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September 2008

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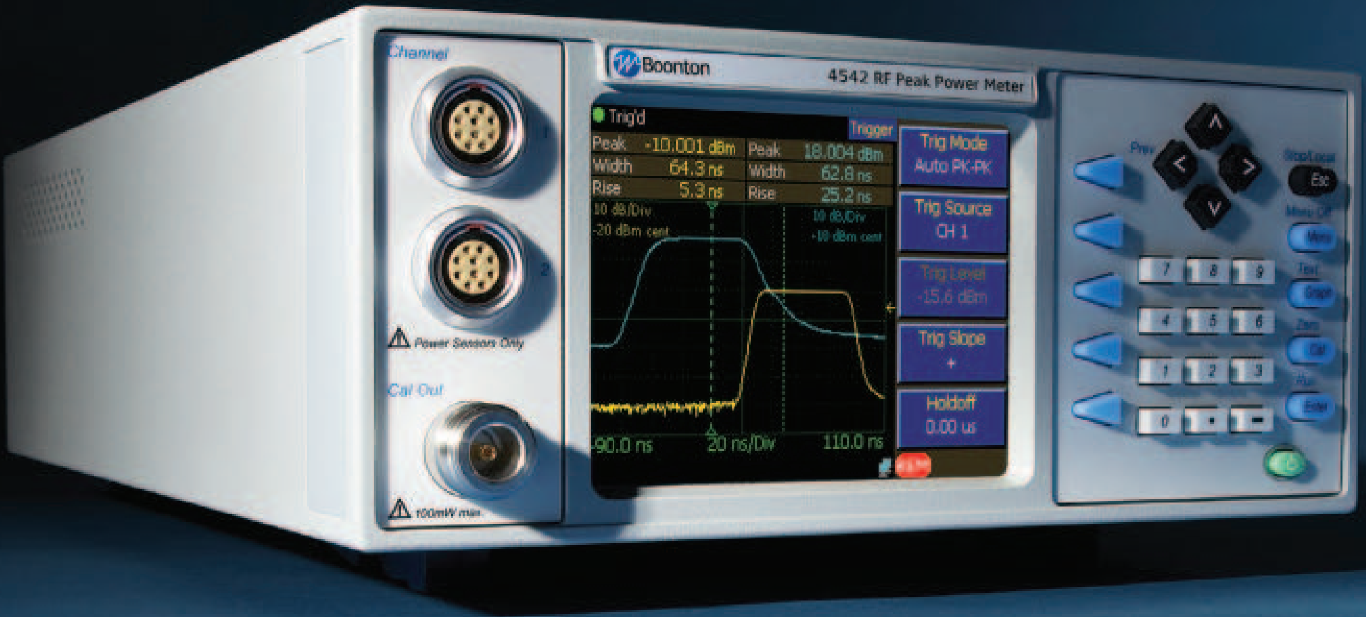

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XTO-05	5-130 MHz	Ovenized Crystal	-95	-120	-140	-155	-160	-	100 MHz	11
PLD	30-130 MHz	P.L. Crystal	-95	-115	-140	-155	-155	-	100 MHz	13
PLD-1C	130-1000 MHz	P.L. Mult. Crystal	-80	-100	-120	-130	-135	-	560 MHz	13
BCO	.100-16.5 GHz	P.L. Single Loop	-65	-75	-80	-90	-115	-	16.35 GHz	13
VFS	1-14 GHz	Multiple Freq. Dual Loop	-60	-75	-110	-115	-115	-	12.5 GHz	13
DLCRO	.8-26 GHz	P.L. CRO Dual Loop	-60	-85	-110	-115	-115	-138	10 GHz	13
PLDRO	2-40 GHz	P.L. DRO Single/Dual	-60	-80	-110	-115	-120	-145	10 GHz	13
CP	.8-3.2 GHz	P.L. CRO Single Loop	-80	-110	-120	-130	-130	-140	2 GHz	13
CPM	4-15 GHz	P.L. Mult. Single Loop	-60	-90	-105	-110	-115	-130	12 GHz	13
ETCO	.1-24 GHz	Voltage Tuned CRO	-	-	-70	-100	-120	-130	2-4 GHz*	13

* Octave band.

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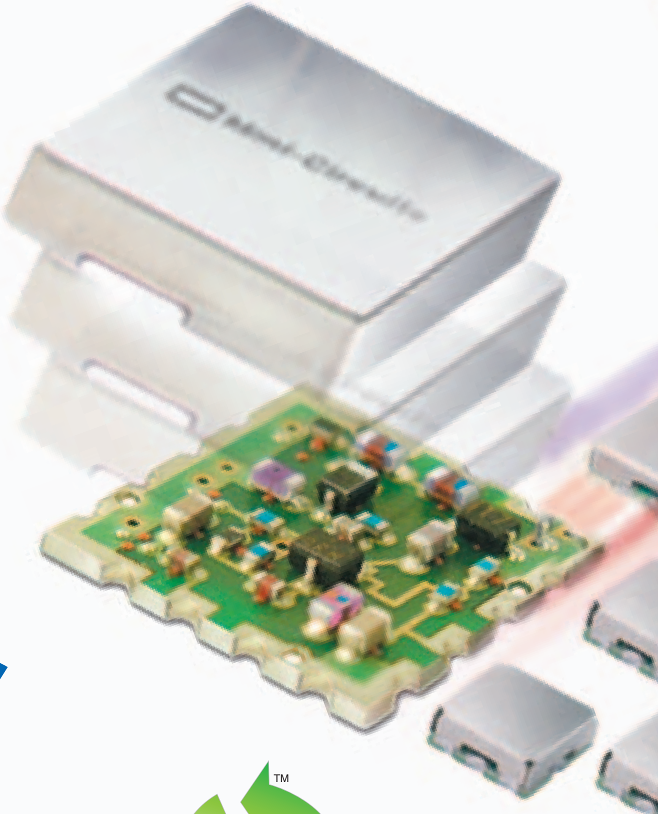

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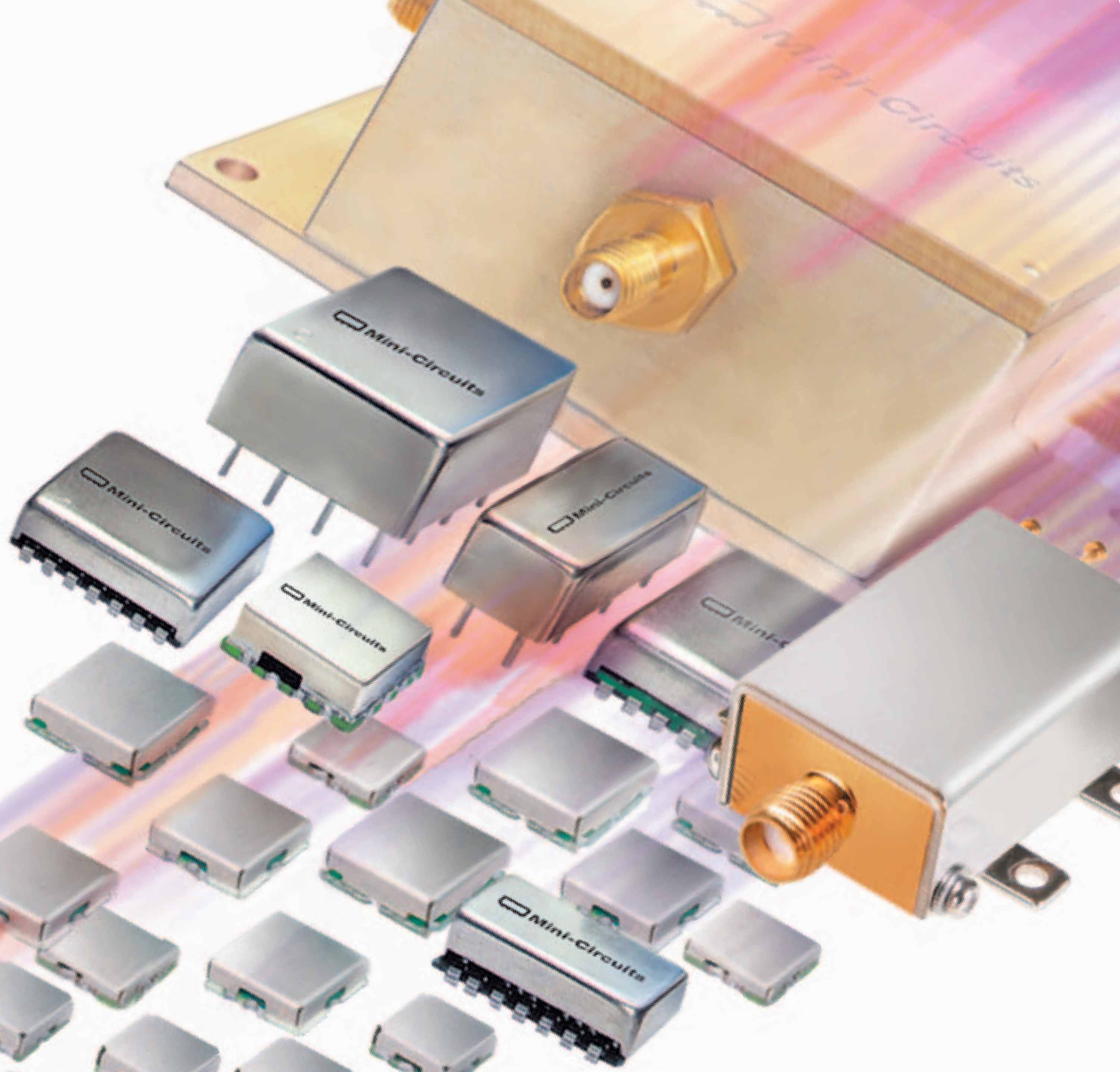

