reader RX, NF	10	10	dB
16. Link margin	3	3	dB
Reverse link maximum allowable loss	58.42	30.93	dB
Reverse link interrogation range	21.74	0.92	m
Total interrogation range	**9.00**	**0.92**	m

bol error rate (SER). A high SNR guarantees a low transmission error rate, but a large transmission power is required. Therefore, the minimum SNR value to meet a required transmission quality is preferable to enhance reader sensitivity.

The factors that can affect reader sensitivity include receiver implementation details, communication protocol specifics and noise, including interference from other readers. For example, according to the encoding scheme, the minimum SNR to meet a given BER can be found by different error probability equations. The minimum SNRs can be found by solving the following equations for a given BER value.

$$P_{FM0-ASK} = 1 - P_c = 1 - \left[1 - Q\left(\sqrt{\rho \frac{E_b}{N_0}}\right)\right]^2 \tag{10}$$

$$= 2Q\left(\sqrt{\rho \frac{E_b}{N_0}}\right)\left[1 - \frac{1}{2}Q\left(\sqrt{\rho \frac{E_b}{N_0}}\right)\right], \text{ where } \rho = \frac{m^2}{1+(1-m)^2}$$

$$P_{FM0-PSK} = 1 - P_c = 1 - \left[1 - Q\left(\sqrt{2\sin^2\theta_s \frac{E_b}{N_0}}\right)\right]^2 \tag{11}$$

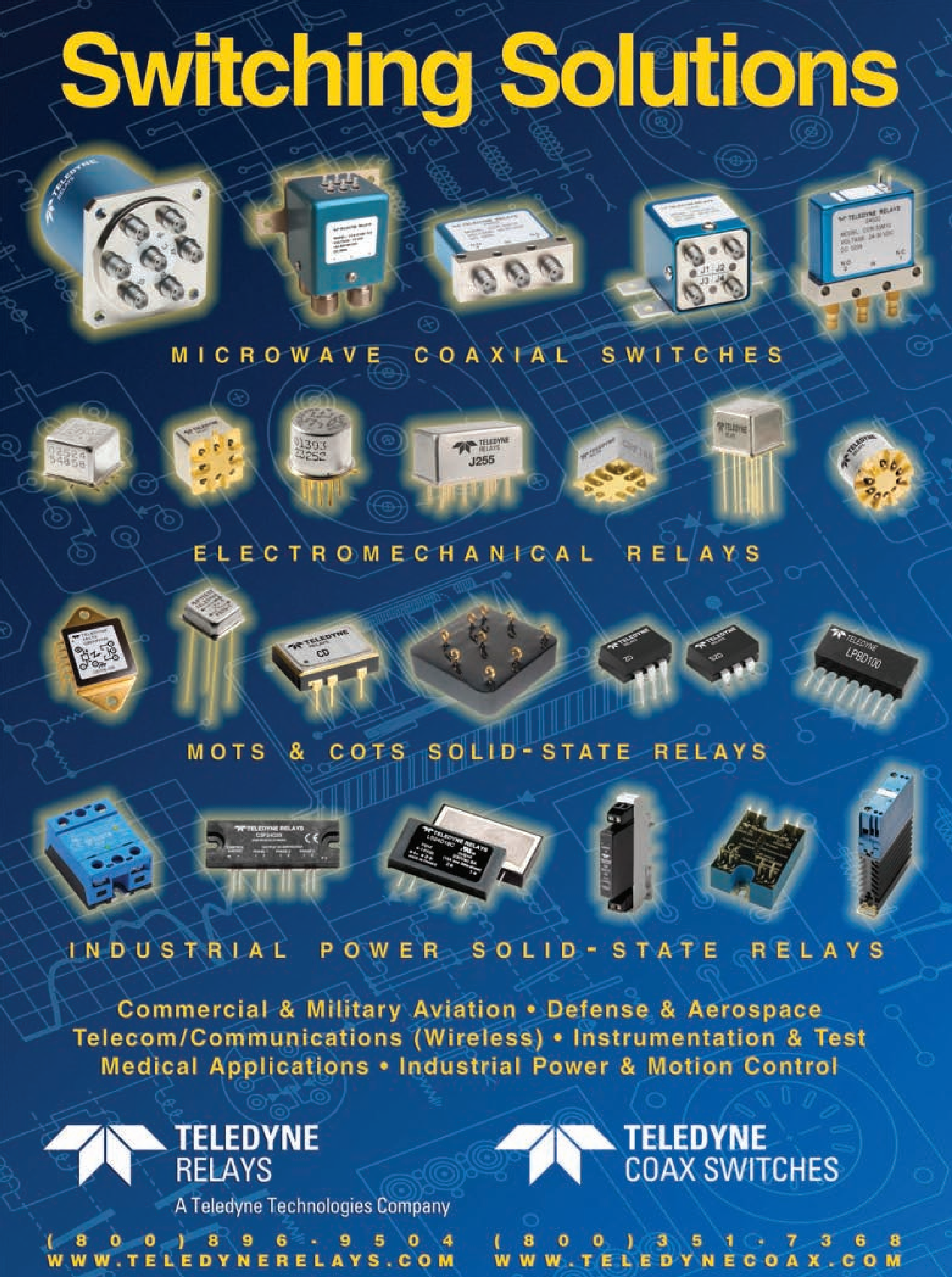
$$= 2Q\left(\sqrt{2\sin^2\theta_s \frac{E_b}{N_0}}\right) \times \left[1 - \frac{1}{2}Q\left(\sqrt{2\sin^2\theta_s \frac{E_b}{N_0}}\right)\right]$$

where
P_e=the error probability
P_c=the probability of a correct decision
θ_s=the modulation phase angle in a PSK
E_b=bit per energy
N_0=the power spectral density of additive white Gaussian noise.

Using Equations 10 and 11, the BER results for ASK and PSK modulation are given in ***Figure 6***. In the ASK case, as m is increased, the BER is decreased. In the PSK case, $\Delta\theta=\pi/4$ shows better BER performance. At a BER of 10^{-3}, the minimum required SNRs are 10 dB for m=1, 12 dB for m=0.8 and 15 dB for m=0.6.

LINK BUDGET CALCULATIONS

To show the usefulness of the link budget analysis, two different cases are presented: a stationary reader case and a mobile reader case. In the mobile RFID case, which uses an internal antenna and a low performance circulator due to size limitations, the antenna gain is -3 dBi, and the circulator performance may be very low. The TX powers are 1 W in the stationary reader and 0.2 W in the mobile reader. In calculating the interrogation range, the used path loss model is the free space model. The interrogation range is easily calculated from the maximum allowable loss and the path loss model.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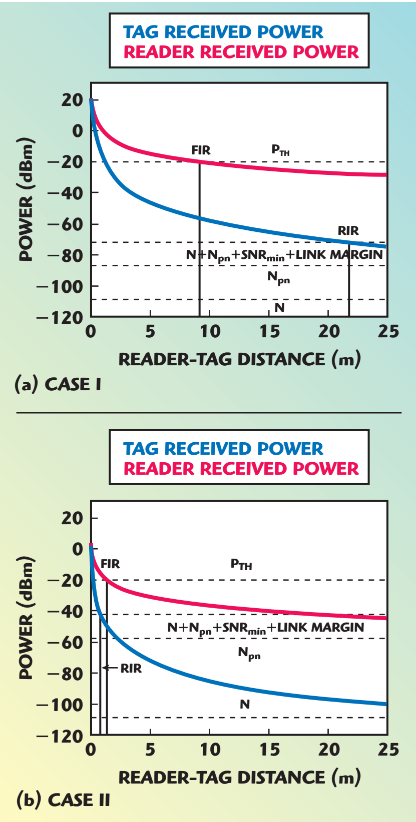
The resulting link budget is given in **Table 2**. Case I shows that the interrogation range in the forward link is smaller than that in the reverse link, which means that stationary RFID is a forward link limited system. Case II shows the opposite result: a mobile RFID is a reverse link limited system. The prominent difference between the two cases is the phase noise of the TX leakage. In case II, therefore, TX leakage should be reduced to overcome the reverse link limit, because a mobile RFID reader similar to that in case II has poor TX/RX isolation, which results in an increase of phase noise. For the same effective isolated radiation power (EIRP), an antenna with a larger gain is preferable for the reader. This can also reduce the phase noise of TX leakage.

If one of the interrogation ranges is much larger than the other, the system might waste some resources. Therefore, to avoid a waste of resources, it is preferable to balance the two interrogation ranges. An easy way to increase the forward link interrogation range (FIR) is to allocate a large amount of TX power for the forward link. This results in an increased TX leakage, which reduces the reverse interrogation range (RIR) and may cause a reverse link limited system. Therefore, simply increasing transmit power cannot always balance FIR and RIR. In such case, the above link budget analysis can be a useful tool that enables FIR to coincide with RIR within an allowable range.

Finally, **Figure 7** shows a link budget according to tag-reader distance. The forward link interrogation range (FIR) is defined as the maximum distance at which the tag receives just enough power to turn on, and the reverse interrogation range (RIR) is the maximum distance at which the tag signal meets the minimum reader sensitivity condition. As shown, the FIR is determined by a tag threshold voltage, and the reverse link interrogation range (RIR) is mainly determined by the TX leakage noise level.



▲ *Fig. 7 Determination of interrogation range.*

CONCLUSION

When system engineers are deploying UHF RFID systems, the interrogation range is a key design parameter. To maintain good performance and stable operation of an RFID system, the interrogation range should first be well understood in relation to the link budget. In this regard, a link budget analysis for UHF RFID systems has been presented in this article. A forward link budget was calculated using the required power at the input of the tag IC chip, while a reverse link budget was calculated from the required SNR at the demodulator output of the reader to detect the receiving tag's data correctly.

As an example of link budget calculation, stationary RFID reader and mobile RFID reader results were compared. In the stationary reader case, the FIR is less than the RIR and in the mobile reader case, RIR is less than FIR. Therefore, the stationary RFID reader case can be described as a forward link limited system, whereas the mobile RFID reader case can be described as a reverse link limited system. Since the threshold power necessary to power up the tag is the dominant factor determining FIR, it is a bottleneck in the stationary RFID. Similarly, the phase noise of TX leakage is a bottleneck in the mobile RFID. The results presented here can serve as a useful reference when deploying UHF RFID systems. ■

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WIDEBAND DUAL-TOP LOADING MONOPOLE ANTENNA

In this article, a low profile, wideband, dual-loaded monopole antenna with a ring-shaped plate is presented. The ring-shaped plate in the ground plane is used to enhance the impedance matching and to increase the antenna gain, resulting from a low radiation resistance in the usable band. The dual-loading is obtained from the ring-plate and an umbrella top loading, which reduces the antenna height and enhances the bandwidth, respectively. Dual dielectric posts are also used to improve the coupling between the lower aluminum post and the umbrella element. This configuration enhances the broadband operation. Experimentally, a lower bandwidth of 61.2 percent (1.62 to 3.05 GHz) and a higher bandwidth of 44.8 percent (3.78 to 5.96 GHz) were obtained for a VSWR less than 2.0. This antenna provides both wideband and multi-band characteristics. The proposed antenna can be used in PCS, DCS, IMT-2000, WLL, DMB, home- and hospital-network operations, and medical instrument applications.

Monopole antennas are used in mobile communications. A monopole antenna is a very simple and efficient radiating element.[1] It is well known that the smaller the size of the antenna, the lower its efficiency and narrower its bandwidth (a few percent).[2] A 36 percent bandwidth enhancement of a monopole antenna using a parasitic normal-mode helix[3] and a planar monopole antenna with a bandwidth of 44 percent[4] have been reported. A small size, top-loaded monopole antenna was described in the literature,[5] but its operational frequency bandwidth is very narrow (a few percent).

In this article, a wide and multi-band top- and center-loaded monopole antenna with a ring-shaped plate is proposed. The ring-shaped plate is used to enhance the impedance matching and to increase the antenna gain by causing a low radiation resistance in the usable band. Moreover, a dual-top loading, consisting of a center-loading (a ring-plate) and a top loading (an umbrella-type), acts to reduce the antenna size and enhance the bandwidth, respectively. This antenna also offers wideband and multi-band characteristics.

ANTENNA STRUCTURE AND EXPERIMENTAL RESULTS

The structure of the proposed wide and multi-band dual-top loading monopole antenna with a ring-shaped plate is shown in ***Figure 1***. It consists of a post-type monopole, a dual dielectric post (dielectric posts 1 and 2), a dual-top load (a ring-plate and an umbrella-type ele-

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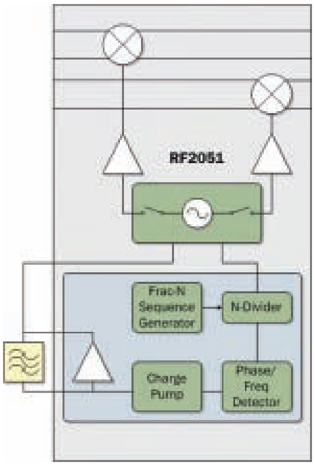

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205x SERIES SPECIFICATIONS

	Units	RF2051	RF2052	RF2053
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On-chip VCOs		Yes	Yes	No
RF mixers		2	1	1
DC Parameters				
Supply voltage	V	3.0	3.0	3.0
Supply current (low-current setting)	mA	55	55	55
VCO and Synthesizer				
Input reference frequency	**MHz**		**10 to 104**	
LO frequency	MHz	300 to 2400	300 to 2400	-
Open loop VCO phase noise at 500 MHz LO frequency	dBc/Hz	-140	-140	-
RF Mixer				
RF and IF port frequency range	**MHz**		**50 to 2500**	
Noise figure (low-current setting)	dB	-	9.5	-
Input IP3 (high-linearity setting)	dBm	-	20	-

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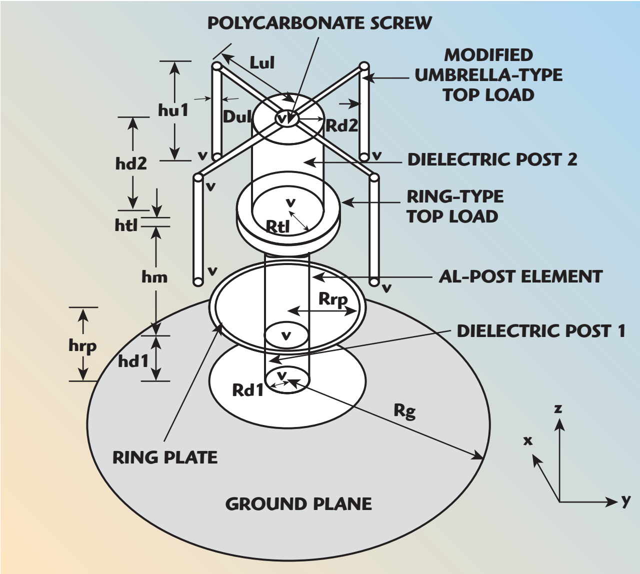
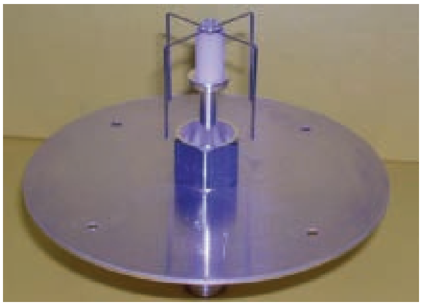


▲ *Fig. 1 Antenna structure.*

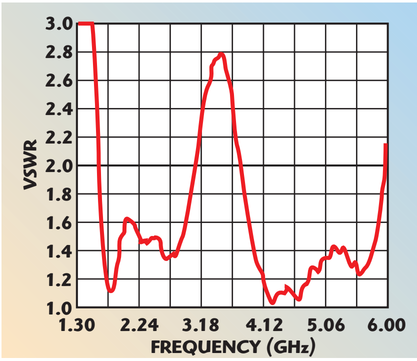
ment), a ring-shaped plate on the ground plane, a circular ground plane and a 50 Ω N-type connector. The lower dielectric post (post 1) is placed between the ground plane and the aluminum post, improving the coupling. The aluminum monopole consists of a ring-shaped loading plate and a post-type element inserted between the dielectric posts 1 and 2. The two dielectric posts, made of polyacetal with a dielectric constant ε_r= 3.7, also improve the coupling between the lower aluminum post and the umbrella-type top element. As a result, a much wider bandwidth is obtained than without the dielectric posts. The 50 Ω N-type connector is attached to the dielectric post 1, through a large hole in the ground plane. The umbrella-type element is composed of four Al rods, which are oriented 90° from each other and attached to the upper dielectric post with a polycarbonate screw (ε_r= 3.0).

L_{ul} and h_{ul} are the lengths of the horizontal and vertical sections of the umbrella element, respectively. D_{ul} is the diameter of the aluminum rod. R_{d1}, R_{d2} and h_{d1}, h_{d2} are the radii and the heights of the first and the second dielectric posts, respectively. H_m is the height of the aluminum post. H_{tl} is the height of the center-loading ring-plate and h_{rp} is the height of the ground ring-plate. R_{tl} and R_{rp} are the radii of the center-loading ring-plate and the ground plane ring-plate, respectively. R_g is the radius of the circular ground plane. The top loading is used to reduce the height of the antenna. The additional ring-shaped plate also leads to obtain a wider bandwidth and a higher gain than the conventional top loading monopole structures. The top loading reduces the high-angle radiation, which leads to a decrease of the multi-path fading, and to increase the service area.[6] ***Figure 2*** shows a photograph of the fabricated antenna.

The fabricated antenna dimensions are as follows: L_{ul}= 18 mm, h_{ul}= 28 mm, D_{ul}= 2.5 mm, h_{tl}= 2.8 mm, R_{tl}= 6 mm, h_{d1}= 3 mm, R_{d1}= 3.5 mm, h_m= 35 mm, h_{d2}= 15 mm, R_{d2}= 4 mm, h_{rp}= 14 mm R_{rp}=10 mm, R_g= 55 mm. The 50 Ω N-type connector is located on the z-axis to feed the proposed antenna. The post-type element is used to enhance the impedance matching.