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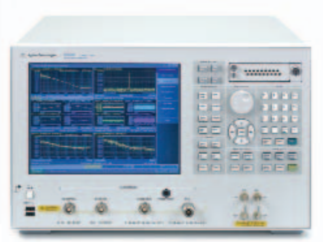

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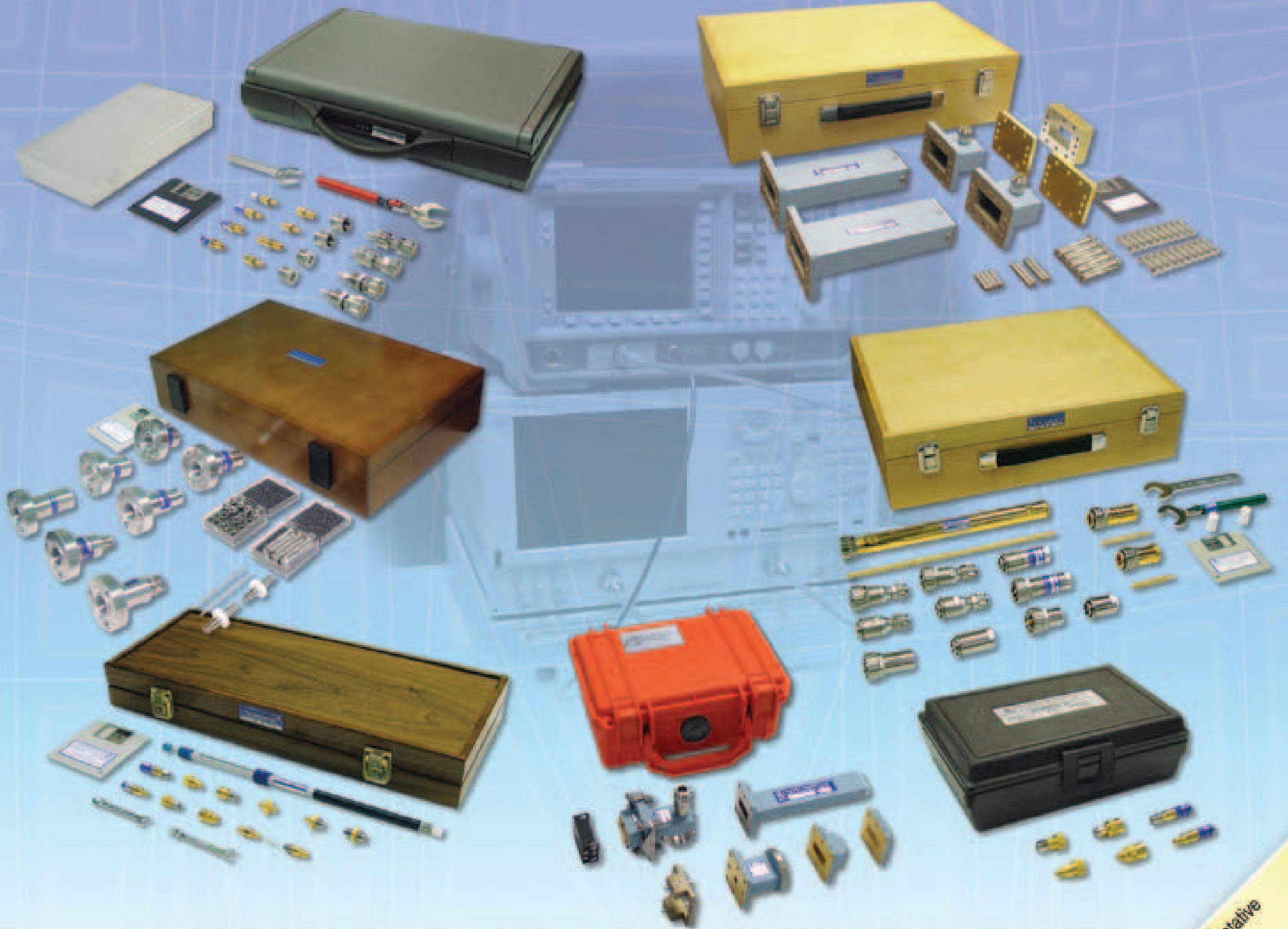

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Model	Frequency Range (GHz)	Attenuation Range (dB)	Notes
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150-75-3	dc-18.0	0-75/5	
150-70	dc-18.0	0-70/10	
150-70-1	dc-18.0	0-70/10	
151-11	dc-4.0	0-11/1	
152-90-3	dc-26.5	0-90/10	
150T-11	dc-18.0	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	

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COVER FEATURE: THEN AND NOW

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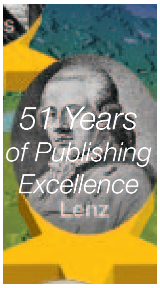

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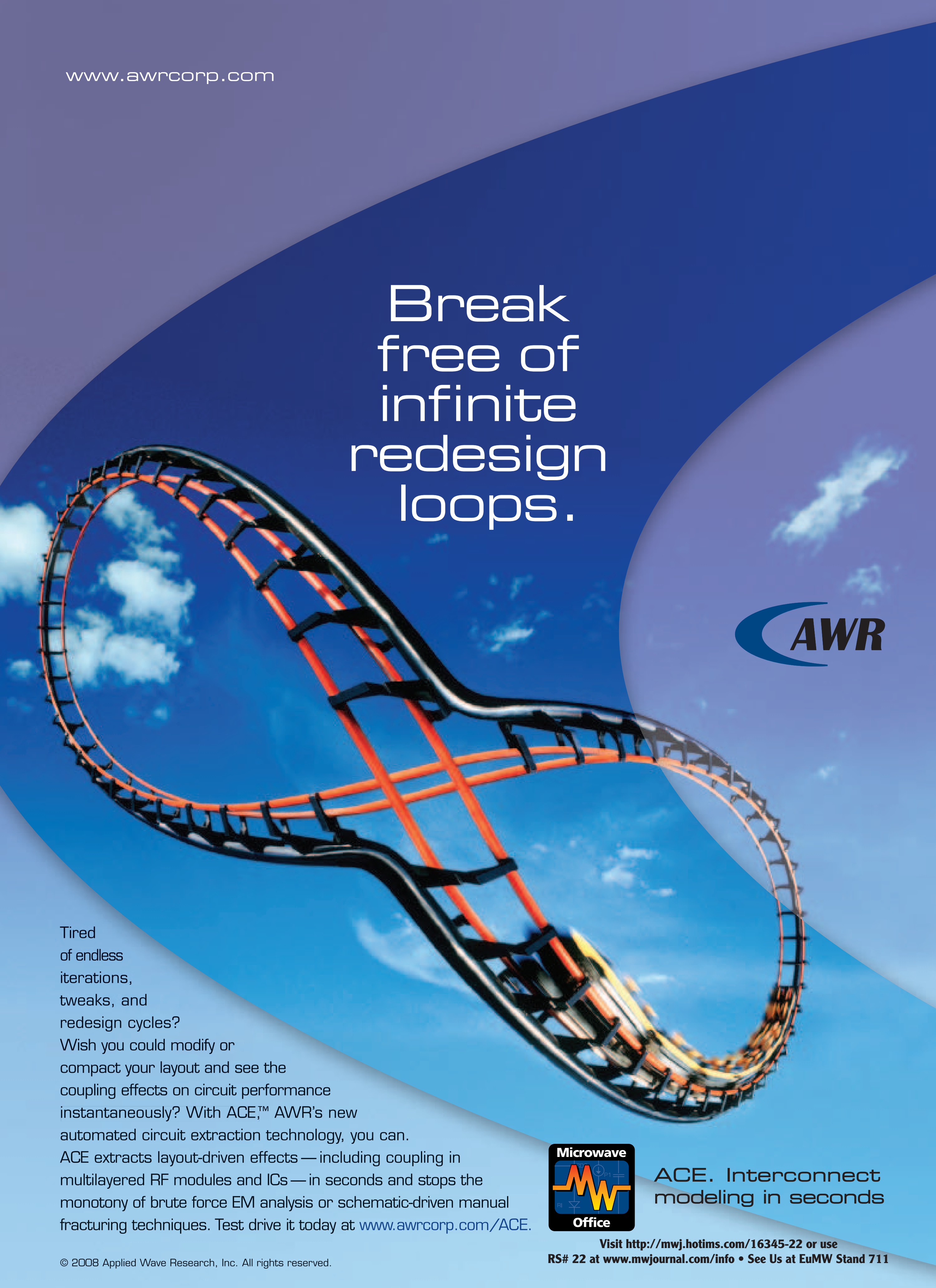
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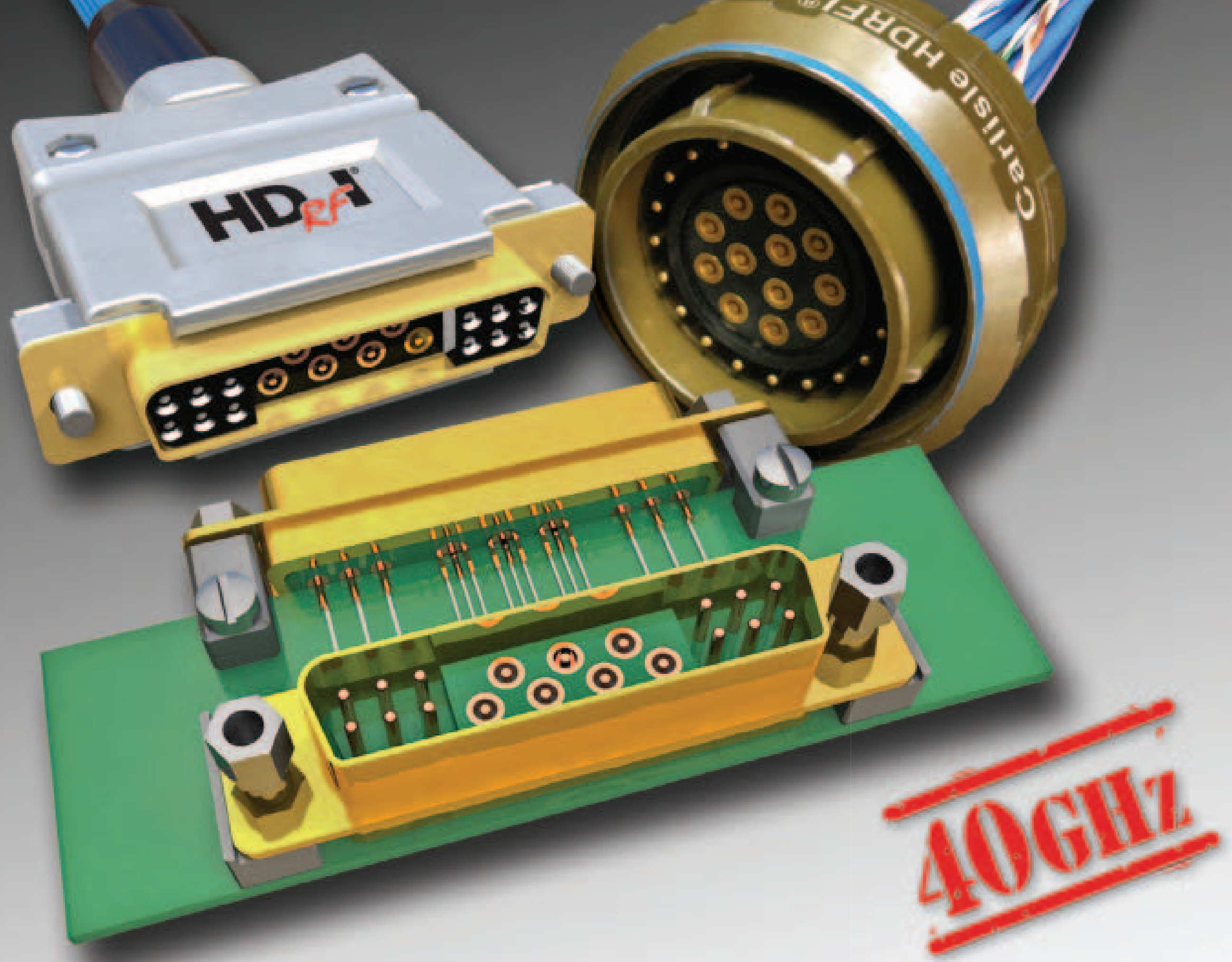

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Online Technical Papers

Performance Evaluation of MIMO Base Station Antenna Designs
R. Bhagavatula and R.W. Heath, Jr., University of Texas at Austin, and K. Linehan, Andrew Corp.

White Paper: Wireless Signals as You've Never Seen Them
Dr. D. Metzger, Constant Wave

Secure Multi-access Channel Using UWB for Next Generation RFID Systems
W. Ismail, JS Mandeep, M.S. Jawad and K. Kejuruteraan, Universiti Sains Malaysia

A Low Profile CPW and Microstrip-fed Half-circle Planar UWB Antenna
Yong-Woong Jang, Keukdong College; Sang-Woo Lee, Hankook Antenna Co. Ltd.; Jeong-Hye Kwon, Dongseo University

Expert Advice

In "Making the Switch: Converting from LDMOS to GaN," Ray Crampton, director of marketing at Nitronex Corp., provides key insight into the most important aspects of RF power amplifier design to consider when adapting GaN power devices.

Read the advice from this industry expert, respond with your comments and win a complimentary copy of *Electrical Engineering: A Pocket Reference* (see www.mwjournal.com for details).

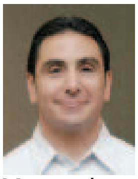
Extras

Retrospectives: Commemorating the 2008 Antenna Applications workshop at Allerton, mwjournal.com reprints the December 1971 article, "Future Antenna Trends at Allerton" by Assistant Editor, R.C. Hansen. We also post a classic from former editor, Joseph White, "What's in a Good Paper?," from May 1979.

Events: Pat Hindle files his show wrap-up on the 2008 IEEE EMC Symposium in Detroit, August 17–22; David Vye covers news at WiMAX World in Chicago, September 25-27; and the MWJ European Microwave Week - Online Show Daily goes live the beginning of October (www.mwjournal.com/eumw2008).

MWJ Blog: *MWJ* Editors David Vye, Patrick Hindle and Richard Mumford report on events big and small in order to keep you up-to-date with the news behind the news and other happenings in the microwave world (microwavejournal.blogspot.com).

Executive Interview



Microwave Journal talks to **Joseph Marenda**, vice president of engineering, Narda Microwave-East, about achieving higher levels of functional integration through microwave integrated circuit (MIC) technology. Marenda explains when MIC should be the technology of choice and how innovations continue to enhance its performance, capabilities and cost.

More Q. Less Cu

29
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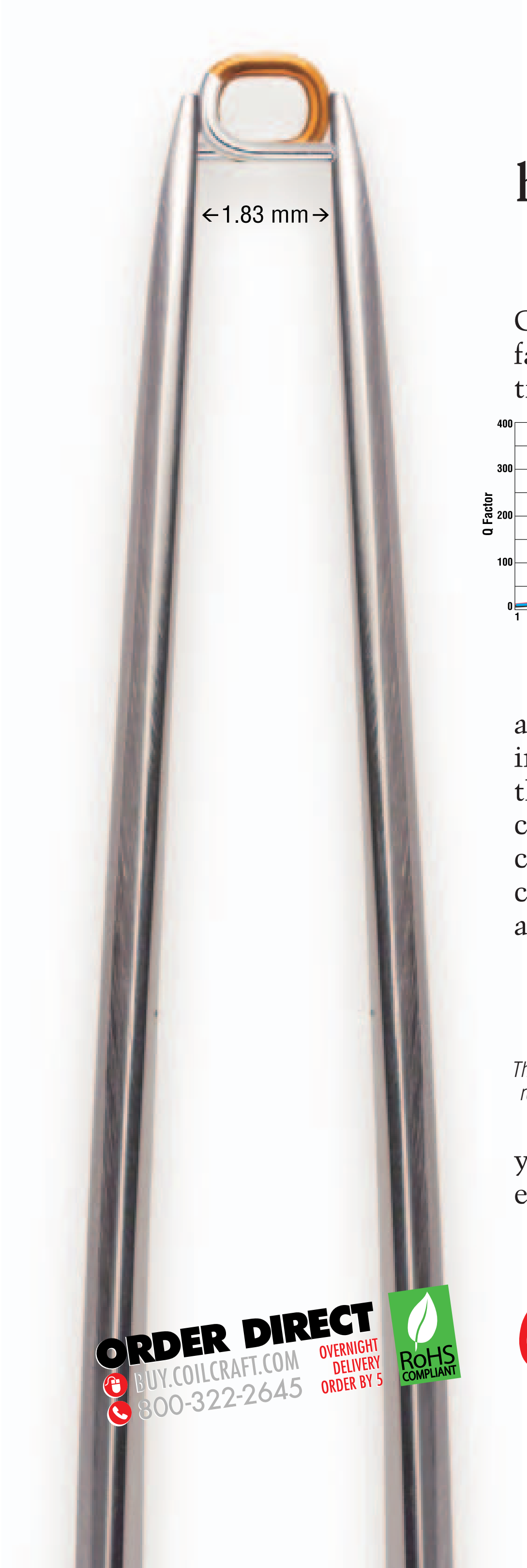
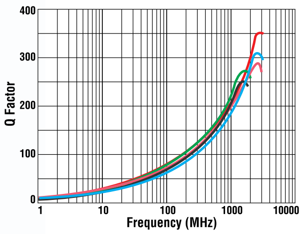
These tiny new air core inductors have the highest Q and current handling in the smallest footprint.



Coilcraft's new SQ air core inductors have unmatched Q factors: most are above 200 in the 1-2 GHz range! That's 3 times higher than comparably sized 0805 chip coils.



Q factors are 3X higher than standard chip inductors

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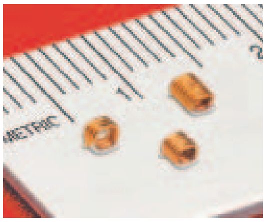
SQ air core inductors are perfect for your LC filter and RF impedance matching applications. They come in 15 values ranging from 6 to 27.3 nH, all with 5% tolerance.



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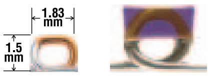

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November 4–6, 2008 • San Jose, CA
www.wcai.com

electronica 2008
November 11–14, 2008 • Munich, Germany
www.electronica.de/en

Antenna Measurement Techniques Association (AMTA 2008)
November 16–21, 2008 • Boston, MA
www.amta2008.org

MILCOM 2008
November 17–19, 2008 • San Diego, CA
www.milcom.org

China International Conference and Exhibition on Microwave (IME 2008)
November 18-20, 2008 • Shanghai, China
www.imwexpo.com

DECEMBER

ARFTG 72nd Microwave Measurement Symposium
December 9–12, 2008 • Portland, OR
www.arftg.org

Asia Pacific Microwave Conference (APMC 2008)
December 16–19, 2008 • Hong Kong, China
December 19–20, 2008 • Macau, China
www.apmc2008.org

JANUARY

IEEE Radio and Wireless Symposium (RWS 2009)
January 18–22, 2009 • San Diego, CA
http://rawcon.org

FEBRUARY

Mobile World Congress
February 16–19, 2009 • Barcelona, Spain
www.mobileworldcongress.com

National Association of Tower Erectors (NATE 2009)
February 23–26, 2009 • Nashville, TN
www.natehome.com

MARCH

Satellite 2009
March 24–27, 2009 • Washington, DC
www.satellite2009.com

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April 1–3, 2009 • Las Vegas, NV
www.ctiawireless.com

JUNE

IEEE MTT-S International Microwave Symposium (IMS 2009)
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Workshops & Courses

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■ **Contact:** For more information, visit www.vectorfields.com.