▲ *Fig. 2 Photograph of the antenna.*



▲ *Fig. 3 Measured VSWR.*

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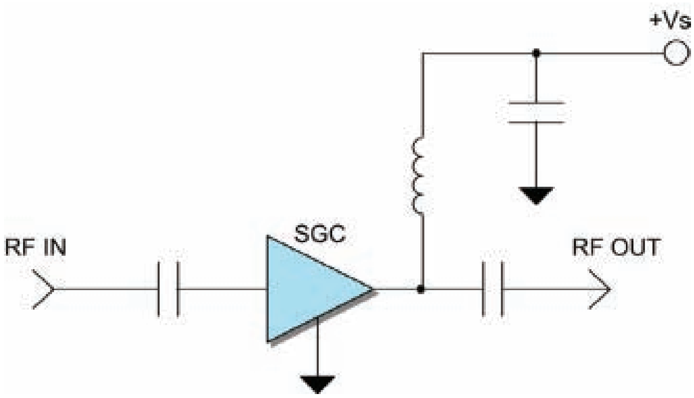

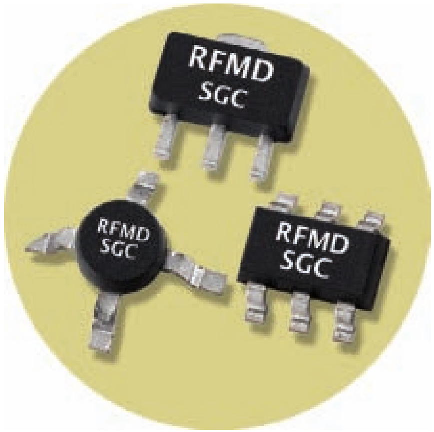

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SGC-24xxZ	50 MHz to 4000 MHz	19.9 dB [1]	25 mA	3.3 dB [2]	23 dBm [1]	10.5 dBm [1]	3.0
SGC-64xxZ	50 MHz to 3500 MHz	22.2 dB [1]	85 mA	2.4 dB [2]	34.1 dBm [1]	20.6 dBm [1]	5.0

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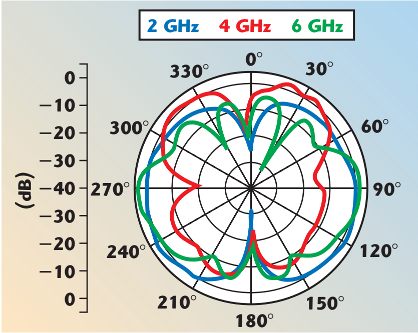
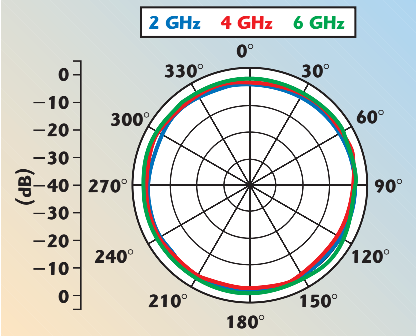
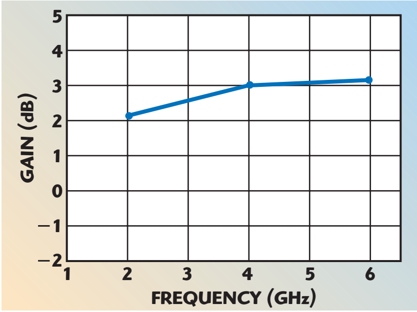


▲ *Fig. 4 Measured radiation pattern in the y-z plane.*



▲ *Fig. 5 Measured radiation pattern in the x-z plane.*



▲ *Fig. 6 Measured antenna gain.*

The circular ground plane is made of aluminum, 1.0 mm thick.

The measured VSWR as a function of frequency is shown in ***Figure 3***. The measured impedance bandwidth shows a lower band of 1.62 to 3.05 GHz (61.2 percent) with a center frequency of 2.335 GHz and a higher band of 3.78 to 5.96 GHz (44.8 percent) with a center frequency of 4.87 GHz for a VSWR of less than 2.0. This antenna offers wideband and multi-band characteristics. The proposed antenna can be applied to PCS, DCS, IMT-2000, WLL, DMB and home-network operations.

After calibration using a horn antenna, the radiation pattern in the far field was measured. An investigation of the radiation pattern characteristics of this antenna shows them to be similar to a conventional monopole. In ***Figure 4***, the measured y-z plane radiation pattern of the proposed antenna is a bi-conical radiation pattern. The x-z plane radiation pattern is omni-directional without distortions, as illustrated in ***Figure 5***.

The measured gain versus frequency for the monopole antenna is given in ***Figure 6***. The measured maximum gain of the proposed antenna is approximately 3.2 dBi.

CONCLUSION

In this article, a low profile wideband dual-loading monopole antenna with a ring-shaped plate is presented. The ring-shaped plate on the ground plane is used to enhance the impedance matching and to increase the antenna gain. Two dielectric posts are used to improve the coupling between the lower aluminum post and the umbrella type element, leading to an enhanced bandwidth. The dual-loading consists of the ring-plate and the umbrella top, which acts to reduce the antenna height and enhance the bandwidth, respectively. A lower band of 1.62 to 3.05 GHz (61.2 percent) and a higher band of 3.78 to 5.96 GHz (44.8 percent) have been measured for a VSWR less than 2.0. This antenna offers wideband and multi-band characteristics. The proposed antenna can be applied PCS, DCS, IMT-2000, WLL, DMB, home- and hospital-network operations, and medical instrument applications. ■

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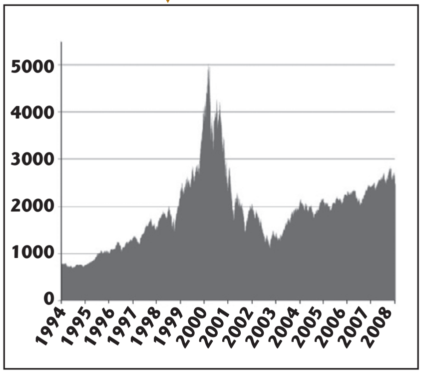
A MICROWAVE JOURNEY, PART VI: THE 2000S

We come to the final chapter in this history of *Microwave Journal*'s first 50 years, a story told through five decades of articles by the industry's business and technology leaders. This story began with entrepreneurs William Bazzy and Ted Saad founding the magazine and serving as the first publisher and technical editor, respectively, in the summer of 1958. We end this journey in the present decade, the first of a new millennium. As we entered the 21st century, technical and non-technical people alike were concerned that shortsighted computer programming would cause worldwide havoc as clocks turned over from 1999 to 2000, an unprecedented election would have the country waiting weeks before a winner was decided and the world would forever change on September 11th, 2001.

Fig. 1 Nasdaq stock index shows the bursting dot-com bubble that kicked off the new decade.



THE 2000s

Led by what would become known as the dot-com bubble, technology ruled the start of the decade—at least in the stock market until the crash wiped out $5 trillion in technology companies' market value between March 2000 and October 2002 (see ***Figure 1***). This enormous loss of faith in technology companies had its impact on the high-flying telecom sector as several communication companies, including NorthPoint Communications, Global Crossing, JDS Uniphase, XO Communications and Covad Communications, burdened with unredeemable debts from their expansion projects, sold their assets for cash or filed for bankruptcy. Demand for the new high-speed infrastructure did not materialize and many fiber networks went dark. The impact would cross over to the commercial microwave industry just as the wireless revolution was gearing up for the next generation of mobile communication.

JANUARY 2000

The technical specifications for building wireless network components was defined in the original version of the standard IEEE 802.11 released in 1997 and modified to the 802.11b in September 1999. Special reports in the January issue reviewed the 1999 wireless

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MSWSH-020-30	6	20	0.25	19	31	2012	Shunt
MSWSH-100-30	6	100	0.15	22	31	CM22	Shunt
MSWSHB-020-30	10	20	0.40*	30*	32*	2012	Shunt
MSWSSB-020-30	10	20	0.60*	20*	35*	2012	Series/shunt

All specs at ambient temperature   ** denotes 10 GHz*

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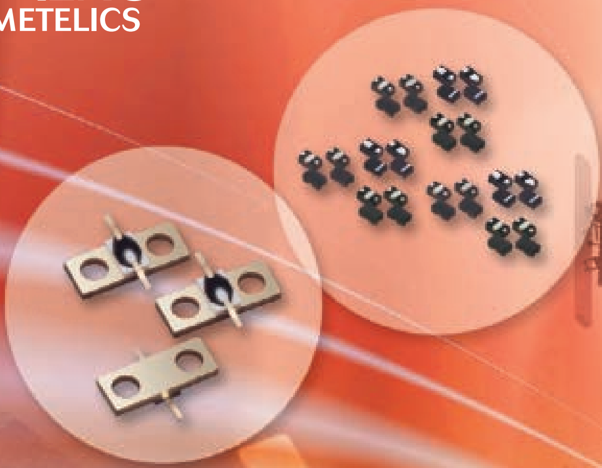

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▲ *Fig. 2 A magazine makeover and editorial change for 2005.*

workshop and previewed the upcoming Wireless/Portable by Design Exhibition and Conference, which included talks by various companies on the use of design software, advances in packaging, advance modulation techniques (spread spectrum, CDMA, frequency hopping, etc.) and RF fundamentals (by Besser Associates). Frank Bashore's "A Review of the 1999 Wireless Workshop" took a look at this workshop held in Gold Canyon, AZ, co-sponsored by Merix Corp., Motorola and Rogers Corp. The technical program was kicked off by Robert Keenan of VerticalNet's Wireless DesignOnline and Bob Sankman of Intel; both discussed various aspects of RF packaging and interconnect challenges for future high speed communication systems. Technical features in this issue focused on various high performance microwave components, such as a fractal antenna, high stability phase-locked source for QAM radio, WLAN directional panel antenna and an ultra-linear, wideband feed-forward amplifier design at 460 MHz using EDA tools.

OCTOBER 2001

Communications is the theme for the month with articles on Orthogonal Frequency Division Multiplexing (OFDM), regrowth of data spectral sidelobes and lossy linearizers for reducing nonlinear distortion. September 11th has already happened, yet the October issue was well into production and there is no mention of the event. News from Washington instead mentions the Bush administration's focus on the presidential Trade Promotion Authority and contracts won by Rockwell, DynCorp and Raytheon.

One report in the Commercial Market by Cahners In-Stat, "Mobile Commerce: A Work in Progress," mentioned the less than stellar economic performance for the wireless industry, looking closely at the issues and possible solutions to the problem. The report blamed the slow uptake on the premature launch of m-commerce services as carrier networks were inadequate to handle the e-commerce experience that had been promised to customers. The report felt packet-switched services such as GPRS held great promise to improve service to the level expected. Another report considered that the growth in the number of remote workers and telecommuters would be responsible for driving up demand for broadband services.

Microwave business was also summarized in a special report by Stuart Litt of OEM Capitol, "Midsummer Thoughts on Microwave and RF Market Opportunities." In the report, the author discussed the fallout from the telecom bust with terms such as "severe business downturn" and the end of the "telecom operators' capital spending binge." The author saw a big challenge ahead for an industry that had grown large by way of lucrative government contracts and stayed fat with excessive investment in capitol equipment by overly eager telecoms building for capacity that did not exist. Thinking ahead about the next phase in the industry's evolution, the author felt the telecom revival would be a long time in coming but that companies could survive the drought if they were willing to trim down, follow the production efficiencies adopted by the computer industry and focus on costs.

OCTOBER 2002

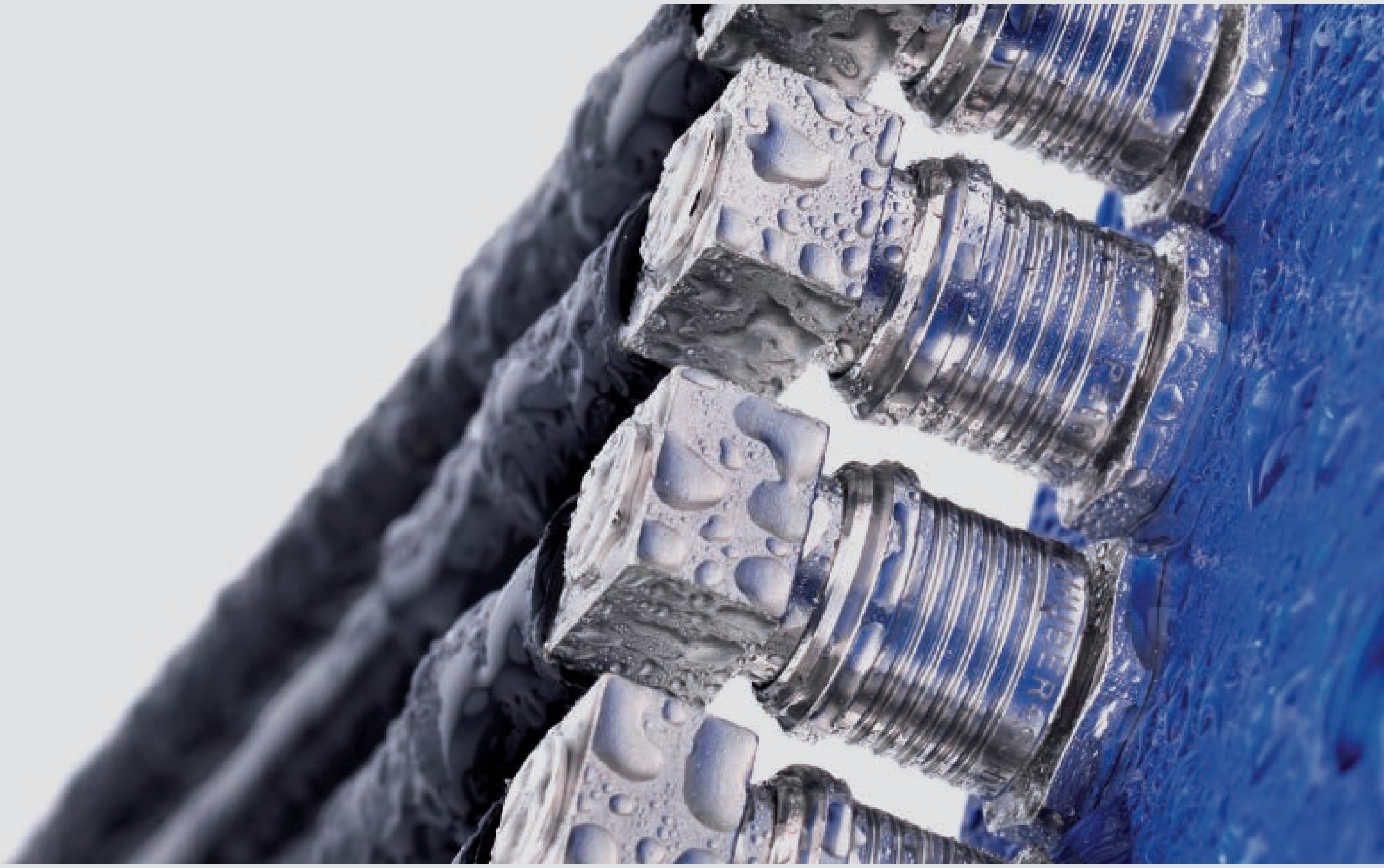
For the third time in the *Journal*'s 44-year history, the publisher's mantle was passed on, this time to veteran National Sales Manager, Carl Sheffres. Harlan Howe wrote the following with regard to the transition: "I find it hard to believe that it has been 12 years since Howard Ellowitz wrote a similar message announcing his retirement and introducing me as the new Publisher/Editor of *Microwave Journal*. Now it is my turn to slow down a little and find some breathing room. With this issue, I am retiring as Publisher of *Microwave Journal*. Like Howard before me, I plan to continue to work part time for Horizon House. I will still be the Editor of *Microwave Journal* and I will continue to share in the management of the MTT-S Exhibition."

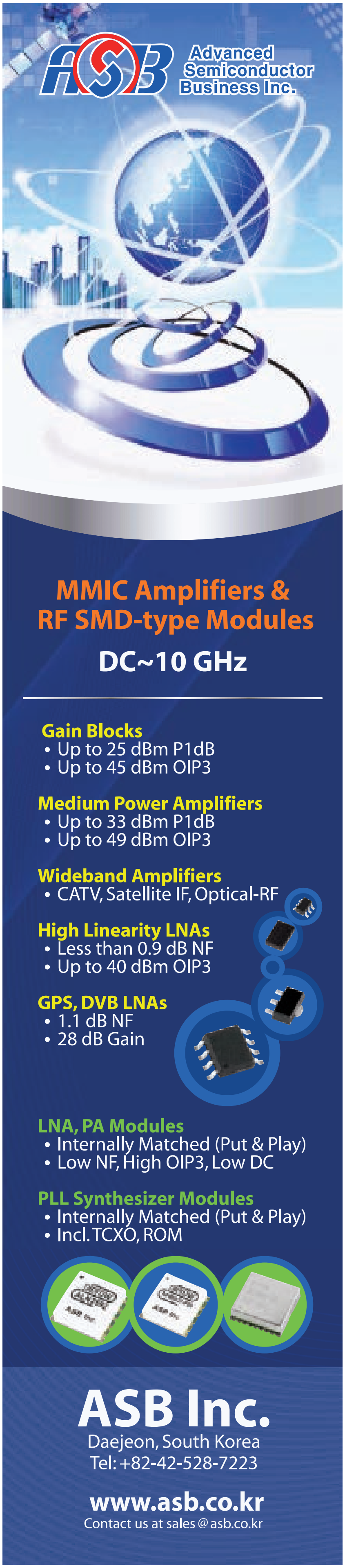
JANUARY 2003

The United States is one month away from the invasion of Iraq and the microwave industry so closely tied to the military seems to be mostly engaged in developing wireless technology. Once again, the *Journal* gives extensive coverage in January to the Wireless Systems Design Show. Also featured are technical articles on RF module design for a multi-mode handset (the transition from 2G to 3G systems is in full effect), a CMOS power amplifier for Bluetooth and WLAN applications, and a 2 x 16 antenna T/R switch matrix for 28 GHz wireless applications. Articles on simulation software from Ansoft and Eagleware reflect their enhanced capabilities and growing importance in reducing design cycles. Sonnet Software would grace the cover of the December issue and November would feature a special one-time supplement devoted to CAD and test and measurement. Despite the lack of technical articles with a focus on military applications, there is a clear uptick in advertisers targeting the military market and the monthly Defense News includes Raytheon's successful underwater launch of a Tomahawk missile, a live-fire test of infrared countermeasures and a Northrop Grumman win for work on radar antenna. Dual-use components would appear to help certain manufacturers re-engage with the military market simply with a change in their marketing campaigns (i.e., warships, fighter jets and desert-camouflaged Humvees).