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■ **Site:** Atlanta, GA
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Integrated Nonlinear Microwave and Millimeter-wave Circuits (INMMiC)

■ **Topics:** INMMiC offers a forum for promoting, discussing and spreading ideas in the field of nonlinear microwave and millimeter-wave circuits. Technical papers describing methodological and practical issues on active device characterization and modeling strategies, CAD analysis methods and design approaches are solicited, according to the conference topic list.
■ **Site:** Málaga, Spain
■ **Dates:** November 24–25, 2008
■ **Contact:** For more information, visit www.inmmic.org.

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■ **Dates:** Open enrollment.
■ **Contact:** For more information, visit www.unex.berkeley.edu.

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■ **Dates:** Archived on-line for anytime viewing.
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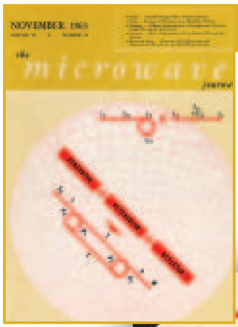

FLIGHT INTO THE EUROPEAN MARKET

TED SAAD • Editor-in-Chief

PART ONE

Last June I spent a week and a half in Europe visiting Sweden, England and Italy. Bill Bazzy and I started the trip together; however, except for two days in Sweden and a day in Rome we went our separate ways.

Sweden

In Sweden I spent a good deal of time with our friends at Magnetic AB. We had some lengthy discussions on the Swedish electronics industry with Bill Aberg and Bengt Dahlman, president and executive vice president respectively of Magnetic AB.

Magnetic is a relatively small company, employing less than 100 persons in the manufacture and sale of microwave components and instruments. Included among its proprietary items are high power terminations, high power attenuators, power measuring devices, spectrum analyzers, noise measuring devices and signal generators. Its instruments and components are marketed all over the world. In many respects the firm is similar to the small microwave manufacturers in the United States.

Magnetic claims to have developed the first commercially available automatic noise figure meter in the world and exports noise figure meters all over the world except to the U.S., where it has a license agreement with the Hewlett-Packard Co. It acts as consultant on noise figure measurements and radar performance measurements to many of the big radar manufacturers and operators in Europe, and also does theoretical and experimental work on echo distortion in microwave links. At present most of its engineers are engaged in the design of what it believes to be the world's most complete system for remote control and check-out of heavy radar systems.

Accent on Manufacturing

As of this writing the microwave industry in Sweden appears to be fairly prosperous. Companies there concentrate more on manufacturing than on R&D. Very few firms do design work. The large companies usually build complete radar sets to the exact drawings of the previous manufacturer. They do not invest money or facilities in a great deal of R&D work since the quantity demands for their products are limited. However, it should be mentioned that at the recent Air Show in Paris a declassified airborne radar designed by the L. M. Ericsson Co. received considerable attention.

Other companies visited during my Sweden itinerary included Sivers Labs, Philips, Svenska Radio Blaget and L. M. Ericsson in Gothenburg. In addition, I visited the Microwave Department of the Royal Institute of Technology in Stockholm, Chalmers Institute in Gothenburg and the Research Institute of National Defense.

I had an opportunity to spend some time with Mr. Sivers at Sivers Labs in Stockholm. Mr. Sivers is a classic figure in the Swedish microwave industry. He claims that he is not much of a business man and that he prefers not to spend time dealing with business problems. He much prefers working in the laboratory on design problems. He has eight engineers working on design, although only one of them is a university engineer.

The company employs about 60 persons. It has a shop with the usual lathes, milling machines, grinders, drill presses, etc. Since 1961, Sivers has had an arrangement with Philips whereby Philips handles its foreign marketing.

Sivers Labs will soon introduce a direct reading digital frequency meter that will have an accuracy of one part in 20,000. Its components also include precision slotted lines with a less than 1.005 residual VSWR, dual channel and high-power rotary joints, and double and triple stub tuners. The firm's waveguide switches have at least 80 db of cross-talk over the full waveguide band with a maximum of 1.05 VSWR.

Mr. Sivers and two other men started the company in a cellar in 1951, originally intending to do development work for other firms. They began developing some fairly good components and thereby created a line of products. By 1959, they occupied no less than seven cellars. His first assistant, Mr. Lennhag, is now sales manager of the company.

According to Mr. Sivers it is difficult raising funds in Sweden for small companies whose growth is based strictly on the money that they earn and retain.

Sivers Labs has sold waveguide switches to both the National Bureau of Standards and Bell Laboratories, and has sold frequency meters to Bell and others.

(*Continued on page 130*)

EDITOR'S NOTE: Because the microwave journal *believes there is a future in Europe for American microwave products, Bill Bazzy and Ted Saad, publisher and editor-in-chief, respectively, traveled to Europe this past summer. The following pages constitute Part 1 of a two-part series of their observations and interviews. Part 2 will appear in the December issue.*

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SAAD

(*Continued from page 128*)

Mr. Sivers pointed out that the new defense system in Sweden is going to be a big contract for the electronics industry for the next five years. He indicated that in electronics the average gross salary, including taxes, for a University engineer who is about 30 years old, is between $550 and $700 per month. Taking the cost of living in Sweden into consideration, Swedish engineers are paid about the same as engineers in the U.S.

All employees in Sweden receive at least three and a half weeks paid vacation. In 1964 this will be increased to four weeks according to law. Salaried workers get 10 paid holidays per year. All companies have a mandatory health insurance plan which is paid for partly by the company and partly by the worker. If an employee is disabled, the company guarantees that he will receive up to a maximum of about $6500 in any one year. There is an agreement between the employees' union and the union of salaried people that the latter get full pay during three months of illness.

The Royal Institute

The next day Bengt Dahlman arranged for Bill Bazzy and me to have lunch with Professor Agdur and Mr. Lundbom. Professor Agdur is head of the Microwave Department of the Royal Institute of Technology. On our way to lunch, we stopped at the institute.

We saw some of the experimental work that was going on in plasma. Members of the staff there are studying the propagation of microwaves on different types of electrical gas discharge plasma structures. They are presently concentrating their studies on problems concerning the coupling of microwaves to and from plasmas and on noise problems in plasmas. Most of their work in this field concerns long plasma columns, and the influence of radial as well as axial variations of the plasma density in this structure on the wave propagation is studied. From the technical point of view this work aims at an understanding of the possibilities of plasma, i.e., plasma amplifiers (where, for instance, the plasma may act as a kind of delay line). This work is also done as a background for studies of similar phenomena in semiconductors which are under progress. Distributed amplifiers of this category may be of interest for the generation of very short wave length. One of their experiments on semiconductor plasmas concerns the propagation of millimeter waves in indium antimonide. They are also studying plasma in metal. They have a technician fabricate a silver wire 2000 angstroms thick. When the wire is heated, they are able to achieve 70 per cent polarization of the radiated energy due to the plasma operation of the metal.

The laboratories in Sweden appeared to be very well equipped and to have good financial support. However, the only places that we could talk to people without restriction were the educational institutions, Magnetic AB and Sivers. We found that when we visited large companies, we were always obliged to sit in a conference room and, due primarily to security problems, discuss generalities.

During lunch we had an extremely interesting conversation with both Professor Agdur and Mr. Lundbom. Mr. Lundbom is the head of the Instrument and Measurements including the Defense Primary Standards Laboratory at the Research Institute of National Defense Radio Department. In September he was the chairman of Commission I, URSI Section in Japan, Session III. He is presently planning to publish a paper on measurements in Scandinavia.

Professor Agdur said that, from the point of view of properly using university-trained people, he thinks more development and research oriented electronic industries should be formed in Sweden since they now would have better possibilities for such activities than before. He pointed out that a very large fraction of the microwave work in Sweden is for the defense effort. Professor Agdur's department, which has now been in existence for three years, employs about 20 persons of whom 10 are working for their PhD. In addition to the work described above, they are also investigating Whistler propagation problems and doing some work on tunnel diode amplifiers and a single diode amplifier. Typical performance at 3000 Mc is a 700 Mc bandwidth with 15 db gain and about 6 db noise.

We asked about the matter of American dollars being invested in Sweden, and Mr. Lundbom and Professor Agdur indicated that there is no objection. However, Mr. Lundbom did point out that it is better not to have a majority control outside Sweden. One hundred per cent outside ownership has not proven to be as desirable as it could be.

In his position Mr. Lundbom is particularly qualified to know what progress has been made in Sweden relating to instruments, measurement techniques and primary standards. He is familiar with all of the people in these related areas in the United States. His activities with URSI keep him abreast of what is going on throughout the world.

After lunch Mr. Lundbom arranged a visit to the Research Institute of National Defense. He was kind enough to convey to me some of the facts relating to radio standards and measurements methods within Sweden. The demand from research institutes and industries for calibration equipment and secondary standards, especially in connection with developing and building military systems, has led to comparatively large investments in precision instruments and measurements methods research. The Instruments and Measurements Group and its Standards Laboratory have accepted by request from research institutions, defense laboratories and industry to serve as a primary institute and the calibration center in the URSI, Commission I sphere of activity. The Standards Laboratory has also by request of the National Bureau of Standards accepted an offer to take part in intercomparison of measurements accuracies of radio electric quantities up to certain limits. At the Research Institute experiments have been performed to a limited extent with an experimental caesium beam frequency standard. The study has been concentrated on improving the spectral purity of the microwave signal.