JANUARY 2004

The Cold War is truly over as this issue of *Microwave Journal* offers a





comprehensive overview of Russian fighter radars from the 1960s to the present in a Special Report called "Got You Covered" by Michal Fiszer and Jerzy Gruszczynski. The article tells of the Soviet planners' decision to equip all MiG-25Ps with a completely new radar after Soviet pilot Viktor Belenko escaped with his MiG-25P to Japan in 1976. An article that told the history, politics and technical challenges behind the evolution of Russian airborne radar, spelled out in such great detail (http://www.mwjournal.com/Journal/article.asp?HH_ID=AR_1336) would have been unimaginable just 10 years earlier.

DECEMBER 2004

This would be the last issue of the *Microwave Journal* with the white border cover format that had been in place for a number of years. In January of 2005, publisher Carl Sheffres would announce several changes to the magazine, the first being a makeover for the magazine cover. As Carl wrote in his Note from the Publisher, "I'll begin with the changes, since you've probably noticed the most obvious of them already. Yes, the cover has a new look and a new direction. The cover graphic will now reflect the editorial theme for the issue, as illustrated in this month's "Radar/Antennas" focus. Less obvious, but no less significant, is the change to the cover story, which will now relate specifically to the featured editorial focus for each month, providing insight into the current state and future trends of that particular market or product segment, and written by an industry expert." This bold step would move the magazine away from featuring a new product on the cover and toward addressing a specific aspect of the monthly theme and tapping industry leaders to share their expertise.

APRIL 2005

This month was a solid issue devoted to amplifiers and oscillators (still the theme for the April issue) with several industry experts and numerous technical articles and state-of-the-art product features. Power amplifier guru Steve Cripps was author of a Special Report called "RF Power 2005" (www.mwjournal.com/Journal/article.asp?HH_ID=AR_353). Cripps very clearly stated the challenges of designing amplifiers, "which can address all wireless systems' need for power, efficiency and linearity." The author worked these requirements back to the system demand for "an ever-increasing number of users, leading to the specifications on adjacent channel interference (which) keep getting more stringent, and more efficient modulation systems (which) keep demanding more dynamic range and higher instantaneous signal bandwidth." Cripps then explored the various available technologies and amplifier topologies with regard to performance trade-offs and other considerations. George Vendelin with Jose Carlos Pedro and Pedro Miguel Cabral discussed some amplifier and solid state fundamentals in their article, "Amplifier and Transistor Gain Revisited" (www.mwjournal.com/Journal/article.asp?HH_ID=AR_354).

NOVEMBER WIRELESS SUPPLEMENT 2006

Our second annual Wireless Technologies Supplement (2006), which will be relabeled *WiMAX and Emerging Technologies* in 2007 and *WiMAX, LTE and Emerging Wireless* in 2008, reflects the shifting standards that are gearing up to leapfrog 3G systems. (Next year we will hedge our bets with our Next Generation Wireless System supplement.) The first year's supplement featured a Special Report from Harlan Howe and Richard Mumford called "Wireless Technologies: Viewpoints from Two Markets and Two Continents" (www.mwjournal.com/journal/article.asp?HH_ID=AR_564). This article was based on interviews with executives from a number of players in the wireless arena, including Jerry Neal of RFMD, Charles McCauley of Renaissance Electronics, Bill Flerchinger of Agilent Wireless Division, Adrian Nemcek of Motorola Networks Business, Jean-Luc Etienne of Chelton Telecom and Wolfgang Bosch of Filtronics. How did the respondents view the evolving requirements of the communications sector in 2006? According to Charles McCauley of Renaissance, "We have seen everything from making products that can be

▲ *Fig. 3 The May 2007 IMS MTT-S show issue.*

used simultaneously for CDMA, TDMA and MSM, to products which are capable of handling the 800, 900, 1800 and 1900 MHz spectrums. The telecommunications market is trying to find new ways to save both space and money, while being able to use every available technology and every kilohertz of bandwidth at their disposal. The bandwidth driver for 3G, 4G, data and video will be the most prevalent of demands." By the second edition, the focus is squarely on WiMAX, HSPU and WiMedia UWB with contributions from Analog Devices, Agilent Technologies and Rohde & Schwarz.

MAY 2007

Did you ever think you would live long enough to see Hawaii on the cover of an issue of *Microwave Journal*? Since the first time when the MTT-S decided to host the national symposium in a visitor-friendly location—choosing the Hotel Del Coronado in San Diego, CA for the 1960 gathering—the *Journal* has dedicated the May cover and its reporting to the IMS. Our art department did its best to portray Honolulu as a serious venue for the world's leading conference on microwave technology, but a tropical island is a tropical island and this month's cover is among our most serene ever.

DECEMBER 2007

This was our first issue dedicated solely to microwave applications that extend beyond communication and the military applications. Since the earliest days of the *Journal*, scientists and engineers have been exploring and writing about how to use microwaves to address medical problems, automotive safety, location technology (GPS and RFID) and machine to machine communications. In 2007, our Industrial, Scientific and Medical Applications issue was launched. The issue will finish each year with reporting on the emerging technologies which may (at the time) reflect relatively small markets yet represents some of the most innovative uses of radio and microwaves coming from academia and commercial R&D labs. Alan Jenkins of Tyco Electronics M/A-COM gets the ball rolling with an article on the development and deployment of millimeter-wave-based technology for remote-sensing applications in vehicles.

CONCLUSION

So here we are, 50 years later. A robust industry and trade journal connected at the hip, walking in locked step. Our industry is a tight community with many personal connections. We have seen many changes to our business and the world around us. We have weathered numerous macro-economic changes that a less resilient and inventive community would not have survived. The staff at the *Journal* is truly grateful to our contributors who share their stories with our readers at large, to our readers for their loyalty and to our advertisers for their financial support. We also appreciate that while it is one of our readers primary jobs to work diligently to reduce the size of their products' footprint, we at the *Journal* have an opposite goal. We strive—with the help of our many contributors and readers—to expand the size of our footprint, spreading news of our industry's successes and helping that industry see over the horizon. Just as we set out to do 50 years ago when two entrepreneurs named Bazzy and Saad started a small trade publication called *Microwave Journal*. ■

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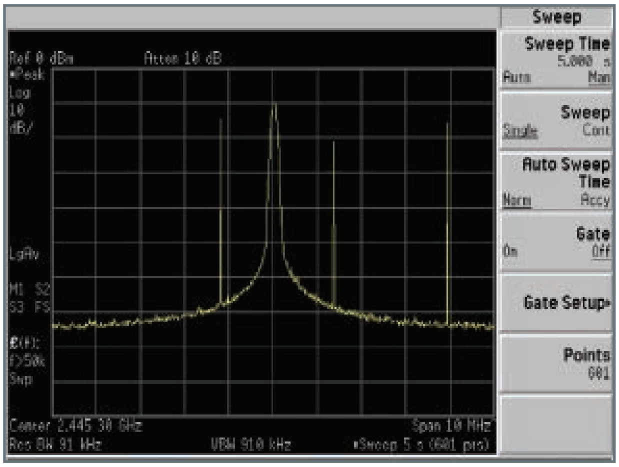
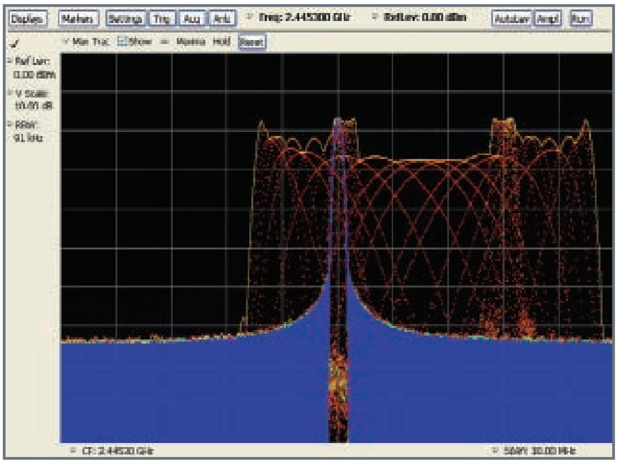
DESIGN



Traditional Spectrum Analyzer
5 seconds



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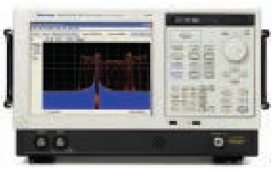

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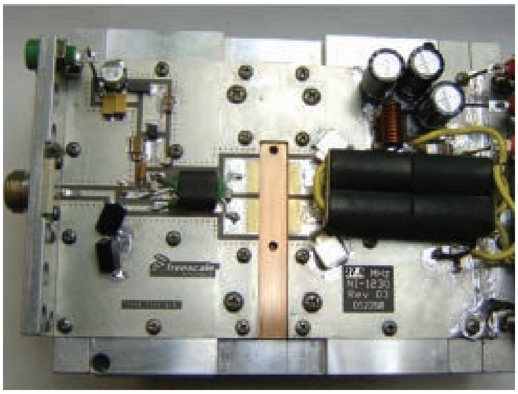

1 kW Pulse Power Amplifier for ISM Band

The recent launch of Freescale RF high power, high voltage LDMOS devices has made possible the design of kilowatt class power amplifiers in a compact format. A 1 kW power amplifier operating in pulse mode at 27.5 MHz intended for ISM applications has been designed. It is targeted for high power applications using a single push-pull device in a symmetric configuration for use in MRI as a RF source building block for multi-kilowatt power amplifiers. The MRF6VP11KH is a 50 V LDMOS device capable of exceeding 1000 W RF pulse output power at 130 MHz at a large-signal gain of 26 dB in Class AB2 and a drain efficiency of 71 percent. It can handle 10:1 VSWR at V_{ds} of 50 VDC, 130 MHz at 1000 W peak power. The ceramic package is a NI-1230 size, case 375D-05, style 1 with gold plated flanges.

COMPONENT SELECTION

At high power levels, large DC and RF currents flow through the circuit and components. Hence, it is important to design and dimension the PC board traces, capacitors, inductors and transformers to operate safely at the rated output RF power of 1 kW. Component selection pointed to the following:

- Gate DC bias decoupling network: a four-stage circuit to reduce power supply noise and provide RF bypass. The first stage is comprised of electrolytic and tantalum bypass capacitors with low ESR to locally reduce ripple and noise, followed by a two-stage LC network that provides RF decoupling via ceramic capacitors. A final RC stage ensures RF bypass before entering the input coupling transformer. The multi-stage approach assures stable operation as the amplifier operates at high gain.
- Input RF sub-network: ceramic capacitors and ferrite core input matching transformer to reduce leakage inductance and improve coupling between primary and secondary.
- Drain DC bias decoupling network: a three-stage circuit to reduce power supply noise and provide RF return to ground. The first stage has electrolytic bypass capacitors with low ESR to locally reduce ripple and noise, followed by a two-stage LC network that provides RF decoupling via ceramic capacitors. Additional RF return to ground is provided by two low ESR ceramic capacitors in parallel at the output transformer primary center-tap. The DC power supply Vsense line has a separate connec-

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tion to minimize voltage drop in the circuit.

- Output RF sub-network: mica HV capacitors and large ferrite core output matching transformer able to carry the maximum power with low loss.

Final component values are given in ***Table 1***.

With an estimated drain efficiency of 65 percent, this represents a heat generation of 35 percent of the DC input power. The thermal design is an important consideration for high power amplifiers as the junction temperature (T_j) must be kept below 200°C, otherwise the device reliability in terms of MTTF will be impacted. A 5 by 5 inch pin fin type heat sink with a Cu heat spreader was selected. Forced air through the fin pins is used

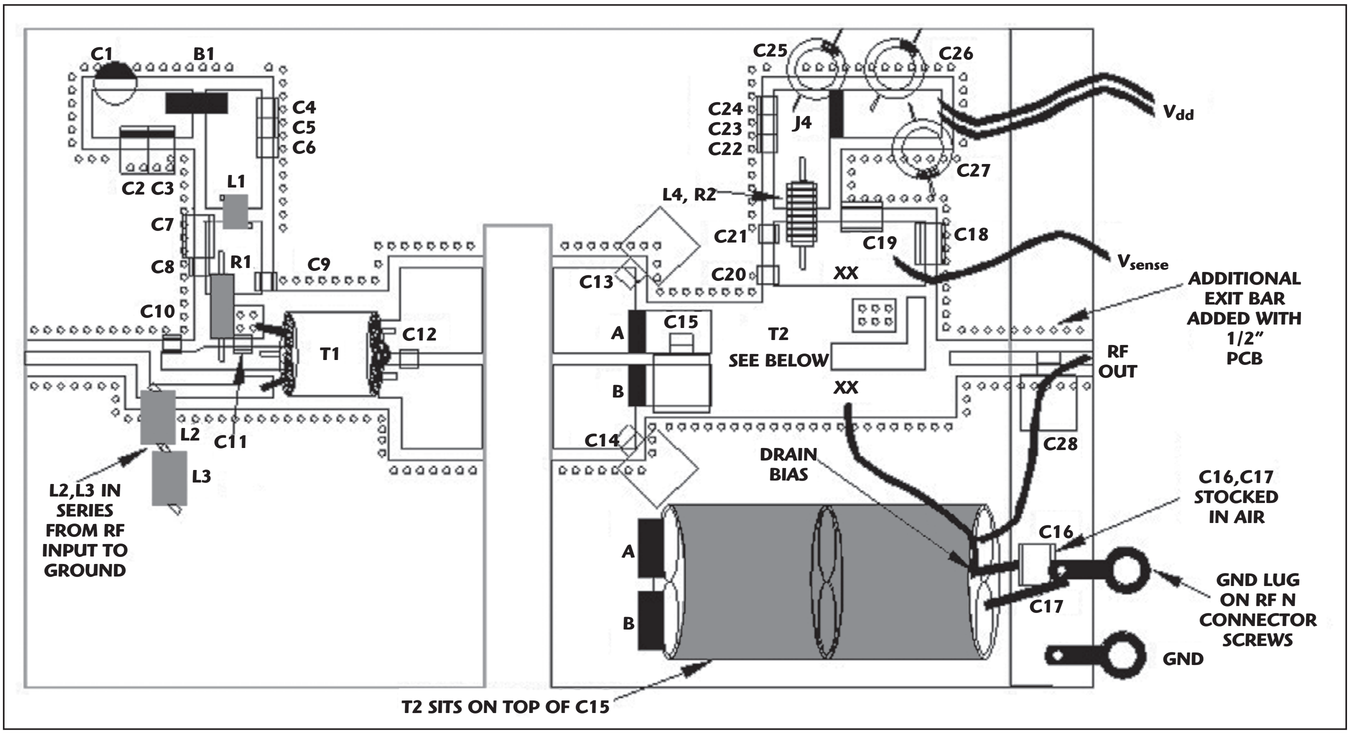


Fig. 1 Parts assembly and PC board layout.

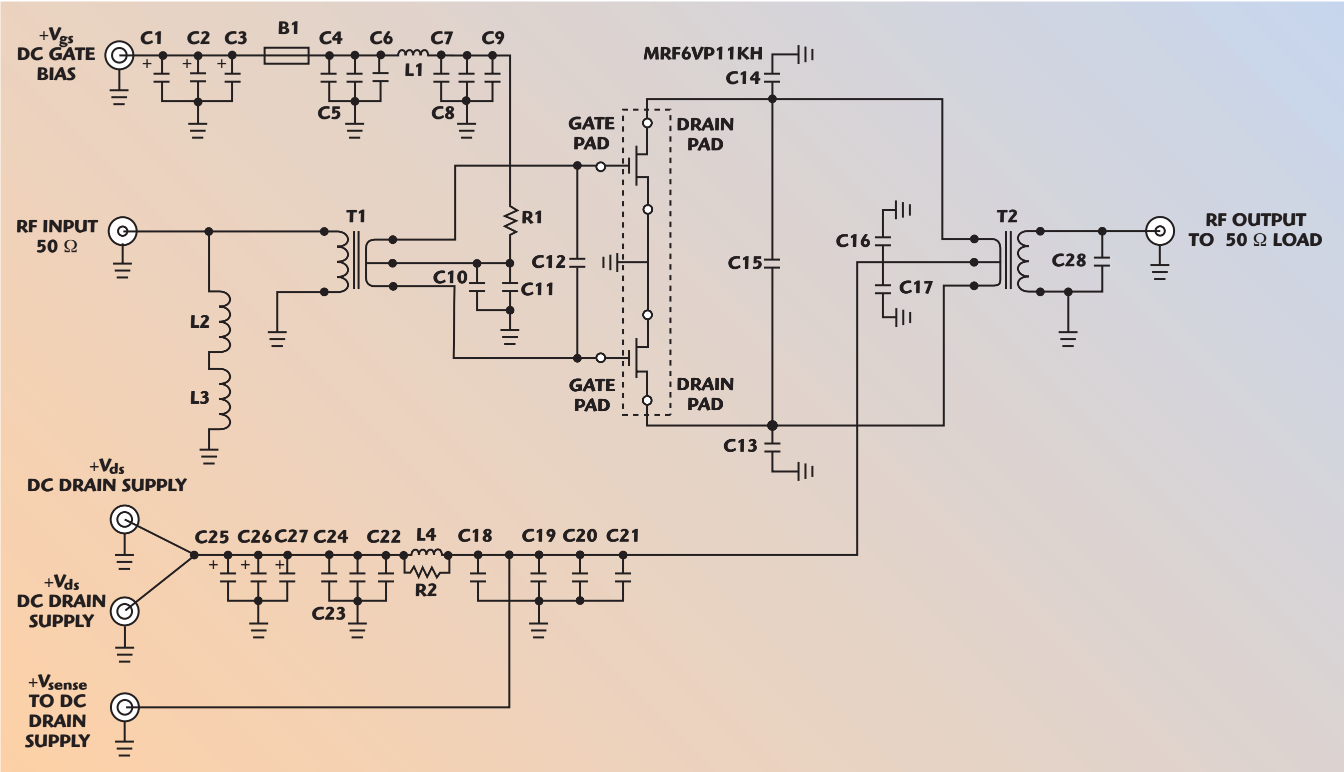
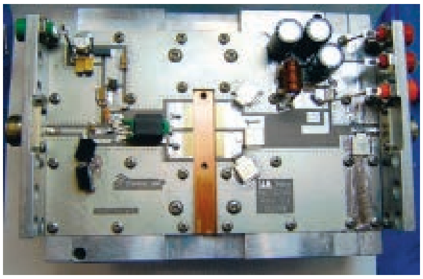


Fig. 2 Circuit diagram.

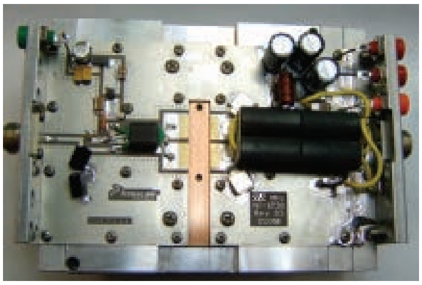
to remove the heat generated during test. In order to minimize the source contact thermal impedance, a small amount of thermal grease compound is applied to the source flange to create a thin layer (1 mil).



▲ *Fig. 3 Photo of assembled board without output transformer.*

PC BOARD LAYOUT AND PARTS LIST

In general, the LDMOS RF power devices present a low input and output impedance. Thus, input and output matching transformers are re-



▲ *Fig. 4 Complete assembled board.*

TABLE I

PARTS LIST FOR 1kW POWER AMPLIFIER

Part	Description	Manuf.	Part #
C1	47 uF 50V Electrolytic Cap	Illinois Cap	476KXM050M
C2	10 uF 35V Kemet Tantalum Capacitor	Kemet	T491D106K035AS
C3	22 uF 35V Kemet Tantalum Capacitor	Kemet	T491X226K035AS
C4,C10,C24	0.1 uF 50V Ceramic Capacitor	AVX	CDR33BX104AKYS
C5,C23	10K pF ATC 200B Ceramic Capacitor	ATC	ATC200B103KT50X
C6,C22	20K pF ATC 200B Ceramic Capacitor	ATC	ATC200B203KT50X
C7,C18,C19	2.2 uF 50V Kemet 1825 Ceramic Capacitor	Kemet	C1825C225J5RAC
C8	220 nF 100V Kemet Ceramic Capacitor	Kemet	C1210C224K1RAC
C9,C11,C20,C21	1000 pF ATC 100B Ceramic Capacitor	ATC	ATC100B102JT50X
C12	150 pF ATC 100B Ceramic Capacitor	ATC	ATC100B151JT500X
C13,C14	120 pF 500V Mica Capacitor	CDE	MCM01-009ED121J-F
C15	470 pF 500V Mica Capacitor	CDE	MCM01-009ED471J-F
C16,C17	2.2 uF 100V Vishay 3640 Ceramic Capacitor	Vishay	VJ3640Y225KXBAT
C25,C26,C27	470 uF 63V Electrolytic Cap	MultiComp	MCGPR63V477M13X26-RH
C28	100 pF 500V Mica Capacitor	CDE	MCM01-009ED101J-F
B1	Bead Long Ferrite (95 ohm@100 MHz)	Fair-Rite	2743021447
L1	82 nH CoilCraft Inductor	CoilCraft	1812SMS-82NJ
L2	90 nH CoilCraft Inductor	CoilCraft	132-09SM
L3	111 nH CoilCraft Inductor	CoilCraft	132-10SM
L4	10 Turn #16AWG Inductor, Handwound, ID=0.190"	Freescale	Handwound
R1	1K ohm Leaded 1W Resistor	Vishay Dale	CPR110R000JKE14
R2	20 ohm Leaded 3W Metal Film Resistor	Vishay Dale	CPR320R000JKE14
T1	Core, Ferrite Type J Material	Ferronics	12-365-J
T2	Core, Ferrite Type 43 Material	Comm. Concepts	RF2043-0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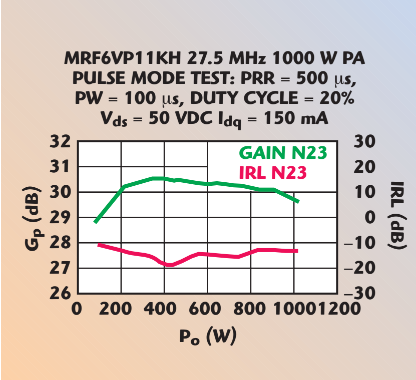
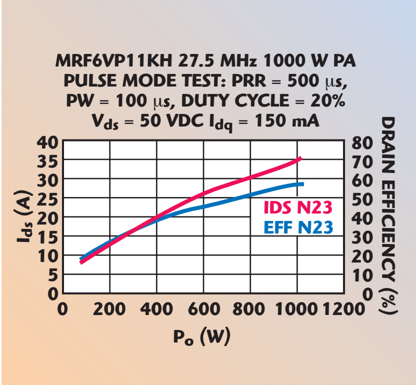


▲ *Fig. 5 Large signal gain and input return loss vs. output power.*



▲ *Fig. 6 Drain efficiency vs. output power and current.*

quired. An associated insertion loss at the input and output can be estimated due to a non-unity coupling factor, leakage inductance and core losses. However, these can be minimized by the use of ferrite cores in both cases. A binocular type ferrite core is used for the input and a commercially available blank core transformer with sleeve ferrites for the output. It was determined that a 2:1 turns ratio (4:1 impedance ratio) input transformer was satisfactory and a 1:3 turns ratio (1:9 impedance ratio) for the output was near optimum.

The parts assembly diagram and printed circuit board layout are shown in ***Figure 1*** (the parts list is given in Table 1). No mechanical hardware is mentioned, as it depends on the final packaging solution chosen. The circuit diagram is shown in ***Figure 2*** and a picture of the assembled board without the output transformer is shown in ***Figure 3***. A top view of the finalized board is shown in ***Figure 4.*** Designators and values can be found in the parts list.

Ferrite core transformers are used in this application for higher efficiency and compact form factor. Input transformer T1 is wound 2:1 turns ratio (4:1 impedance ratio) on a binocular type core. Primary is 2 turns No. 22 AWG plastic insulated stranded copper wire and secondary is 1 turn with centre tap No. 22 AWG Teflon insulated wire. Primary is wound first tight against the core, followed by the secondary. Different wire colors can easily identify the windings. Output transformer T2 is wound 3:1 turns ratio (1:9 impedance ratio) on a ferrite core which already has a 1 turn copper tube primary with CT. Secondary is 3 turns No. 16 AWG Teflon insulated stranded copper wire. Secondary is wound tight against the core to minimize leakage inductance.

PERFORMANCE

Measured performance of the power amplifier test fixture is given in ***Figure 5*** as a graph of large signal gain G_p versus output RF power P_o. In the same figure, the input return loss IRL is plotted against P_o. Gain compression at P_o, slightly above 1 kW, is $\Delta G_p \leq 1$ dB. ***Figure 6*** shows a graph of drain efficiency versus P_o and drain current I_{ds} with V_{ds} at 50 VDC and I_{dq} at 150 mA. The maximum efficiency is 58 percent at 1 kW of output power.

CONCLUSION

A test circuit using a high power LDMOS transistor operating at 27.5 MHz and capable of delivering 1000 W pulse power into the load demonstrates the application of the Freescale MRF6VP11KH. The test fixture exhibits high gain and reasonably good efficiency at maximum power in pulse mode with PRR=500 µs, PW=100 µs and duty cycle=20 percent. The second harmonic measured level is −45 dBc, which is a good indication of the input and output network balance. The third harmonic level is −27 dBc typical at P_o 1000 W.

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LATEST ADVANCE IN RF POWER DETECTION: RMS DETECTOR WITH iPAR

RF engineers are primarily concerned with real signal power when sizing components and implementing controls for optimization of signal fidelity and/or data integrity. In communication links, RF signal power is carefully managed to maintain high performance and reliable connections over some distance. Transmitters carefully monitor signal power to maintain high levels of efficiency, and conformity to spectral regulations. Receivers monitor signal power to maintain optimal sensitivity and selectivity.

Most every power detector available on the market has been designed for broadband communications systems. However, it is the manufacturers of test equipment, developers of military and space technology, and advanced physics labs that have challenged companies such as Hittite Microwave Corp. to develop power detector technology best suited for measurement performance in terms of input sensitivity, dynamic range, repeatability, speed and accuracy over temperature. The HMC614LP4E RMS Power Detector with iPAR is the latest outcome of that work.

In general, power detectors sense an RF signal and produce an output signal that corresponds to that level of signal energy. A subsequent processor takes that detector output and correlates it to real signal power. Log detectors and RMS detectors have largely replaced diode detectors for large dynamic range applications, but each type has characteristics that lend themselves better to some applications than others. ***Table 1*** provides a comparison between power detector types (key advantages of each detector type are indicated in bold).

LOG DETECTORS

Log detectors work well for systems in which the RF signal is pulsed (such as TDMA systems) and/or when the signal's peak-to-average power ratio (PAR) remains relatively constant. The output of a log detector correlates well with real signal power; however, that correlation varies as waveshape and PAR vary. The latest generation of broadband communication systems employ complex modulation schemes and sophisti-

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800 SERIES Case B	**Capacitance Range**	**Electrical Specifications**
.110" x .110" (2.79 mm x 2.79 mm)	0.1 pF to 1000 pF	Voltage Rating: Up to 500 WVDC • IR: 10^5 MΩ @ 25°C • TCC: 0 ±30 PPM/°C

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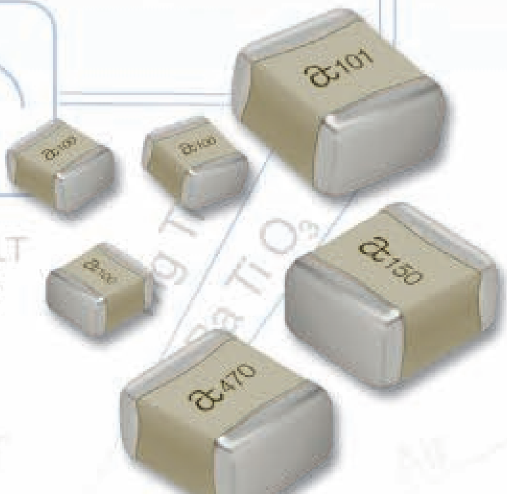
62 to 100 pF	150 WVDC	200 WVDC
100B/700B		
Capacitance Range	Standard WVDC	Extended WVDC
0.1 to 47 pF	500 WVDC	1500 WVDC
51 to 100 pF	500 WVDC	1000 WVDC
110 to 200 pF	300 WVDC	1000 WVDC



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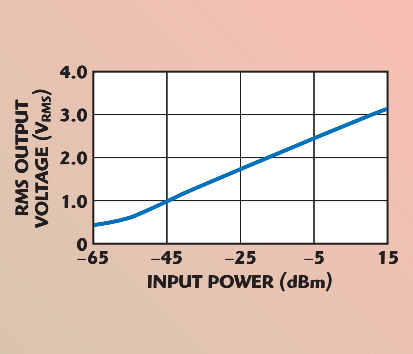


▲ *Fig. 1 RMS Detector output voltage vs. input signal power.*

cated spread-spectrum techniques often producing signals with PAR fluctuating over time, occasionally rising to high levels. These "peaks" in the amplitude-modulated (AM) RF envelope introduce an error on the log detector's output. In contrast, true RMS power detectors are not afflicted with the same weakness. RMS power detectors maintain an accurate read of average signal power regardless of RF signal waveshape or PAR. However, RMS detectors are relatively slow when compared with their faster responding siblings.

TABLE I

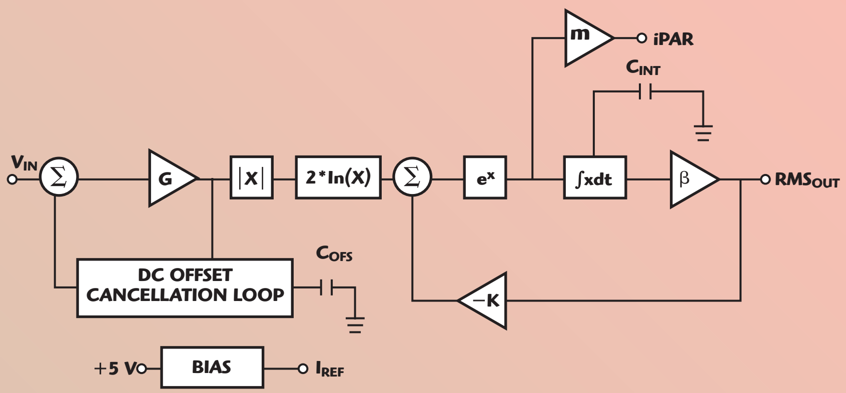
FUNDAMENTAL DIFFERENCES BETWEEN POWER DETECTOR TYPES

Envelope Detectors (Diode-based)	*Log Detectors*	*Hittite RMS Detectors*
Detector output is proportional to RF envelope amplitude	Detector output is proportional to RF envelope amplitude in dB	**Detector output is proportional to root-mean-square of RF signal power in dB**
Small input dynamic range	**Large input dynamic range**	**Large input dynamic range**
Poor temperature stability without temperature compensation	**Good to excellent temperature stability**	**Good to excellent temperature stability**
Dependent on input signal waveshape and/or PAR	Dependent on input signal waveshape and/or PAR	**Insensitive to input signal waveshape and/or PAR**
Fastest responding	Relatively fast response time	RMS integrator slows response time

RMS DETECTORS

True RMS detectors are in effect analog calculators, calculating RMS power of the input signal, unlike other types of power detectors that are designed to respond to the RF signal's AM envelope. At the core of an RMS detector are a full-wave rectifier, log/antilog circuit and an integrator. The RMS output signal is directly proportional to average input signal power expressed in dB. The bias block also contains temperature compensation circuits that stabilize output accuracy over the entire operating temperature range. The DC offset cancellation circuit actively cancels internal offsets so that even very small input signals can be measured accurately.

The "average" power indication from an RMS detector is well suited for signal level and gain control. However, it is often critically important to be aware of other details of RF signal characteristics beyond average signal power. For example, continuous monitoring of peak signal power is often necessary to avoid overdriving signal chain components



$$V_{RMSout} \cong \frac{1}{k}\ln\left(\beta k G^2 \int V_{IN}^2\, dt\right)$$

$$\therefore V_{RMSout} \propto \ln\sqrt{\overline{V_{IN}^2}}$$

$$V_{iPAR} \cong \frac{m V_{IN}^2}{\beta k \int V_{IN}^2 dt}$$

$$\therefore V_{iPAR} \propto \frac{V_{IN}^2}{\overline{V_{IN}^2}}$$

▲ *Fig. 2 HMC614LP4E RMS Detector with iPAR behavioral model.*

into saturation. Similarly, monitoring signal crest factor for a radio transmitter enables efficiency controls on the power amplifiers. Every traditional approach to this problem has employed two separate power detectors operating in parallel: an RMS power detector and an envelope detector.