Experiments at the University of Lund are being made with optical pumping using sodium in hope of their resulting in — among other things — a sodium gas cell frequency standard with a frequency of 1772 Mc per

(*Continued on page 134*)

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APA3438-38	3.4 to 3.6	30	3.5	0.5	38	48	3.4 A
APA3438-41	3.4 to 3.6	30	3.5	0.5	41	51	5.5 A
APA3642-39	3.6 to 4.2	40	4.0	1.0	39	49	3.3 A
APA4450-40	4.4 to 5.0	40	4.0	1.0	40	50	5.5 A
APA4450-42	4.4 to 5.0	40	4.0	1.0	42	52	3.3 A
APA4450-44	4.4 to 5.0	40	4.0	1.0	44	54	9.5 A
APA5964-36	5.9 to 6.4	40	4.5	0.5	36	46	2.6 A
APA5964-42	5.9 to 6.4	40	4.5	1.0	42	52	5.3 A
APA5964-44	5.9 to 6.4	40	4.5	1.0	44	54	9.5 A
APA5864-46	5.8 to 6.4	40	4.5	1.0	46	56	11.0 A
APA6472-36	6.4 to 7.2	40	4.5	0.5	36	46	2.6 A
APA6472-42	6.4 to 7.2	40	4.5	1.0	42	52	5.9 A
APA7785-39	7.7 to 8.5	40	4.5	1.0	39	49	3.6 A
APA1112-36	10.7 to 11.7	40	4.5	0.5	36	46	2.6 A
APA1112-42	10.7 to 11.7	40	4.5	1.0	42	52	5.9 A
APA1414-37	14.0 to 14.5	40	4.5	0.5	37	47	2.6 A
APA1414-40	14.0 to 14.5	40	4.5	0.5	37	47	2.6 A
APA1414-43	14.0 to 14.5	40	4.5	0.5	37	47	2.6 A
APA3031-36	30.0 to 31.5	27	6.0	1.0	36	43	5.6 A

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SAAD

(*Continued from page 130*)

second. They recently purchased a rubidium gas cell standard with a tuning range of $\pm 5 \times 10^{-10}$ and a magnetic field of 80 milligauss at the lower part of the frequency range. Its long term stability will be measured against VLF transmission.

In the area of power measurements they have ordered a power calibrator of U.S. make. In addition, they have a balanced microwave calorimeter which is presently being improved. They have purchased a thermistor mount and bridge which will enable them to measure power of 1 milliwatt at several frequencies up to 4000 Mc. With a second thermistor and mount they will be able to extend their range to 9000 Mc. They are completing a self-balancing dc bolometer bridge, and, using this equipment, they will be able to measure power in the milliwatt level at any frequency within the bolometer mount waveguide bands with an accuracy of 1 per cent to 2 per cent.

They have recently purchased a two-probe, phase measuring instrument for the frequency range from 300 Mc through 4000 Mc and X band. For attenuation measurements they have a Weinschel calibrator and are able to cover up to 12,000 Mc.

Reflection Method

A reflection method has been developed for measuring the Q-factor in absorption cavities. The method is quite flexible and allows measuring Q-factors up to about 50,000 in the 3 centimeter region. By a simple modification of the measuring device, they can measure the Q-factor of transmission cavities as well.

They have also developed a simple and accurate method for measuring dielectric constants of styrofoam and similar materials with a dielectric constant of 1.2 or less, having low losses. The technique is to measure the resonance frequency of a high Q cavity which has been filled with material.

At their Microwave Division they have been using cavity techniques for measuring plasma and hole densities. They have ordered from Sivers Labs the precision cavity frequency meter mentioned previously. The frequency meter employs a cavity in the TE_{011} mode covering the whole frequency band of the waveguide. The unwanted modes are taken care of by means of a second cavity used as a filter ahead of the main cavity and as a coupling input to the external circuit. The main TE_{011} cavity is equipped with a diode for resonance indication. The two cavities are mechanically ganged and single knob tuned, and the frequency readout is obtained from a mechanical counter in conjunction with a 10-meter-long linearly calibrated conversion tape.

They have been making comparison measurements on noise between the British CV 1881 argon discharge tube and the U.S. neon tubes and have shown agreement within 0.1 db of nominal in the 3 centimeter region. Measurements on modern U.S. receiving equipment show a good correlation of 0.1 to 0.2 db between these tubes and the present U.S. standard. They have ordered the development of a complete radiometer for 10 centimeter and 3 centimeter bands. There has been constructed at the Research Institute a hot-cold body standard noise generator for the 20 centimeter band. They are also investigating the noise emitted by plasmas. In their work on noise standards and noise measurements, they often draw on the talents of the people at Magnetic AB.

At the Research Institute I talked with five gentlemen on some of the work they are doing. They showed me a rat race switch that uses stripline techniques and employs a single varactor diode terminating one coupled arm and a capacitive tuning device in the other coupled arm. When the diode conducts, the switch has about a 3 db loss in the output, and when the diode is open it has about a 50 db loss. The frequency of operation is about 3 Gc with a minimum of 10 per cent bandwidth.

They are interested in stripline, and have four persons working in this area. They are also doing some work on Y circulators at 200 Mc. They are making ferrites from raw materials. The ferrite group has six employees, including three engineers. They have designed some circulators in stripline and are working on broadband and X-band circulators; they are attempting to attain 20 per cent bandwidths. They are also working on a ferrite modulating switching device. They have done some filter design, again using printed circuit techniques, and have designed some bridge-type directional couplers in conventional printed circuits.

They indicated that their most impressive laboratory was the Antenna Lab, although I had no opportunity to visit there. They mentioned that they had built a stripline monopulse circuit integrated with an antenna. The laboratory is capable of working over all frequency ranges. Located 20 kilometers outside of Stockholm, the laboratory employs 10 persons. Its primary function is to design aircraft antennas; however, when an antenna is designed that goes into production, the production is handled by private firms.

At their Tube Section one group is working on parametric amplifiers. They have diode amplifiers that use circulators, mostly in the L and S band. They are working on the broadband problem. They are using the technique of detuning the signal and idler resonance for staggered operation. This provides three times the bandwidth as compared with sharp tuning of both the signal and idler. They have built a parametric amplifier for a scatter link.

One of the gentlemen I spoke with, Mr. Bengt Henoch, had had published in the *PTGMTT Transactions* of January, 1963 a paper entitled "A New Method for Designing Wideband Parametric Amplifiers."

They have also measured the Swedish-made varactor diodes and have succeeded in fabricating ordinary types with cutoff frequencies of 30 to 50 Gc. These are cartridge types made by the Swedish Semiconductor Laboratory, which is partly government sponsored. They have about 20 persons doing some sophisticated solid state work, but practically no production. They are interested in CW amplitrons and at the time had a man visiting SFD in the U.S. to get information on crossed-field technology. Their Tube Group is concentrating on investigating slow wave circuits for broadband forward amplification. They have approximately 1500 employees in the entire laboratory, about 100 of whom are working on microwaves.

(*Continued next month*)

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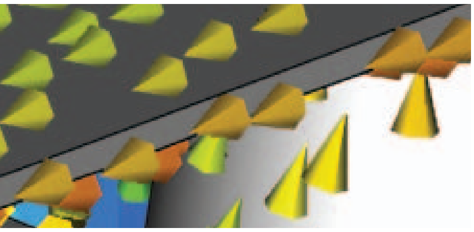

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MICROWAVES IN EUROPE: HISTORICAL MILESTONES AND INDUSTRY UPDATE, PART I

Tracing from Maxwell, through World War II to the communications boom and beyond, this report provides an insight into Europe's historical role and the part it continues to play in the development of the global microwave industry.

When Ted Saad and Bill Bazzy took their "Flight into the European Market" in 1963, they presented a snapshot of the European microwave market at an interesting point in time. At the beginning of the 'Swinging 60s' there was a hopeful perception that the swing would be towards prosperity driven by innovation. The continent was well on its way to economic recovery after World War II, fuelled by technological and commercial development, and eager to satisfy the appetite of a developing consumer society. Yet, in hindsight, it was also a time that was ignorant of the imminent communications boom (and bust) that has since impacted significantly on society and the microwave industry that serves it.

Nearly 50 years on, do Saad's and Bazzy's observations still ring true? Do European companies concentrate on manufacturing rather than research and development? Is the largest percentage of microwave work in the defence sector? And whatever did happen to that Swedish company, L.M. Ericsson?

This article aims to answer some of those questions, while maintaining the historical theme of *Microwave Journal*'s 50th anniversary year with a potted history of microwaves in Europe in addition to considering present and future trends. To do so *Microwave Journal* has enlisted the expertise and knowledge of Prof. Roberto Sorrentino, the president of the European Microwave Association, aided by EuMA regional members from selected European countries. They chart historical, industrial, academic, research and political changes, and proffer an insight into future trends.

Space constraints mean that this report cannot include every significant, industry defining event. Please visit our blog to add events you think should have been included (microwavejournal.blogspot.com).

THE GEOGRAPHICAL LANDSCAPE

Microwaves in Europe Overview

Roberto Sorrentino and André Vander Vorst
EuMA

Electromagnetic science was born in Europe, essentially in the 19th century. We all know the names and contributions of Ampère, Coulomb,

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Microwave Journal *European Editor*

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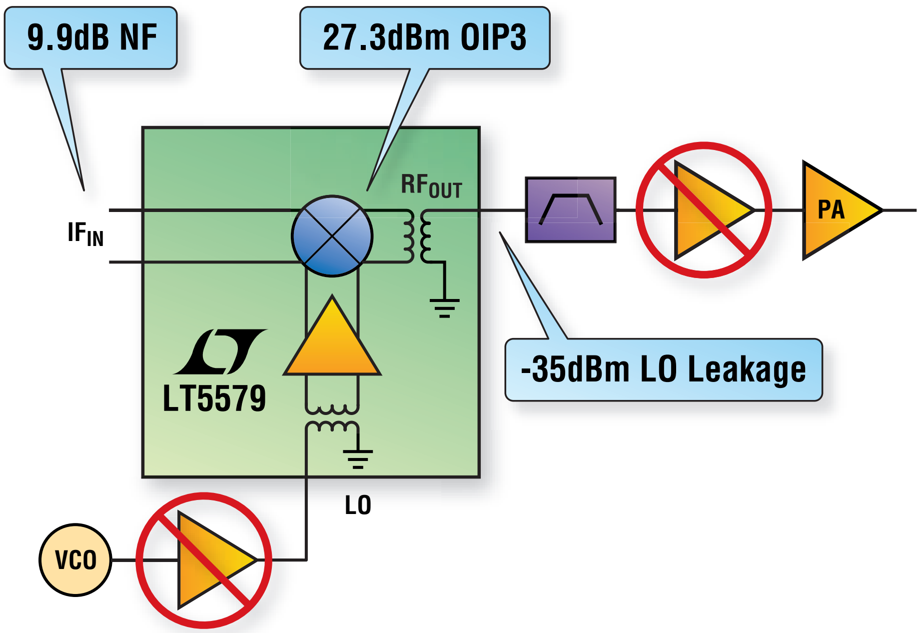

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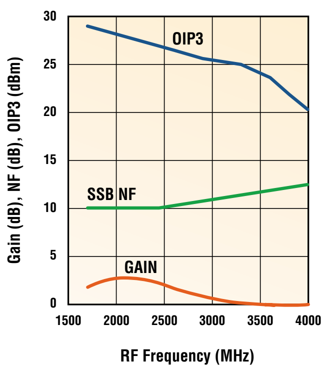

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LINEAR TECHNOLOGY

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Faraday, Gauss, Lenz, Oersted, Ohm and others. They were clever enough to make accurate measurements at a time of limited funds and of expensive equipment, and for extracting experimental laws out of their measurements.

Then came Maxwell who spent his professional life working as a professor in Aberdeen, London, and Cambridge, UK, with his two contributions: One which said that all these former experimental laws needed to be taken into account, not independently but as a system of equations; the other by introducing a 'missing term': the displacement current.

Maxwell's equations did not become famous rapidly. As well as being modest, Maxwell did not have formal use of div and curl, so he had 20 equations in 20 variables with what we today call magnetic vector potential as primary. Maxwell's equations were simply too complicated. Also, when he published the equations in their complete form (1865), he made no attempt to connect them back to the lord and ruler of physics at that time, Isaac Newton; there was no mechanical model.

As a result, no one realized the significance of Maxwell's equations until over 20 years after Maxwell's 1865 publication and almost a decade after his death. This is when Hertz independently derived them in their modern form and went on to experimentally confirming that light is indeed an electromagnetic wave.

The abstract concept of using what came to be known as 'fields', with absolutely no connection to Newton and f = ma, revolutionized physics. Maxwell was in fact the inspiration for Einstein and his (field) theories of relativity. Freeing physics from the confining womb of Newtonian mechanics led directly to all the major developments of 20th century physics. It was actually this much more significant but lesser realized accomplishment that was Maxwell's most significant legacy.

Hertz confirmed experimentally that light is an electromagnetic wave and that these waves propagate. He showed that high frequency oscillations could produce an effect at a distance, and that this action requires time. The word 'propagation' comes from these two concepts: action at a distance and non-instantaneous character of the effect.

Applications were there and around 1894, Marconi invented 'radio', the practical way to transmit information trough air at a distance. In 1899, his signals went beyond the Channel; in 1901, beyond the Atlantic Ocean. To do so, antennas had to be developed: propagation and radiation are intimately entwined. Simultaneously there were proposals for having electromagnetic wave propagation along structures of varied form, like two-wire lines, coaxial cables and metallic guides.

The 20th century had not yet begun when Lodge invented radiation from waveguides, Rayleigh published solutions of Maxwell's equations for fields in rectangular and circular waveguides, Bose developed a semiconducting detector at 60 GHz, and the door opened on Hertzian links with paraboloidal aerials.

From a theoretical point of view, the first ten years of the 20th century saw Einstein publishing his famous four papers. Later, it was shown that

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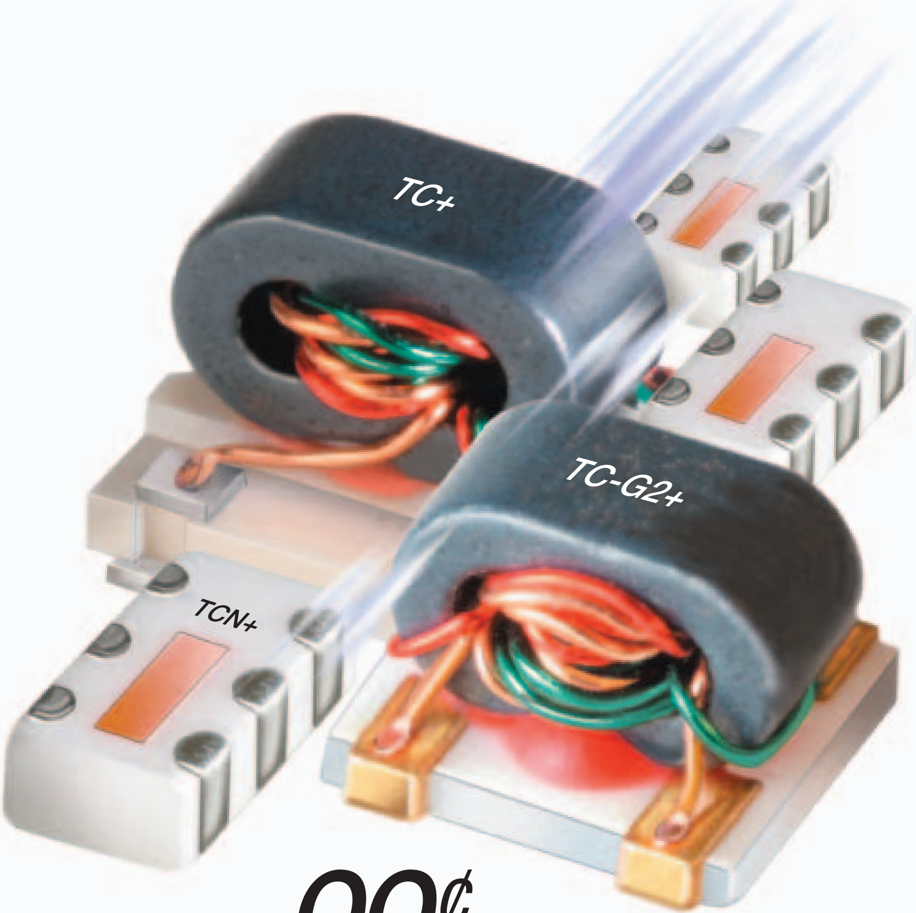

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applying a relativistic transformation to Coulomb's law while postulating the speed of light constant with respect to the observer, a postulate proven later by experiment, yields relativistic expressions for electromagnetic force, from which Maxwell's equations can then be deduced: In significantly less than 100 years, the 19th century electric and magnetic experimental laws were proved to be included in the theory of relativity.

All this generated a very significant microwave legacy, and explains why comprehensive advances in microwaves have been achieved in Europe in the 20th century, in line with the 19th century developments.

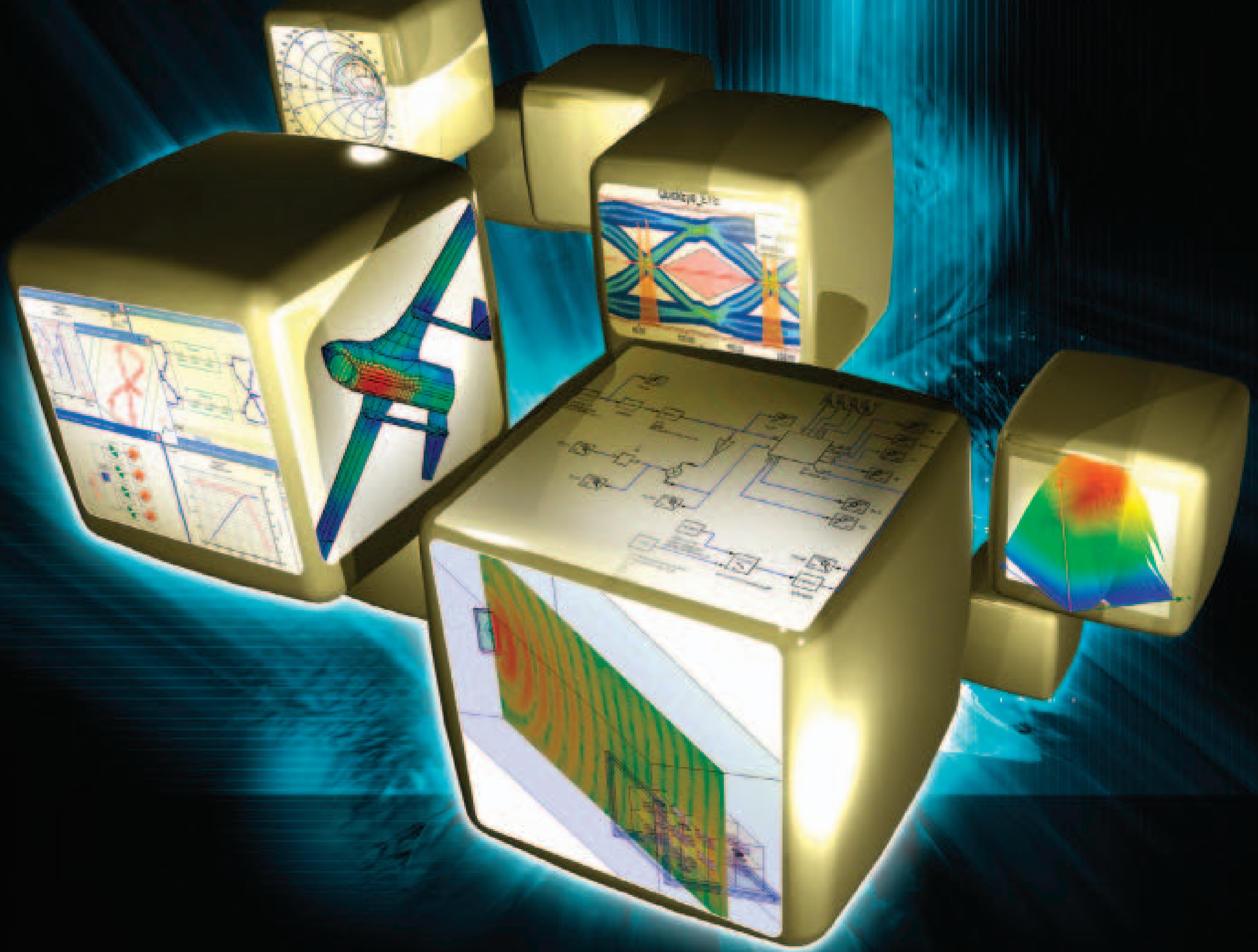
One example concerns the concepts of bi-isotropy, bi-anisotropy, non-reciprocity and chirality, introduced by Arago and Pasteur in the 19th century, and further investigated in 1920 and later. Another is the scattering matrix (S-matrix) of most common use for tens of years, developed independently in Europe and in the US around 1945. A third is the gyrator, also developed at the end of the 1940s. Also, a significant European-coordinated effort in the field of microwave propagation, in particular tropospheric propagation. Even the term 'microwaves', in its current meaning, was first introduced in an international scientific journal (*IRE Proceedings*) in 1932 by the Italian physicist N. Carrara.