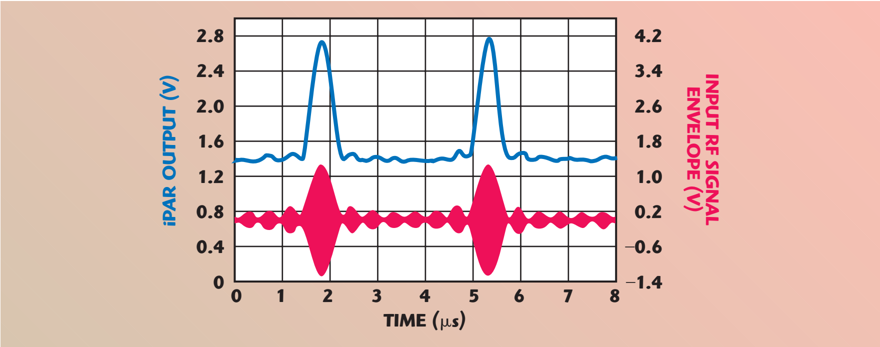
TWO SIMULTANEOUS OUTPUTS FROM THE SAME MEASUREMENT STRUCTURE

A new type of power detector, the HMC614LP4E, now combines the strengths of both envelope detectors and RMS detectors. At the front-end of an RMS power detector is an enve-

TABLE II
HMC614LP4E KEY SPECIFICATIONS

Parameter	Typical	Units
Input frequency range	0.1 to 3.9	GHz
Dynamic range (±1 dB linearity error)	70	dB
Minimum input power at ±1 dB error	–57	dBm
Measurement deviation over temperature*	less than ±0.5	dB
RMS measurement deviation for different modulation schemes (Deviation to measurement with CW input at same signal power), Vtgt = 1.0 V		
1 Carrier CDMA	less than ±0.08	dB
2 Carrier CDMA	less than ±0.11	dB
4 Carrier CDMA	less than ±0.23	dB
QAM256	less than ±0.05	dB

* *over full temperature range, with no external temperature compensation*



▲ *Fig. 3 HMC614LP4E iPAR output.*

lope detector, which then feeds into an analog RMS processing circuit. Looking deeper within Hittite's RMS detector, there is a signal that correlates to instantaneous envelope power normalized to average power, or in other words envelope-to-average power ratio. That signal is buffered and brought to the outside world as "iPAR", alongside the RMS output. Thus, this same power detector produces two simultaneous outputs from the very same measurement structure. Furthermore, a simple peak-hold capacitor on the iPAR output produces a peak-to-average power ratio output. Hittite's HMC614LP4E RMS Detector with iPAR combines all of the benefits of an RMS power detector, with the iPAR output providing the speed of an envelope detector. The simultaneous detector outputs provide a read of peak signal power, average power, peak-to-average power ratio and RF wave-shape. Key performance specifications of the HMC614LP4E RMS Detector are shown in ***Table 2***.

Traditional RMS measurement solutions employ two separate detectors that require two separate sets of calibration factors over temperature and, consequently, correlation between detector outputs can become a complex problem. The iPAR solution has the fundamental advantage of using the very same measurement and compensation structures as the RMS detector, so the HMC614LP4E iPAR output is intrinsically normalized to RMS power.

The iPAR output can be configured in one of two ways: iPAR can either track the instantaneous RF signal envelope power, or iPAR will indicate peak envelope power (with a peak-hold capacitor on the iPAR output pin). iPAR is brought out as a relative reading, rather than as an absolute reading of signal power. iPAR is normalized to RMS signal power thereby providing two distinct advantages over the two detector traditional approach:

- The iPAR output is independent of average signal power (over a very large range)
- With two separate power detectors, the absolute readings provided by each detector must always be made to fully correlate over input signal frequency and over temperature (Hittite's iPAR solution eliminates the struggle of correlating two different detector types). Since the HMC614LP4E RMS and iPAR outputs share the same measurement and compensation structures, they are well correlated over signal frequency and temperature

As mentioned previously, the averaging operation within the RMS detector slows its response. The averaging time-interval is set by the user using an external "integration" capacitor (C_{INT}). RMS detector measurement accuracy requires a compromise between the averaging time-interval and output transient response. Larger values of C_{INT} will correspond to a longer averaging time-interval; however, it will also slow the power detector's transient response favoring detector output accuracy over speed. Conversely, a smaller value of C_{INT} will favor detector speed over measurement accuracy.

The HMC614LP4E iPAR output, however, responds very quickly, as it is not hampered by the RMS integration function. iPAR provides a real-time indication of RF signal power envelope:

$$\text{iPAR} \propto \frac{\text{input signal power}}{\text{RMS signal power}}$$

CONCLUSION

Hittite Microwave has developed a new type of RMS power detector, the HMC614LP4E, which combines the benefits of both envelope detectors and RMS detectors to provide an indication of average power, instantaneous envelope power ratio and peak-to-average power ratio. The HMC614LP4E operates from 0.1 to 3.9 GHz with up to 71 dB of input sensing range (to ±1 dB measurement error). This RMS detector is ideally suited to many wide bandwidth, high dynamic range applications requiring repeatable measurement of real signal power, especially where the RF/IF wave-shape and/or crest factor change with time.

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

RS No. 303


INTEGRATED ASSEMBLIES
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• IF output frequency range 2 to 16 GHz
• Integrated LO multipliers and filters
• Integrated RF and IF filters
Low Noise Block Downconverter
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• Internal LO 17 GHz
• IF output 1 to 5 GHz
• Noise figure 2.9 dB
• 60 dB image rejection
Sub-Harmonic Upconverter and Power Amplifier Module
• RF output range 36 to 37 GHz
• LO input frequency 17.5 GHz
• Output 1 dB compression point +24 dBm
• Conversion gain 20 dB
• Carrier suppression 40 dB
• High reliability miniature hermetic MIC construction
Low Noise Block Converter with Fiber Optic IF Output
• RF input frequency range 24 to 40 GHz
• IF output frequency range 2 to 18 GHz
• Instantaneous bandwidth 16 GHz
• Noise figure 4 dB typical
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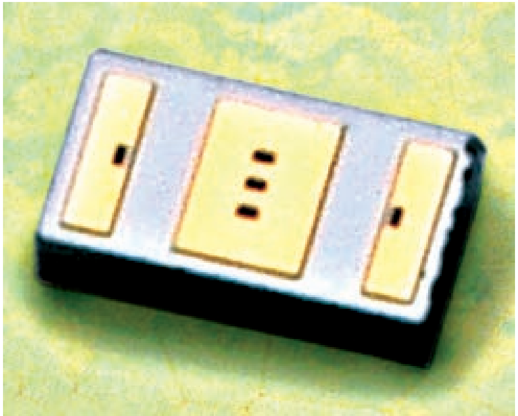


WAFERCAP-PACKAGED AMPLIFIERS DRIVE INNOVATION INTO RF DESIGNS

EXECUTIVE INTERVIEW SERIES

MWJ SPEAKS WITH BRYAN INGRAM, SENIOR VICE PRESIDENT AND GENERAL MANAGER OF AVAGO TECHNOLOGIES.

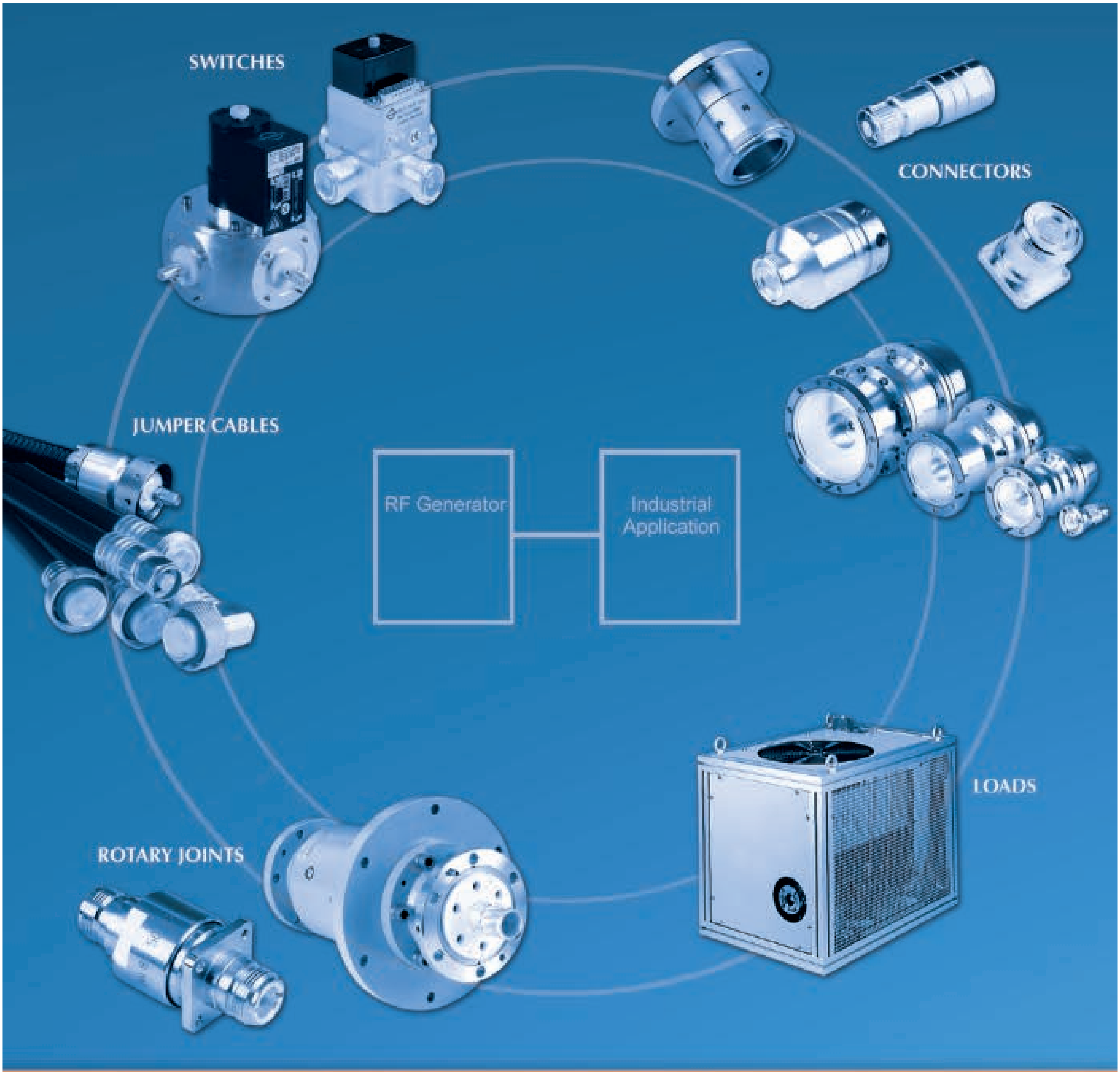
VISIT WWW.MWJOURNAL.COM TO READ THIS IN-DEPTH INTERVIEW.

Wireless connectivity, whether for simple commercial applications such as garage door openers or for more complex military applications such as ultra-small radios, continues to be an integral part of product innovation. Embedding RF into these different applications often requires highly compact form factors and support for a wide range of frequencies. Avago Technologies' VMMK series of amplifiers is a dramatic step in supporting this direction with micro-miniaturization of high frequency components. VMMK's compact size and exceptional performance gives the system designer increased flexibility in meeting the demanding needs of today's small size, high data rate RF environment. Additionally, the ability to assemble these devices using standard surface-mount techniques ensures their smooth inclusion in today's electronic assembly line.

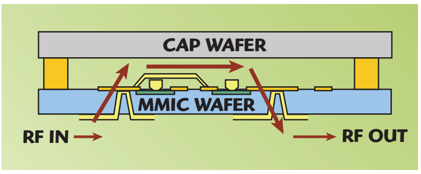
CHALLENGES OF CONVENTIONAL PLASTIC PACKAGING

The demand for constant connectivity and smaller form factors continues to drive the need to miniaturize devices with RF functionality. Many mobile applications today demand a very thin profile that makes it extremely difficult for module manufacturers to use conventional plastic packaging. In addition, today's high volume, high frequency plastic packaging introduces many unwanted electrical parasitics to the final product. These include dielectric parasitics due to the plastic encapsulant, transitional parasitics due to the bond wires that are needed to connect to the chip and parasitics due to the lead-frame on which the chip is mounted. This is especially harmful to wider band, higher frequency components. Attempts to change the standard packaging have resulted in solutions such as flip chip devices, where special assembly techniques are required to work with these new packages, or the use of more expensive materials to ensure proper electrical performance. The leads and associated lead-frames also limit the minimum footprint and profile that can be achieved.

AVAGO TECHOLOGIES
San Jose, CA


SWITCHES
CONNECTORS
JUMPER CABLES
RF Generator
Industrial Application
LOADS
ROTARY JOINTS

▲ *Fig. 1 Top and bottom views of the VMMK devices.*



▲ *Fig. 2 Cross-section of WaferCap chip scale packaging.*

WAFERCAP PACKAGING MINIATURIZES RF COMPONENTS

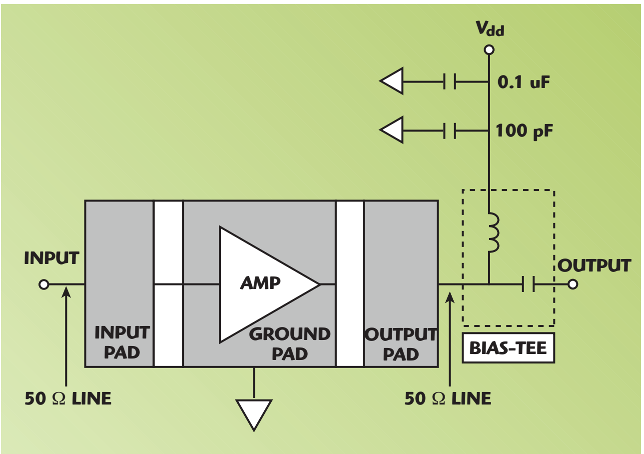
Avago has been using Chip Scale Packaging for many years to package its line of film bulk acoustic resonator (FBAR) products for use in mobile telephones. A cap wafer is essentially mounted to the device wafer through the use of a seal gasket. The result is a packaged device when the wafer is singulated. Avago has used this style of packaging to ship over a billion FBAR filters in the course of the last decade. This packaging methodology can also be applied to help solve the problem of high frequency packaging. Avago's unique WaferCap package uses standard wafer fabrication techniques to create a completely packaged part that is equivalent in footprint to a 0402 passive component, but with a much lower profile. The final product measures 1.0 x 0.5 x 0.25 mm, providing the flexibility and performance required to fit in a wide range of RF designs. ***Figure 1*** shows the VMMK devices.

The WaferCap package is simply the electronic wafer with a cap wafer and a seal to bond the two together. This gasket provides the structural integrity that results in a part that can go through all the conventional assembly equipment used today such as chip shooters and solder reflow machines. The gasket allows WaferCap-based products to achieve a Moisture Sensitivity Level rating of 1, making them ideal for automated assembly and long-term storage. As shown in ***Figure 2***, the gasket also allows for an air cavity to be formed between the circuit and the cap resulting in a very benign RF environment with little or no parasitics.

TABLE I

VMMK FAMILY OF AMPLIFIERS

Device	VMMK-2103	VMMK-2203	VMMK-2303	VMMK-2403	VMMK-2503
Freq. range (GHz)	0.5-6	0.9-11	0.5-6	2-4	1-12
Bias/current	5V/25mA	5V/28mA	1.8V/20mA	5V/50mA	5V/60mA
Gain (dB)	14	16	13	15	14
NF (dB)	2.4	2.3	<2.5	2.5	3.7
OIP3 (dBm)	23	15	23	32	28
P1dB (dBm)	N/A	N/A	10	20	17



▲ *Fig. 3 Typical application circuit for VMMK amplifiers.*

Particular attention was made to the metallurgy used on the bottom of the device so that it could be directly soldered without any change in the normal assembly process and no resulting damage to the packaged device. With WaferCap-based devices, contact is made to the chip through vias that connect the circuit board directly to the IC with no intervening bond wires. This allows for the solder pads to be entirely contained on the bottom side of the package, thus minimizing the package footprint. The 0402 package size results in a part that is 5 percent of the volume and 10 percent of the footprint of an SOT-343 package.

INTRODUCING THE WAFERCAP-BASED VMMK FAMILY OF AMPLIFIERS

The VMMK series of amplifiers represents the first products using this revolutionary new packaging technology. These tiny amplifiers can shrink the footprint an RF device takes on a PCB by as much as 50 percent while achieving the desired support for a wide range of frequencies. VMMK amplifiers are fabricated with Avago's industry leading enhancement mode PHEMT process and require no negative supply voltage for their operation. ***Table 1*** shows the line-up of five amplifiers that cover the frequency range from 0.5 to 12 GHz. These amplifiers are fully matched and require very little external circuitry for full operation. ***Figure 3*** shows the typical application circuit for these products.

The low parasitic package allows excellent broadband performance from these amplifiers. They offer excellent gain and noise figure while being matched to 50 ohms. The VMMK-2103 and the VMMK-2203 are wideband low noise amplifiers with low power consumption that can be used in diverse applications including UWB and wireless USB. The VMMK-2103 also offers a switch bypass function for optimum flexibility. The VMMK-2303 offers a choice of bias options since it can operate at a low 1.8 V and from a battery bias voltage of 3.3 V, which makes it well suited for a vast array of mobile applications. It also offers a convenient

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RF/IF MICROWAVE COMPONENTS

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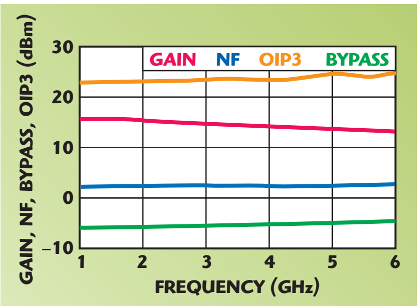
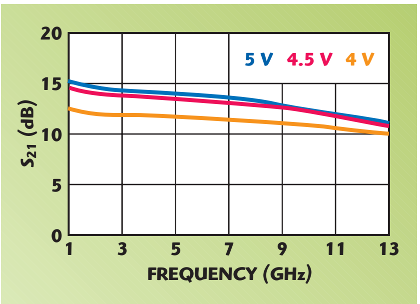


▲ *Fig. 4 Gain, NF, bypass and OIP3 vs. frequency for VMMK-2103.*



▲ *Fig. 5 Typical performance for VMMK-2503.*

shut down feature to further minimize power consumption. Typical performance for the VMMK-2103 is shown in ***Figure 4***.

The VMMK-2403 and the VMMK-2503 offer higher power options with outstanding linearity levels. The VMMK-2403 features a 30 dBm output intercept point level with a 1.8 dB noise figure operating off a 3 V supply and drawing less than 40 mA. The VMMK-2403 can also be safely biased at 4 or 5 V as desired. At 3 V, the performance is an optimal compromise between power consumption, noise figure, gain and power/linearity. It can be used as a low noise block or driver. At 4 and 5 V, it draws about 48 and 62 mA, respectively. At higher V_{dd}, the amplifier can provide 1 to 2 dBm more output power for LO or transmitter driver applications where high output power and linearity are often required.

The VMMK-2503 is an ultra-wideband device operating from 1 to 12 GHz with a gain of 14 dB, an OIP3 of 27 dBm, a noise figure of 3.7 dB, and an excellent input and output match. Operating from a 5 V supply and drawing 65 mA, the VMMK-2503 is an outstanding multi-purpose gain block whose bias can be varied between 4 and 5 V for optimum current draw and performance. Typical performance for the VMMK-2503 is shown in ***Figure 5***.

CONCLUSION

The VMMK series of amplifiers is the next step in ultra-miniature RF components and offers the systems designer the utmost in performance and small size. These amplifiers can be used in a wide range of RF applications, including 2.4, 3.5 and 5 to 6 GHz WLAN and WiMAX notebook computers and access points; 802.16 and 802.20 BWA systems; as well as military radar, radio and ECM systems. The 0402 footprint and the ability to assemble the devices with standard surface-mount assembly techniques give the radio designer outstanding flexibility to innovate their product designs with smaller, high-performance RF systems.

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ANOTHER MAJOR BREAKTHROUGH IN VCO TECHNOLOGY

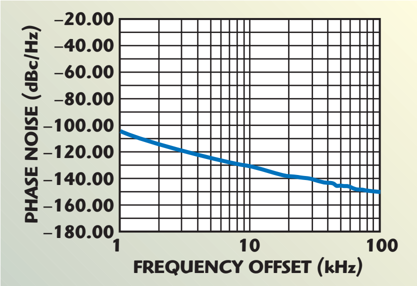
Modern digital communication systems using complex modulations such as Orthogonal Frequency Division Multiplexing (OFDM) or Quadrature Amplitude Modulation (QAM) require controlling bit error rate (BER) in order to achieve a given signal-to-noise ratio (SNR). The achievable BER is a function of many system parameters. Most important among them is the random phase fluctuations called phase jitter, which is a function of the phase noise contributed by the local oscillators in the transmit-receive path. Voltage-controlled oscillators (VCO), which serve as local oscillators in the transceiver of digital communication systems, play a very important role in meeting these goals by providing clean signals. The impact is even stronger in receivers as it leads to receiver desensitization by degrading the receiver's ability to detect weak signals and therefore reduces the transmission distance of the communication system.

The VCO's phase noise is affected by many factors, such as the shot noise of the active device, its flicker corner frequency, power gain, loaded Q factor of the resonating element, tuning sensitivity, tuning bandwidth, varactor equivalent noise resistance, frequency pulling, pushing, etc. Further, the overall performance of the VCO depends upon the variations in its parameters over extreme temperatures. It is therefore important to maintain superior performance over the operating temperature range. Besides phase noise, tuning linearity is also an important parameter in designing stable frequency sources. In addition, providing low frequency pulling and pushing is required as they contribute to the overall phase noise. All these factors put a heavy burden on the VCO designer.

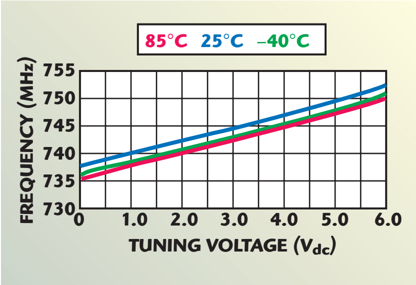
The latest development from Z-Communications Inc. is a new series of coaxial resonator-based voltage-controlled oscillators called the ZRO series. These VCOs have been designed with innovative noise suppression techniques that allow for extremely low phase noise values and excellent bias stabilization. Also, the unique temperature compensation techniques used in its design enable excellent stability over temperature for phase noise, output power and tuning linearity.

To meet the demand of today's digital communication systems and their strict phase noise requirements further lends to greater production strains on VCO manufacturers. Design margins for VCOs have needed to be greatly reduced in order to address these low noise specifications, but this comes with a price due to the impact it has on production yields, cost and the overall effect it can have on deliveries. However, the emergence of the ZRO series and its performance stabilization characteristics allows for the design of even tighter margins without compromising product throughput. This helps ease the

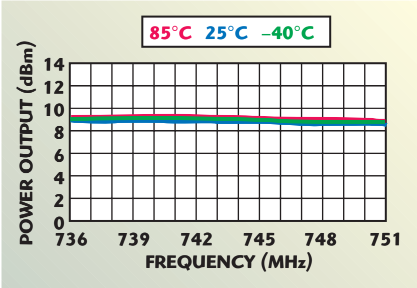
Z-COMMUNICATIONS INC.
San Diego, CA



▲ *Fig. 1 Typical phase noise of the ZRO0743B2LF.*



▲ *Fig. 2 Tuning characteristics of the ZRO0743B2LF.*



▲ *Fig. 3 Typical output power characteristics for the ZRO0743B2LF.*

concerns of those in the original equipment and contract manufacturing community who require quick turn deliveries of high performance VCOs to meet their tightening customer schedules.

The first VCO of the ZRO series is the ZRO0743B2LF, which has typical phase noise performance of −131 dBc/Hz at 10 kHz offset and −151 dBc/Hz at 100 kHz offset in a frequency range between 738 and 748 MHz (see ***Figure 1***). The ZRO0743B2LF also has very good tuning linearity over the tuning range from 0 to 6 V (see ***Figure 2***) with a typical tuning sensitivity of 2 MHz/V. It also offers very good pushing (60 kHz) and pulling (300 kHz/V) performance thereby reducing their contribution to the overall phase noise.

Figure 3 shows the typical output power of the ZRO0743B2LF over its operating frequency and temperature range (−40° to +85°C). The typical output power delivered is 9 dBm. The built-in temperature compensation circuitry ensures linear output power over the extended temperature range. The harmonic rejection is better than −20 dBc over the operating frequency range.

The ZRO series is available from 650 MHz to 4 GHz in narrow bands. For specific requirements or frequencies, customized VCOs are available. They come in two different package styles, the newly developed ZMX-14-SM package, which measures 0.75" x 0.75" x 0.22" and Z-COMM's industry standard MINI-16 package, which measures 0.5" x 0.5" x 0.22". Both packages are surface-mount and manufactured to meet the European RoHS directive.

Z-Communications Inc.,
San Diego, CA (858) 621-2722,
www.zcomm.com.

RS No. 302

Test Solutions

Aeroflex.com has been completely redesigned to be more user-friendly and easily accessible. The home page has been cleanly divided with an overview of Aeroflex corporate at the top, followed by entry points for either the Test Solutions or Microelectronic Solutions Groups, highlighting a featured product from each. The information on the Aeroflex Test Solutions home page has been streamlined significantly, making it far more efficient to find information. The page features improved navigation options, an improved menu structure and a product directory.

Aeroflex Inc., 35 South Service Road, Plainview, NY 11803-0622

www.aeroflex.com

RF/Microwave Components

This newly redesigned and updated web site offers an easier to use interface to Aeroflex/Weinschel's RF and microwave components and services. The web site also keeps the same great features from the company's old site such as one line product quote/design form, links to download PDF product catalogs/individual datasheets and keyword search. The best addition to the new site is an Aeroflex Product Locator, which is located at the bottom of each page and provides crossover linking to other Aeroflex Microelectronics Solution product offerings.

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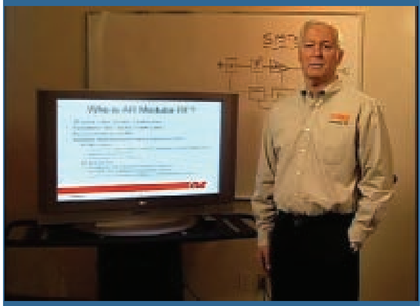

Capabilities Video

AR Modular RF's web site now features a capabilities video that discusses solutions for several markets, including military and commercial applications. The video also highlights the engineering capabilities of AR Modular RF as well as new RF modules, amplifier systems and military booster amplifiers that are currently being developed.

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Hittite's redesigned web site includes crisp new webpage designs and a dynamic homepage featuring full specifications for 700 products across 18 product lines, press releases and featured articles. Comprehensive Individual Product "Splash Pages" containing in-depth product information and technical content are located on one easy to navigate page. Engineers will find improved Product Support and streamlined Quality & Reliability pages containing invaluable reference materials including: application notes, quality assurance, RoHs and packaging information.

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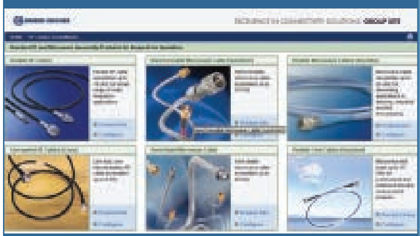

Cable Assembly Building On-line

The new web-based product RF Cable Assembly Configurator offers an intelligent, fast and easy way to design, specify and request a coaxial RF cable assembly on-line. It enables users to create, save and print a HUBER + SUHNER datasheet based on the input. The configurator sends a request for quotation and delivery information on-line, with confirmation sent via e-mail including a datasheet per configuration. It is simple to use and the easy way to build cable assemblies.

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Filtering Solutions

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www.klmicrowave.com
www.klfilterwizard.com

RF Connectors and Adapters

LTI recently updated its company web site, RFconnector.com, with over 1,000 of its RF connectors, adapters and accessories. Each product listing includes a photograph and a link to download specifications. In addition, each product listing is one click away from requesting a custom quotation. All quote requests are answered promptly, within 48 hours. The most exciting feature of RFconnector.com is its RF Cable Assembly Wizard™. The on-line application allows users to build a custom cable assembly.

Lighthorse Technologies Inc.,
9511 Ridgehaven Court, Suite B,
San Diego, CA 92123

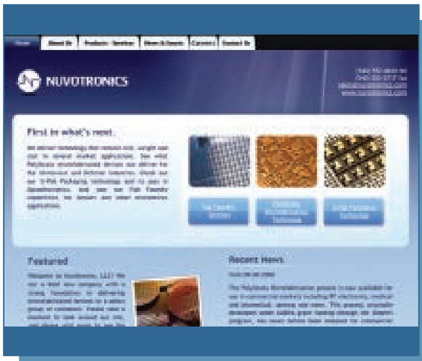
www.rfconnector.com

Microwave Integrated Circuits

Mimix Asia, a supplier of Gallium Arsenide (GaAs) microwave integrated circuits (MMIC), announced the launch of its web site and publication of a short-form catalog. The web site and catalog highlight Mimix Asia's product offering, including high power amplifiers, attenuators, phase shifters and core chips. Comprehensive datasheets are available on-line at www.mimixasia.com with supporting application notes.

Mimix Asia Inc., 3F, 3-2 Industry East IX Road, Science-based Industrial Park, Hsinchu, Taiwan, ROC

www.mimixasia.com



PolyStrata Microfabricated Devices

Nuvotronics is pleased to announce the deployment of the company's new web site, www.nuvotronics.com. Information on the PolyStrata™ Technology for RF, microwave and mm-wave components is provided in a few easy to navigate pages. The PolyStrata Microfabrication Technology provides a revolutionary way of producing very small and complex 3D structures out of metal and plastic.

Nuvotronics, 3155 State Street,
Blacksburg, VA 24060

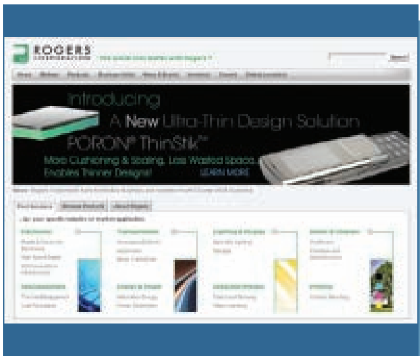
www.nuvotronics.com

Interconnect Technology

RFCONNEXT Inc. has a new webpage featuring its product and services. The company has developed PMTL™, a new patent pending, transmission line technology, for high speed interconnect and packaging of devices and systems. This webpage provides datasheets for a family of products, based on the patent pending PMTL such as single and differential impedance flex/rigid jumper/connectors, wafer and PCB probes, test fixtures and sockets, and technical service targeting the signal integrity, and testing connectivity market, across the spectrum.

RFConnext Inc.,
info@rfconnext.com, (408) 981-3700

www.rfconnext.com



High Performance Materials

This dynamic new web site has been designed to be customer-centric first and foremost, focusing on worldwide markets, product applications, and Rogers' specific products for those markets. Its most critical designed-in feature is its ability to provide streamlined links from markets to applications to products in order to help customers create innovative design solutions. The site aims to be attractive and extremely user-friendly for both new customers as well as established users of Rogers' materials.

Rogers Corp.,
One Technology Drive,
Rogers, CT 06263

www.rogerscorp.com

Semiconductors

This web site offers new capabilities for checking product inventory and generating quotes. These capabilities are available via the "Check Distributor Stock" function located directly on the Vishay homepage. Visitors to the web site can now enter a part number in the "search" window at the top right of the homepage, select "Check Distributor Stock", and click the "search" button to see the quantity available by distributor and the geographic region in which the inventory is located.

Vishay Intertechnology Inc.,
63 Lancaster Avenue,
Malvern, PA 19355-2143

www.vishay.com

The Composite family is expanding
Available colors
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RADIALL
The next conneXion

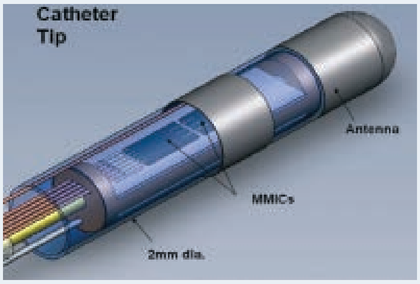
Solid-state Amplifiers

AR RF/Microwave Instrumentation's new solid-state amplifier family covers the 8 to 20 GHz frequency range. Model 5S8G20A offers 5 W of power and model 20S8G20A provides 20 W. Both models are perfect for EMC and wireless testing. Like the other members of the "S" Series amplifiers, both models are extremely tough, durable and are full Class A. They have superior linearity and they are 100 percent VSWR tolerant. Even when mismatch is severe, AR's "S" Series amplifiers will not fold-back or shut down. They continue to deliver 100 percent of the rated power to the load.

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

RS No. 216

Software and Foundry Process

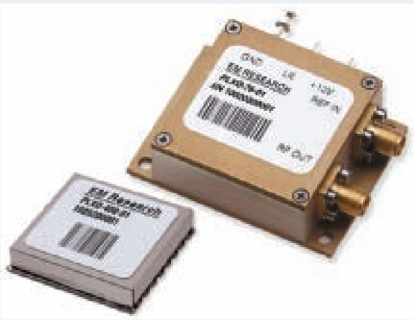


A catheter developed by Meridian Medical Systems (MMS) simultaneously delivers microwave radiation for tissue heating and directly senses the temperature of the heart wall using a radiometer remote sensing device fabricated as a microwave monolithic integrated circuit (MMIC). The MMIC was designed using AWR's Microwave Office® high-frequency EDA software and transferred to TriQuint Semiconductor's foundry using a process design kit (PDK) developed jointly by AWR and TriQuint. For more information, visit www.awrcorp.com.

AWR/TriQuint, www.mms-llc.com.

RS No. 241

Reference Oscillators



This phase-locked crystal oscillator (PLXO) series is a great companion to high frequency synthesizers requiring reference oscillators from 5 to 420 MHz. The PLXO units feature excellent phase noise at 230 MHz (<−130 dBc/Hz at 1 kHz). The PLXO is available in a miniaturized surface-mount package, 0.9" x 0.9" x 0.15", or connectorized version, 1.5" x 1.5" x 0.6". The PLXO units are ideal for use as reference oscillators in VSAT radios, point-to-point and point-to-multipoint radios, test equipment, industrial controls and military applications.

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

RS No. 217

Micro-miniature 5 to 2000 MHz Couplers

These 5 to 2000 MHz DBTC directional couplers are available in nine different coupling values ranging from 9 to 20 dB that deliver extremely flat coupling over very broad multi-octave bandwidths. Standing just 0.15" square, these very small and inexpensive 50 and 75 ohm models employ LTCC construction to embed circuits inside the ceramic base, thus realizing excellent temperature stability, repeatability and ruggedness. Patented with additional patent pending. Price: from $1.99 each (Qty. 25).

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

RS No. 218

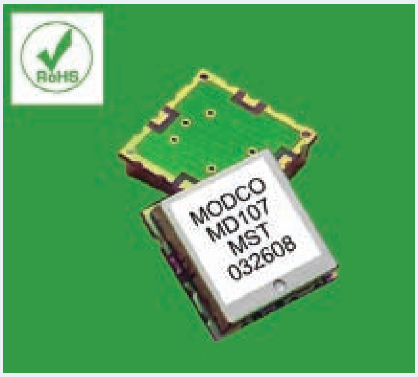
Four I/O RF Switch Matrix

The model 18A1NAI is a four I/O RF switch matrix with four coupled ports that operate between 100 and 55 MHz. This matrix is designed for RF simulation applications that require ability to inject and measure signal integrity in the presence of an interference signal. The maximum input power level at any I/O port is 1 W and the unit is fully programmable using GPIB commands. This model operates in a frequency range from 100 to 550 MHz, offers input power level of 1 W and all paths have 90 dB/1 dB or 130 dB/1 dB programmable attenuators.

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

RS No. 219

Voltage-controlled Oscillator



These economical voltage-controlled oscillators offer low phase noise in the industry-standard one half inch square package. Model MD-107MST operates in a frequency range from 1405 to 1480 MHz and is rated −108 dBc at 10 kHz offset. Many other catalog models are available and custom designs can be supplied with no NRE.

Modco Inc.,
Sparks, NV (775) 331-2442,
www.modcoinc.com.