There is no definitive date but microwave activities in a number of European countries may be traced back to the radar interests of the 1930s, although the first patent had been taken in Germany before 1910. Several companies worked on the first magnetrons. A quite significant achievement was the design and installation of a chain of radar stations (Chain Home) along the East and South coast of England in 1938, in time for the outbreak of war.

Microwave development during World War II was outstanding. Since then, the microwave infrastructure has grown extensively, encompassing university, industry, and government ministries, in support of comprehensive research, development, and production of microwave practices to meet wide-ranging applications covering all microwave fields from radio to terahertz frequencies. In the early decades, this was motivated by military needs; more recently, civil broadcast and communication interests have become increasingly dominant.

One of the most exciting fields of advancing technology over the last 50 years has been in microwave solid-state devices with associated integrated circuits. Such a very large quantitative growth, as well as continuous advances in research, industrial development, and education, has been driven by the dramatic growth of applications, particularly of telecommunications systems.

By its very nature Europe is a conglomeration of individual and disparate countries with its own established industries and centres of academic and commercial research. In the past, many of these research establishments would have worked independently. However, that has gradually changed with the expanded Eu-



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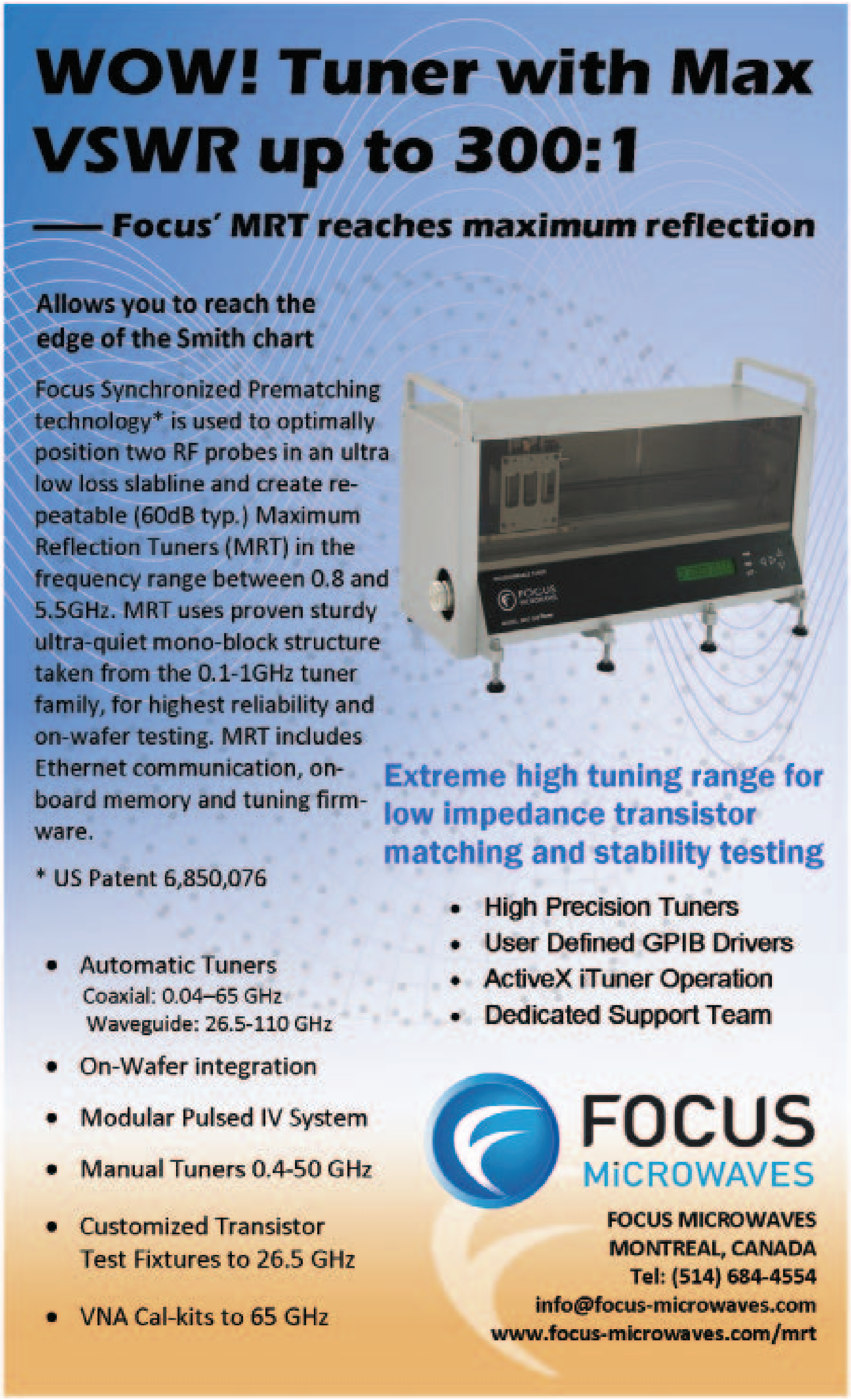
ropean Union putting greater emphasis on cooperation and collaboration to pool resources, harness technological expertise, and forge partnerships to create real and productive initiatives.

A major medium for addressing these issues is the EU Framework Programmes (FP) that identify key areas of research and development and organise and fund specific pan-European collaborative projects via its Networks of Excellence (NoE) Programmes that encourage pan-European collaboration and the input of academia, research institutes and industry.

That is a very succinct overview of the history and development of the European microwave industry as a whole. To gain an insight into the roles that individual European nations have, and continue to play, the following reviews consider the contribution of individual countries. The reviews were coordinated by EuMA colleagues; most of them had previously contributed to a paper[1] presenting an overview of microwave activities and infrastructures in Europe, which they have updated. Due to space constraints and the vastness of the subject, not all European countries can be included.



Sweden/*E. Kollberg*

From fairly on, the Swedish company, SRA, later part of Ericsson, focused on mobile systems for telephony, which paved the way for the key role that Sweden now plays in wireless communications. The cellular systems NMT 450 and NMT 900, developed in Sweden, marked a significant change toward non-military applications of microwaves. Ericsson is still the dominating Swedish company in the microwave field with its focus on communications. The company also had a special arm focusing on microwave technology, Ericsson Microwave Systems AB with microwave products for both civilian and military applications, in particular, transmission, certain base stations and sensor (radar) systems. The defence arm of the company later became part of Saab, which is the largest Swedish company with development of advanced microwave systems for military applications.

Smaller companies like Saab Space, Sivers IMA, and Omnisys Instruments focus on civilian products for different applications. Rosemount Tank Radar (part of Emerson Process Management) has a strong reputation for radars based on FMCW techniques such as level gauging applications in oil tankers.

Academically, modern microwave technology teaching and research began during the early 1940s at the Royal Institute of Technology (KTH), Stockholm, and at Chalmers University of Technology, Göteborg. Defence-oriented research in propagation, microwave technology, and radar/EW systems became important during the war and, since 1945, has been continued at FOA, today the Swedish Defence Research Agency FOI.

FOI, Linköping, is active in the fields of phased-array antenna technology (e.g., antennas, T/R modules, broadband microwave circuits and components), high-power microwave

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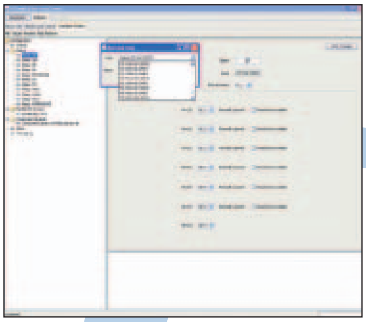
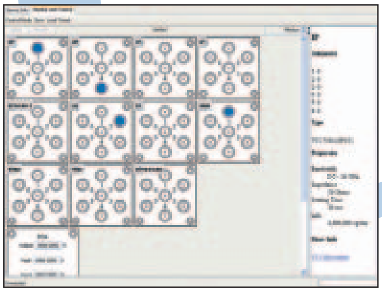


configuration interface



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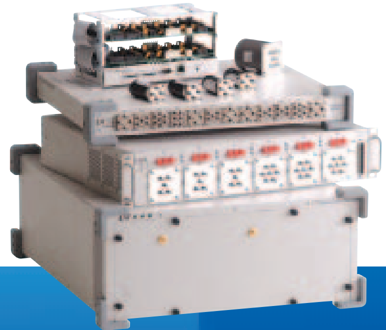