RS No. 221

Voltage-controlled Oscillator

The model SMV0290A-LF is a RoHS compliant voltage-controlled oscillator (VCO) in the VHF-band. The SMV0290A-LF operates in a frequency range from 284 to 294 MHz with a tuning voltage range of 0.3 to 3 VDC. This VCO features an excellent typical phase noise of −118 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 9 MHz/V. The SMV0290A-LF is designed to deliver a typical output power of −1 dBm at 3.3 VDC supply while drawing only 17 mA (typical) over the temperature range of −40° to 85°C. This VCO comes in Z-Comm's industry standard SUB-L package with low shield measuring only 0.3" x 0.3" x 0.08".

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

RS No. 222

MINI-CIRCUITS

USB POWER SENSOR

Turns Your Laptop Into A Power Meter

-30 to +20 dBm 1 to 6000 MHz

POWER SENSOR PWR-6G+ Package

only $695 ea. (qty.1-4)

Includes:
PWR-SEN-6G+ Power Sensor Unit
Power Data Analysis Software
SMA Adaptor, USB Cable

Fully loaded software features

- *Power data analysis*
- *Power level offset*
- *Scheduled data recording*
- *Average of measurements*
- *Interface with test software*
- *Multi sensor support software*
  (up to 16 sensors support software)

Now, Mini-Circuits offers a USB Power Sensor and software that will reduce your equipment costs and provide new application features that will simplify your power measurements.

All you need is a personal computer (PC) or laptop computer and a Mini-Circuits PWR-6G+ USB Power Sensor. It turns any computer into a powerful power meter having a measurement range of -30 to +20 dBm at frequencies from 1 to 6000 MHz. The PWR-6G+ is supplied with easy-to-use, Windows-compatible measurement software to speed and simplify your power measurements, allowing you to set as many as 999 averages and to record results for further analysis. The PWR-6G+ USB Power Sensor provides 0.01-dB measurement resolution and impressive accuracy over temperature. Visit the Mini-Circuits' web site at www.minicircuits.com to learn more.

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IF/RF MICROWAVE COMPONENTS

457 rev A

Amplifiers

Solid-state Power Amplifier

The part number SSPA 8.5-9.6-30-28V is a high power, X-band, solid-state power amplifier that operates from 8.5 to 9.6 GHz. The saturated output power is 30 W typical at 25°C. Typical small-signal gain is 50 dB. Noise figure is 10 dB typical at 25°C. Input VSWR is 2.0 maximum. Output VSWR is 2.0 maximum. This unit is equipped with Aethercomm's proprietary DC switching circuitry that enables and disables the DC-DC circuitry in 1000 nSec maximum. This power amplifier operates from a +28 VDC power supply with a class A bias of typically 11.0 amps. This amplifier operates from −40° to +65°C base plate temperature. This SSPA is ideal for X-band radar and communication systems that require high reliability and high power in a rugged and compact module. Standard housing size is approximately 8.78" x 7.75" x 1.20".

Aethercomm Inc., San Marcos, CA (760) 598-4340, www.aethercomm.com.

RS No. 223

Low Noise Amplifiers

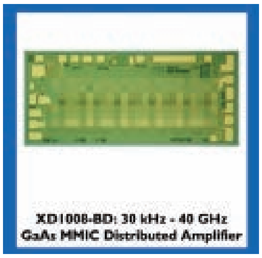
These three new SMT packaged GaAs PHEMT MMIC low noise amplifiers (LNA) are

ideal for automotive, broadband, cellular/3G, WiMAX/4G and fixed wireless applications from 2.1 to 6 GHz. The HMC715LP3E, HMC716LP3E and HMC717LP3E are GaAs PHEMT MMIC LNAs that are rated from 2.1 to 2.9 GHz, 3.1 to 3.9 GHz, and 4.8 to 6 GHz, respectively. These high linearity LNA MMICs deliver up to 19 dB gain and +33 dBm output IP3, with noise figure as low as 0.9 dB. In addition, the HMC715LP3E, HMC716LP3E and HMC717LP3E can operate from either a +3 or +5 V bias supply, making them ideal for infrastructure and subscriber applications in automotive, Cellular/3G, WiMAX/4G and other broadband wireless transceivers.

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

RS No. 224

Distributed Amplifier



The XD1008-BD is a GaAs MMIC distributed amplifier with 15 dB gain, 22.5 dBm P1dB at 22 GHz, and 4.5 dB noise figure at 26 GHz. This distributed amplifier covers 30 kHz to 40 GHz and includes surface passivation to protect and provide a rugged part with backside via holes and gold metallization to allow either a conductive epoxy or eutectic solder die attach process. The XD1008-BD is ideal for microwave, millimeter-wave, military, wideband and instrumentation applications.

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

RS No. 225

Ka-band Waveguide LNAs

The AMFW-8F-17702130-120-23P is a low noise, high dynamic range Ka-band waveguide front-end. Isolator protected at both the WR-42 waveguide input and SMA(F) connector output, the low noise amplifier is lightweight and offers an extremely small profile and footprint. The aluminum alloy housing is environmentally sealed and comes with a mounting plate. EMI shield and weather-resistant packaging options are also available. LNA includes reverse voltage, over current and over temperature protection in addition to full internal regulation. The AMFW-8F-17702130-120-23P offers a typical noise temperature of 100K, with a maximum of 120K, and it is capable of a minimum 23 dBm of P1dB across the full band, 17.7 to 21.3 GHz. Output IP3 is 33 dBm minimum.

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

RS No. 226

Low Noise Amplifier

R&K has introduced two broadband low noise amplifiers (LNA) that operate in a frequency range from 2 to 10 GHz, at output power of +10 dBm (at 1 dB Comp), and available with two gain types of +29 dB (LA0210G-3010-M) and +42 dB (LA0210G- 4010-M). Features include: noise figure of 3 dB, supply input of DC +5 V, lightweight and easy-to-use compact package. As a low noise pre-amplifier, these products are suitable for many commercial applications.

R&K Co. Ltd., Shizuoka-Pref., Japan 0545-31-2600, www.rk-microwave.com.

RS No. 227

Antennas

Ambidextrous Spiral Antenna

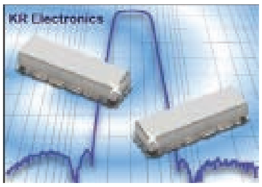
Cobham SASL's ASO-1995 ambidextrous spiral antenna provides dual circular polarization performance in the form factor of a single spiral antenna. With excellent input VSWR, these antennas provide smooth broadband gain, controlled axial ratio, and repeatable pattern performance over 2 to 18 GHz comparable to Archimedean spirals. This model was designed and developed for applications requiring a low cost solution for a single aperture dual circular polarized antenna element. The ASO-1995 ambidextrous antenna is a proven choice for amplitude monopulse RWR, ESM and ELINT applications. It is an excellent low power dual circular aperture for flight line test sets and is a cost-effective aperture for use in an RF threat simulator laboratory. The nominal 2.4 inch diameter x 1.5 inch height ASO-1995 antenna is sized to be compatible with existing spiral apertures to allow retrofitting of single polarization spirals to a dual circularly polarized antenna.

Cobham SASL, Lansdale, PA (215) 996-2416, www.cobhamdes.com.

RS No. 228

Passive Components

Surface-mount Bandpass Filter



This small, high performance, surface-mount, group delay equalized, elliptic bandpass filter is supplied in a surface-mount package measuring 0.5" x 1.5" x 0.3". KR 2818-2 has a 70 MHz center frequency with a 0.35 dB bandwidth of 40 MHz. Passband group delay variation is less than 2.5 nsec. The filter offers

excellent symmetry and quick transition to the stopband. The filter can be customized for other center frequencies and bandwidths.
KR Electronics Inc., Avenel, NJ (732) 636-1900, www.krfilters.com.

RS No. 230

AWS Cavity Duplexer

The WP-100069 is a duplexer that covers the full Advanced Wireless Services (AWS) frequencies. The WP-100069 duplexer exhibits less than 0.5 dB of insertion loss across the passbands of 1710 to 1755 MHz and 2110 to 2155 MHz while providing greater than 80 dB of rejection. The unit measures 5.0" x 4.0" x 2.3" and is available from stock.
Lorch Commercial and Wireless, Salisbury, MD (410) 860-5100, www.lorchwireless.com.

RS No. 231

Directional Couplers

MECA's 715 series directional couplers feature unique air-line construction that provides for the lowest possible insertion loss (less than 0.1 dB), high directivity (30 dB typical) and exceptional VSWR (1.10:1 typical) across the 0.800 to 2.200 GHz and 2.000 to 4.200 GHz bands. Rated for 500 W average power (10 kW peak). Nominal coupling values of 6, 10, 20, 30 and 40 dB. These couplers are available from stock to two weeks ARO. The couplers are made in the US and offer a 36-month warranty.
MECA Electronics, Denville, NJ (973) 625-0661, www.e-meca.com.

RS No. 232

Ultra-broadband Threshold Detector

This ultra-broadband threshold detector operates in a frequency range from 2 MHz to 18 GHz. The VSWR is 1.9 maximum and the thru path insertion loss is 2.5 dB maximum. The dynamic range is -30 to 0 dBm with a 10 kHz video bandwidth. The output polarity is positive and the threshold level is 0 to 2.5 V. The size is 2.90" x 2.50" x 0.5". PMI offers many threshold detector designs with features to satisfy virtually any system requirement.
Planar Monolithics Industries Inc., Frederick, MD (301) 631-1579, www.planarmonolithics.com.

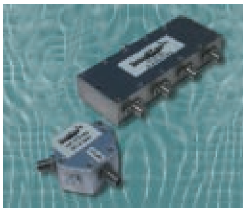
RS No. 233

500 W Combiner

The model PP2-18-450/22N is a high power combiner that can deliver 500 W to the sum port over the frequency range of 2 to 200 MHz, with 0.6 dB insertion loss, 20 dB isolation and VSWR of 1.30 maximum. Amplitude and phase unbalance are 0.3 dB and 5 degrees, respectively. Connectors are N female and the dimensions of the housing are 5" x 3" x 1.5".
Pulsar Microwave Corp., Clifton, NJ (973) 779-6262, www.pulsarmicrowave.com.

RS No. 234

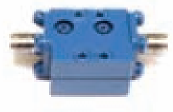
WiFi/WiMAX Power Dividers



The model 151-173-002 is a two-way, 50 Ohm, DC to 6 GHz, 1 W unit with SMA female connectors. Insertion loss is ±0.5 dB maximum DC to 4 GHz and ±0.8 dB maximum 4 to 6 GHz with maximum VSWR 1.50. Model 151-231-004 is a four-way, 50 Ohm, DC to 6 GHz, 5 W unit with SMA female connectors. Insertion loss is ±1.0 dB nominal with maximum VSWR 1.50. These devices are ideal for dividing signals for in-building wireless, WiFi, WiMAX and Homeland Security/Public Safety systems.
BroadWave Technologies Inc., Franklin, IN (317) 346-6101, www.broadwavetech.com.

RS No. 220

18 to 40 GHz High Pass Filter



The part number 7HS-18G/40G-K11 is a broadband high pass filter passing 18 to 40 GHz. This small unit features low loss and in excess of 30 dB rejection from DC to 16 GHz. The company manufactures many different varieties of filters; please contact them with your specific need.
Reactel Inc., Gaithersburg, MD (301) 519-3660, www.reactel.com.

RS No. 235

Dual Directional Couplers

These high power directional couplers offer accurate coupling, low insertion loss and high directivity in a compact package. The standard units are optimized for two octave bandwidths and are available with a choice of coupling values. These units are ideal for sampling forward and reflected power with a negligible effect on the transmission line and very low intermodulation products.
RLC Electronics Inc., Mount Kisco, NY (914) 241-1334, www.rlcelectronics.com.

RS No. 236

Dual Directional Coupler

Werlatone's patented design provides continuous 10 to 500 MHz bandwidth, 100 W CW power handling, at 40 dB coupling. Available with all SMA connectors, this low loss design provides superior performance throughout the entire bandwidth. The model C8155-102 provides insertion loss of 0.35 dB, VSWR(ML) of 1.20, coupling flatness of 40 dB ± 0.5 dB and directivity of 20 dB. Package size: 1.5" x 0.95" x 0.52". Note: Non-connectorized version, Model C8189.
Werlatone Inc., Brewster, NY (845) 279-6187, www.werlatone.com.

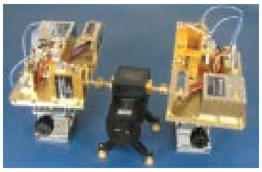
RS No. 237

Subsystem

RF Subsystem

This E-band radio link RF subsystem operates over the E-band frequency spectrum from 71 to 86 GHz. One of its applications can be found in the E-band multi-gigabit wireless communication system, which offers local area networks and "Virtual Fiber" local loop for wireless transmission of data, voice and video at 1-10

Gbps speed. DTI's E-band radio link RF subsystem includes two transceiver blocks. The block A transmits at the frequency of 71 to 76 GHz and receives at 81 to 86 GHz, while the block B works at the opposite frequency ranges. Each block has transmitter (TX), receiver (RX), local oscillator (LO) chain and phase-locked dielectric resonator oscillator (PLDRO) modules.



Ducommun Technologies Inc.,
Carson, CA (310) 847-2859,
www.dt-usa.com.

RS No. 238

Test Equipment

High Performance Synthesizer

The KHP-S500530 is a high performance, high resolution synthesizer that operates in a frequency range from 5 to 5.3 GHz. This synthesizer is housed in a small connectorized package that measures 20 x 12 x 3 cm. The step size in the 300 MHz operating bandwidth is 1 Hz with maximum phase noise of -105 dBc/Hz at 1 kHz, –120 dBc/Hz at 10 kHz, –120 dBc/Hz at 100 kHz, and –120 dBc/Hz at 1 MHz offset. Non-harmonic spurious suppression is –60 dB typical with RF output power of +10 dBm over the specified operating band.

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

RS No. 239

Transmission-line Components

TuffGrip Adaptor

This 7-16 bullet adaptor is designed to facilitate RF testing at the cell tower top. Current adaptor designs are small, making them difficult to handle particularly with gloves in cold weather and are easily lost or dropped creating a hazard. The new Times TuffGrip Adaptor (stock code 3191-291) 7-16 female bullet adaptor features the patented TuffGrip handle that provides a secure way to grip the device during use. It has superior RF characteristics through 6 GHz and is manufactured from 100 percent stainless steel.

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

RS No. 240

New Literature

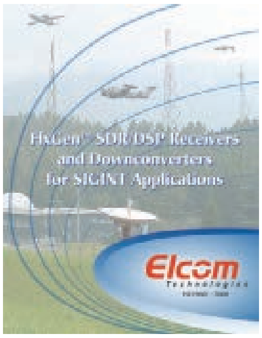
MIMO Poster

This poster is designed to enrich engineers' understanding of Multiple Input, Multiple Output (MIMO), an enabling technology for communication standards that is used with WiMAX™, LTE and WLAN. This free full-color poster, "Ten Things You Should Know about MIMO," presents MIMO operation and test methodologies, using specific examples to highlight the impact on the radio system or associated test.

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

RS No. 200

SIGINT Brochure



Elcom Technologies, a designer and manufacturer of synthesizers and receivers up to 40 GHz in the RF and microwave frequency spectrum for applications in the ATE, SIGINT, Custom Hi-Rel and SATCOM markets, has just released the new FlxGen™ family of HF-VHF/UHF-MW receivers and downconverters brochure.

Elcom Technologies, Rockleigh, NJ (201) 767-8030, www.elcom-tech.com.

RS No. 201

Product Selection Guide

This product selection guide summarizes over 700 items including 34 new products. New for this publication is an expanded Frequency Generation section that features Fractional-N and Integer-N PLL ICs. The guide also contains expanded market and application sections featuring automotive, broadband, cellular infrastructure, fiber optics and microwave and millimeter-wave communications, and includes competitor cross reference tables.

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

RS No. 202

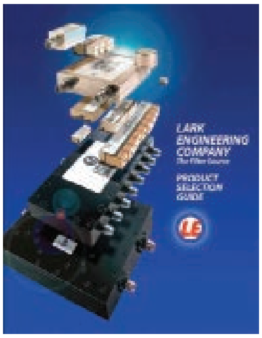
Test and Measurement Product Guide

Keithley's 2009 product guide includes information on the company's latest hardware and software innovations to address challenging test and measurement applications, as well as informative tutorials and selector guides. To request your free copy, visit www.keithley.com/at/556 or call (800) 588-9238.

Keithley Instruments Inc., Cleveland, OH (800) 588-9238, www.keithley.com/at/556.

RS No. 203

Product Selection Guide



This product selection guide highlights the company's wide range of filter products including new switch filter systems. The eight-page short form catalog features a user friendly, quick reference to filter specifications and capabilities that guides users to the filter ideally suited for the application. Specifications and performance simulations are instantly available using the filter design tool located on the company's web site.

Lark Engineering, San Juan Capistrano, CA (949) 240-1233, www.larkengineering.com.

RS No. 204

Product Catalog

This 72-page JS amplifier products catalog provides a comprehensive listing of standard designs for the company's octave band, multi-octave band, ultra-wideband, moderate band, low-noise waveguide, and fiber optic amplifiers as well as its capabilities to customize in accordance with your specifications. Technical specifications, typical test data and outline drawings have also been included on some of the company's custom products.

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

RS No. 205

2009 IEEE Radio Frequency Integrated Circuits Symposium
Boston, Massachusetts
June 7-9, 2009

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RFIC 2009 Call for Papers

The **2009 IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2009)** will be held in Boston, Massachusetts on June 7-9, 2009. For the latest information, visit: **www.rfic2009.org**

Electronic Paper Submission/Communication: Technical papers must be submitted via the RFIC 2009 web site at **www.rfic2009.org.** Hard copies will not be accepted. Complete information on how and when to submit a paper will be posted on the RFIC 2009 web site.

Technical Areas: Papers are solicited describing original work in RFIC design, system engineering, system simulation, design methodology, RFIC circuits, fabrication, testing and packaging to support RF applications in areas such as, but not limited to:

- **Cellular System IC's and Architectures:** GMSK/8PSK, TDMA, CDMA, 3/4 G, WCDMA, GPS.
- **Wireless Data System IC's and Architectures:** WLAN, Bluetooth, 802.1x, Telemetry, RFID.
- **Wide Band System IC's:** UWB, MMDS, CATV, Optical System, Backplane.
- **Small-Signal Circuits:** LNA's, Mixer's, VGA's, Active Filters, Modulators.
- **Large-Signal Circuits:** Power Amplifiers, Drivers, Advanced TX circuits, Linearization.
- **Frequency Generation Circuits:** VCO's, PLL's, Synthesizers.
- **RFIC Device Technologies:** IC Technologies, Si, MEMs, SOI, GaAs
- **RFIC Testing:** Packaging, Modules, Embedded Testing.
- **Modeling and CAD:** RFIC Modeling, Characterization of Active and Passive Devices.
- **Si Millimeter Wave IC's:** Circuits (PA, Mixer, LNA) and Systems (Vehicular, Medical).

Technical Format: The technical sessions will be held for three days from Sunday through Tuesday. Workshops will be on Sunday. Several invited sessions and talks will take place during the conference.

Microwave Week 2009: The RFIC 2009 will be in conjunction with the IEEE MTT-S International Microwave Symposium (IMS). Microwave Week 2009 will continue with the International Microwave Symposium and Exhibition, and the Microwave Historical Exhibit.

Guest Program: Famous for everything from the Red Sox and Paul Revere to Cheers and seafood, Boston is a popular destination. The Freedom Trail, a well preserved pedestrian path weaves in and out of historic neighborhoods. Between landmarks, you can shop stores on Newbury Street, have an authentic Italian meal or browse the antique shops. Boston also features a renowned aquarium, children's museum and science museum.

Electronic Submission Deadlines

Technical Paper Summaries in PDF format:	**6 January 2009**
Final Manuscripts for the Digest and CD-ROM:	**3 March 2009**
All submissions must be made through the RFIC2009 portal:	**www.rfic2009.org**
ALL SUBMISSIONS MUST BE IN PDF FORM	**Hard copies not accepted**

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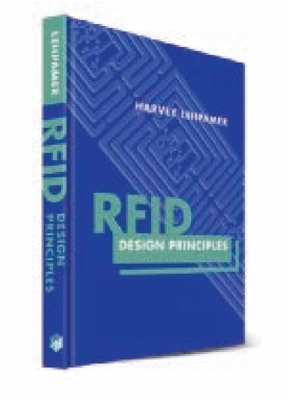
EDS

RFID Design Principles



Harvey Lehpamer

This cutting-edge book serves as a comprehensive introduction to RFID, offering you a detailed understanding of design essentials and applications, and providing a thorough overview of management issues. By comparing RFID with WLAN and Bluetooth, this practical resource shows you how RFID technology can help you overcome many design challenges and limitations in the field. The book explains the design of electronic circuits, antennas, interfaces, data encoding schemes, and complete RFID systems. Starting with the basics of RF and microwave propagation, you learn about major system components including tags and readers.

To order this book, contact:

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16 Sussex St. · London SW1V 4RW, UK · +44 (0) 207-8750
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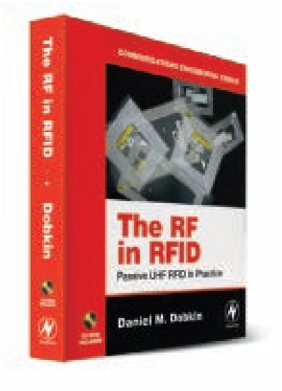
The RF in RFID: Passive UHF RFID in Practice



Daniel M. Dobkin

This book includes a survey of all RFID fundamentals and practices in the first part of the book while the second part focuses on UHF passive technology. This coverage of UHF technology and its components including tags, readers, and antennas is essential to commercial implementation in supply chain logistics and security.

Readers of this book should have an electrical engineering background, but have not yet dealt with RFID. To this end, Dobkin will be very careful to illustrate all concepts and detail his explanations meticulously. In this way, he will bring the reader along organically showing him/her what to expect, develop, and use while implementing an RFID system.

To order this book, contact:

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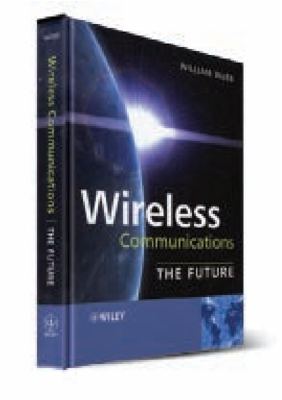
Wireless Communications: The Future



William Webb, Editor

Predicting the future is an essential element for almost everyone involved in the wireless industry. Manufacturers predict the future when they decide on product lines to develop or research to undertake, operators when they buy licences and deploy networks, and academics when they set PhD topics. *Wireless Communications: The Future* provides a solid, clear and well-argued basis on which to make these predictions.

Starting with a description of the current situation and a look at how previous predictions made in 2000 have fared, the book then provides the contributions of six eminent experts from across the wireless industry. Based on their input and a critical analysis of the current situation, it derives detailed forecasts for 2011 through to 2026. This leads to implications across all of the different stakeholders in the wireless industry and views on key developments.

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Information for Authors

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Paper Topics of Interest

The IEEE EMC Society seeks original, unpublished papers covering all aspects of EMC, including technology areas such as: Regulations, Broadcast, Military, Wireless, Power Transmission, and Networking. Topics include and are not limited to the following technical areas:

TC-1 EMC Management
- EMC Personnel Accreditation
- Laboratory Accreditation
- EMC Education
- EMC Legal Issues

TC-2 EMC Measurements
- Test Instrumentation
- Measurement Techniques
- Emissions and Immunity
- Standards and Regulations
- Test Facilities

TC-3 EM Environment
- EM Signal Environment
- Atmospheric Noise
- Man-Made Noise

TC-4 EM Interference
- Shielding, Gasketing & Filtering
- Cables and Connectors
- Coupling
- System EMC Analysis
- Grounding
- PCB Issues

TC-5 High Power Electromagnetics
- ESD
- EMP & Lightning
- Transients
- Power Transmission

TC-6 Spectrum Management
- Spectrum Management
- Spectrum Monitoring

TC-7 Nonsinusoidal Fields
- Ultrawideband EMC
- Impulse Radar
- Time Domain Modeling

TC-8 Electromagnetic Product Safety
- EMC & Functional Safety
- Biological Effects
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- Environmental Safety

TC-9 Computational Electromagnetics
- Computer Modeling
- Model Validation
- Statistical Analysis

TC-10 Signal Integrity
- Packaging
- Model Parameter Determination
- Device Modeling
- Crosstalk

TC-11 Nanotechnology
- Nanomaterials
- Nanostructures
- Carbon Nanotubes
- Nanofibers
- Smart Materials

Author Submission Schedule

- **Preliminary Full Paper Manuscript:** November 1, 2008 - January 8, 2009 (late papers will not be accepted)
- **Acceptance Notification:** March 7, 2009
- **Final Paper and Workshop/Tutorial Material Due:** May 1, 2009

Paper Formats

- **Traditional Oral presentation:** Presentation for those interested in presenting to learge groups with limited potential for interations with attendees. Six-page paper maximum, 20 minute presentation.
- **Open Forum:** Presentation for those interested in direct interaction with individuals or small groups.

Career Corner

Times of Challenge Also Present Opportunities

In contrast with the general slow-down in the economy, the demand for wireless connectivity has created a surge in the demand for experts in RF and wireless technologies. The trend for wireless interconnect has permeated every aspect of our daily lives, from mobile telephones, WiFi on computers, gaming console remotes, access and security systems. In addition, wireless sensor networks are becoming increasingly common in commercial and industrial applications. New developments in RF technology have made it economically attractive to move from traditional hard wired systems to wireless.

Following are a few showcases demonstrating the point.

Test engineering: Test engineers face new challenges as RF and wireless applications expand. RF and wireless traditionally have been very specialized fields, but the industry is experiencing a trend where wireless capability is being integrated into more products. Soon, RF instrumentation could become as ubiquitous as general-purpose instruments such as digital multimeters. This growth requires test engineers to learn wireless protocols and keep pace with the rapid introduction of new standards. A critical part of keeping up with these new technologies is a test platform that engineers can rapidly reconfigure to test any wireless standard.

RFID: The challenge to create new, increasingly complex systems-in-a-package (SiP) at lower cost and in shorter lead times is pressuring companies to develop new methodologies to meet market demands. Miniaturization has been the hot trend over the past decade, and RF components are the critical parts for wireless communications and system-in-package .

RF & Microwave Technology, Circuits & System: Increasing demands in the telecommunications market have put stringent requirements on the design of RF components. The RFIC Group focuses on the design of transceiver architectures for contemporary communication protocols.

Micro-electromechanical Systems: Silicon micromachining technology has become the predominant method in the fabrication of micron-sized electromechanical systems. MEMS devices have found applications in numerous areas, including RF device technology, chemical sensing and ultrasonic imaging. RF-MEMS are one example. In order to diversify the services available to customers while remaining competitive, today's wireless communication systems must utilize technologies that enable faster performance and higher levels of integration but maintain lower cost.

Corporations that succeed in attracting these skilled human resources will be able to make that leap ahead of their competitors. Countries able to cultivate the skills on demand through their education systems will benefit from prosperous industries and a multitude of research centers. This already plays a role in the upcoming race between geographies and economies. It may be too late to save production jobs lost due to offshoring. The focus should now be on increasing the numbers of sophisticated knowhow, ingenuity, creative and research professions, such as RF & microwave engineering in this country.

Isaac Mendelson
ElectroMagneticCareers.com
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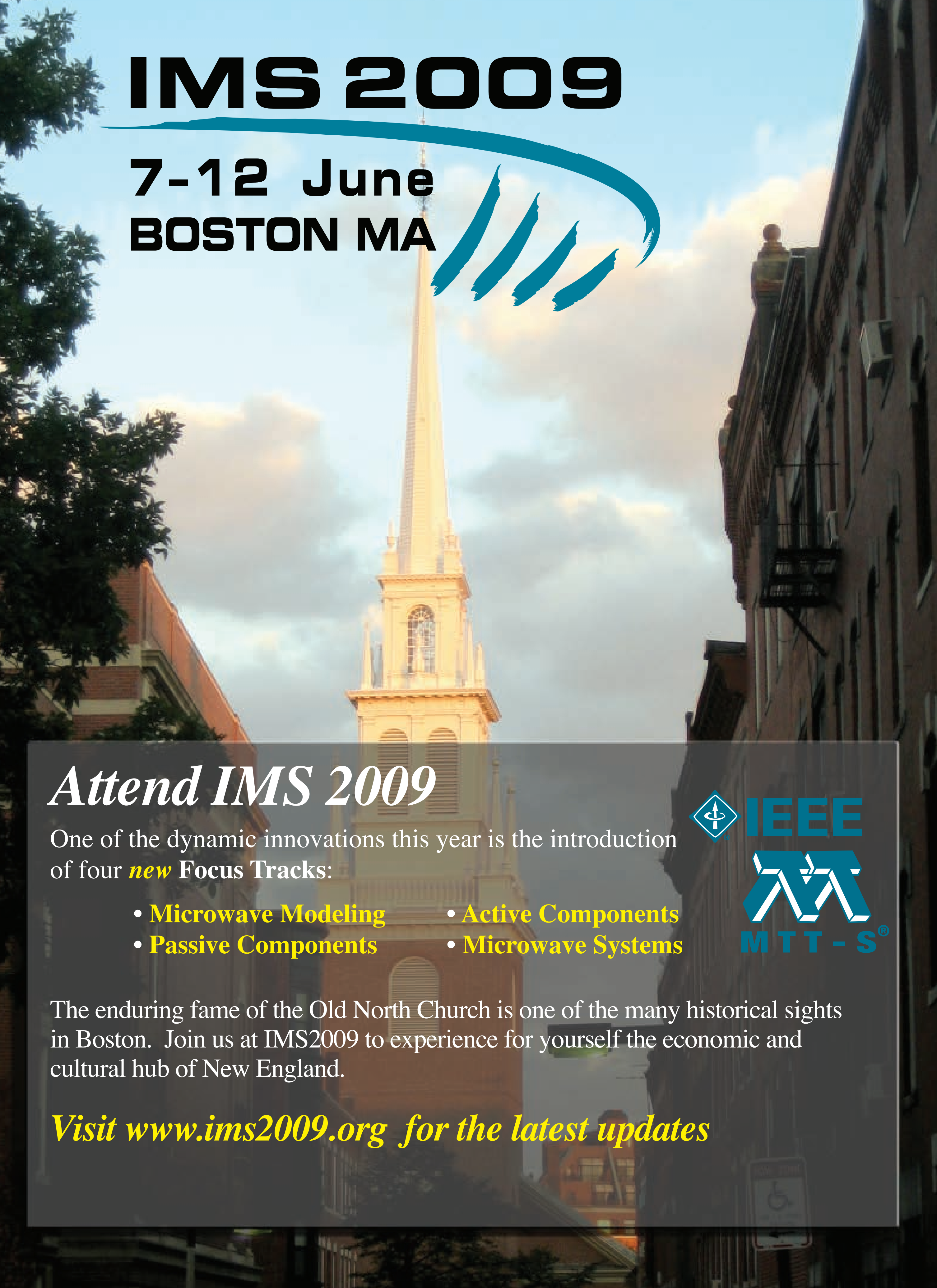
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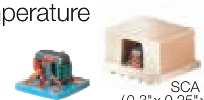

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PLD	30-130 MHz	P.L. Crystal	-95	-115	-140	-155	-155	-	100 MHz	13
PLD-1C	130-1000 MHz	P.L. Mult. Crystal	-80	-100	-120	-130	-135	-	560 MHz	13
BCO	.100-16.5 GHz	P.L. Single Loop	-65	-75	-80	-90	-115	-	16.35 GHz	13
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CP	.8-3.2 GHz	P.L. CRO Single Loop	-80	-110	-120	-130	-130	-140	2 GHz	13
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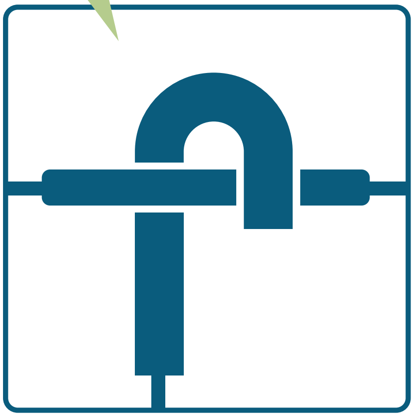

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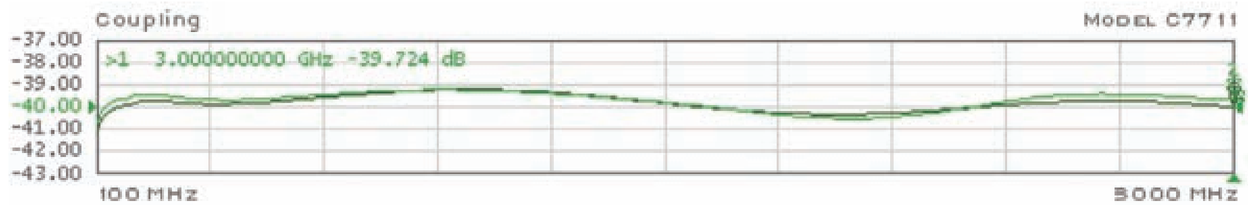
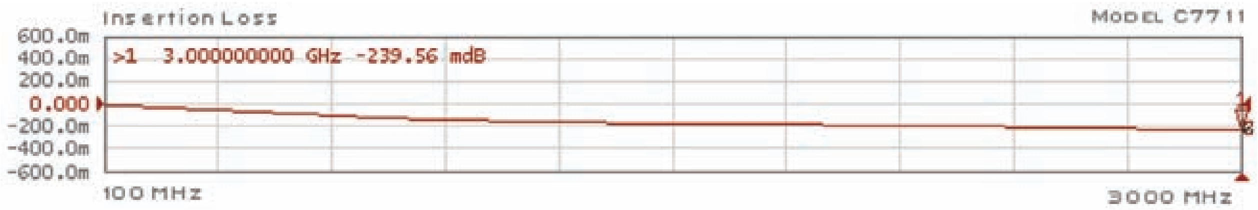
- Stripline designs invade traditional lumped element territory





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Model	Coupler Type	Frequency (MHz)	Power CW (Watts)	Coupling (dB)	Flatness (±dB)	Insertion Loss (dB)	VSWR (Mainline)	Directivity (dB)	Size (Inches)
C7734	Dual Directional	30-2500	100	43	±1.5	0.35	1.25:1	18	3.5 x 2.6 x 0.7
C7148	Bi Directional	60-600	200	10	±1.0	0.35	1.20:1	20	6.0 x 4.0 x 0.75
C7711	Dual Directional	100-3000	100	40	±1.0	0.35	1.25:1	18	3.0 x 2.2 x 0.7
C7783	Bi Directional	200-1000	200	20	±0.75	0.2	1.20:1	20	3.0 x 1.5 x 0.53
C6600	Bi Directional	200-2000	200	20	±1.2	0.25	1.25:1	18	4.0 x 2.0 x 0.72
C7152	Bi Directional	300-3000	100	20	±1.0	0.35	1.20:1	15	3.7 x 2.0 x 0.75
C7811	Dual Directional	500-2500	100	40	±0.5	0.2	1.25:1	20	3.0 x 2.0 x 0.6
C7753	Bi Directional	700-4200	100	20	±1.0	0.35	1.25:1	18	1.8 x 1.0 x 0.6

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