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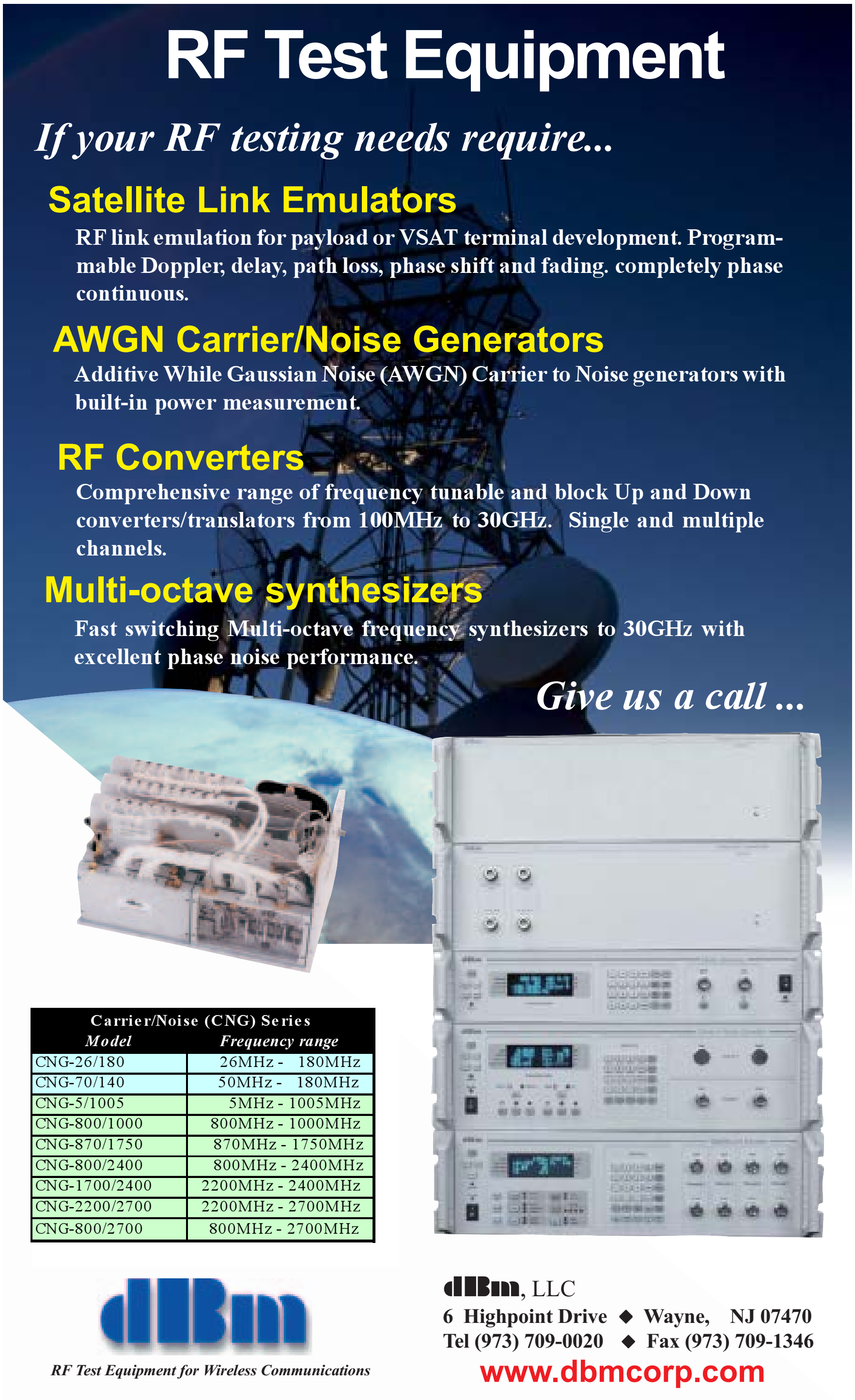
protection and electromagnetic compatibility, radar cross-sectional analysis, and the design of radar and EW systems. The well-known CARABAS synthetic aperture radar developed at FOI points the way ahead for future radar systems. In the 1960s and 1970s, the Microwave Institute, now ACREO, Stockholm, built up competence in semiconductor microwave components.

Also, radio astronomy has historically been strong in Sweden, with the Onsala Space Observatory for radio astronomy established in 1949. Today, the observatory is responsible for telescopes not only at Onsala, but also in Chile. Due to the inspiration from radio astronomy research, low noise has for many years been an important focus at Chalmers. In February 2001, the Odin satellite radio astronomy observatory was launched with advanced quasi-optical 500 GHz receiver and amplifiers (IF and 119 GHz) designed and built at Chalmers. Chalmers has also delivered world-record low-noise temperature THz heterodyne receivers for the Herschel telescope soon to be launched by the European Space Agency.

Other Chalmers' microwave research activities concern wide bandgap technologies (SiC and Gan MMICs, SiC MOSFETs); tuneable components based on ferroelectrics, THz varactors, and array-type SIS receivers. There is also significant activity regarding III-V MMIC design for multi-functional solutions in mm-wave communication and sensor systems. Today, much of the Swedish microwave research is performed in partnerships between Chalmers and industry. In the GigaHertz Centre, the focus is on switched-mode amplifiers for efficient PAs in radio base stations while Chalmers and FOI are researching sensor systems beyond 100 GHz.



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United Kingdom and Republic of Ireland/*Terry Oxley*

Microwave activities within the United Kingdom and Republic of Ireland (UK&RI) may be traced back to radar interests of the 1930s/40s as demonstrated by the Marconi Co. work on design/installation of the 'Chain Home' network of radar equipment and the General Electric Company (GEC)/Birmingham University work (Randall & Boot) on the first magnetrons.

Over the last fifty years or so, one of the most exciting fields of advancing technology has been in microwave solid-state devices with associated integrated circuits. Originating from the work in World War II by GEC Research Laboratories and British Thomson Houston Research Laboratories (merged with GEC in the 1960s) on semiconductor diode receiver technology, there have been many participating establishments that have contributed to the UK&RI world competitive position in the field, and provided the focus for internationally recognized technical achievements. However, as will be demonstrated, as the result of company mergers, many major companies involved in early microwave business have been restructured with rationalisation of their autonomous product companies.

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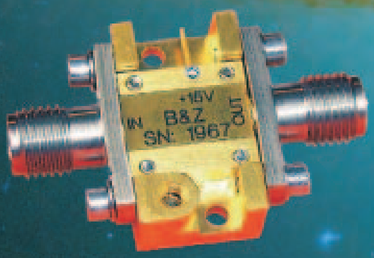

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BZP160UD1	0.1 - 60	7.5	15	2.8	8	2.5:1 / 2.5:1	BZP118UC1	0.1 - 18	2.1	29	1.0	5	2.0:1 / 2.0:1
BZP150UD1	0.1 - 50	5.0	18	2.5	8	2.5:1 / 2.5:1	BZP114UB1	0.1 - 14	1.9	23	1.2	8	2.0:1 / 2.3:1
BZP140UD3	0.1 - 40	3.8	25	1.5	8	2.5:1 / 2.5:1	BZP112UB1	0.1 - 12	1.7	24	1.2	8	2.0:1 / 2.0:1
BZP126UD1	0.1 - 26	3.3	27	1.5	10	2.0:1 / 2.0:1	BZP110UB1	0.1 - 10	1.5	25	1.0	8	2.0:1 / 2.0:1
BZP120UD1	0.1 - 20	2.2	34	1.7	8	2.3:1 / 2.3:1	BZP108UB1	0.1 - 8	1.4	25	1.0	8	2.0:1 / 2.0:1
BZP120UC1	0.1 - 20	2.3	28	1.5	5	2.3:1 / 2.3:1	BZP106UB1	0.1 - 6	1.0	27	1.0	10	2.0:1 / 2.0:1
BZP0118UC2	.01 - 18	2.5	28	2	13	2.5:1 / 2.5:1	BZP104UB1	0.1 - 4	0.9	28	1.0	10	2.0:1 / 2.0:1
BZP118UD1	0.1 - 18	2.0	37	1.3	8	2.0:1 / 2.0:1	BZP102UB1	0.1 - 2	0.7	28	1.0	10	2.0:1 / 2.0:1
							BZP102UB2	0.1 - 2	1.0	26	1.0	10	2.0:1 / 2.0:1

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Model	Freq. (Ghz)	Noise Fig. (dB Max.)	Gain (dB Min.)	Gain Flat (±dB Max.)	Pout 1dB (dBm Min.)	VSWR (In / Out)	Model	Freq. (Ghz)	Noise Fig. (dB Max.)	Gain (dB Min.)	Gain Flat (±dB Max.)	Pout 1dB (dBm Min.)	VSWR (In / Out)
BZ4060LD1	40 - 60	6.0	18	2.5	8	2.7:1 / 2.7:1	BZ1822LC1	17.7 - 21.5	1.3	28	1.0	7	2.0:1 / 2.0:1
BZ1230LD1	12 - 30	3.0	27	1.5	8	2.0:1 / 2.0:1	BZ0618LC1	6 - 18	1.3	28	1.5	5	2.0:1 / 2.0:1
BZ1840LD1	18 - 40	2.7	25	2.0	8	2.3:1 / 2.3:1	BZ0818LC1	8 - 18	1.2	28	1.2	8	2.0:1 / 2.0:1
BZ2640LD1	26 - 40	2.5	25	1.8	8	2.0:1 / 2.0:1	BZ1218LC1	12 - 18	1.2	28	1.0	8	1.5:1 / 1.5:1
BZ1428LD1	14 - 28	2.5	28	1.5	8	2.0:1 / 2.0:1	BZ0612LC1	6 - 12	0.9	30	1.3	5	2.0:1 / 2.0:1
BZ1226LD1	12 - 26	2.3	30	1.6	8	2.0:1 / 2.0:1	BZ0208LB1	2 - 8	1.0	22	1.5	5	2.0:1 / 2.0:1

Wideband Medium Power Amplifiers

Model	Freq. (Ghz)	Noise Fig. (dB Max.)	Gain (dB Min.)	Gain Flat (±dB Max.)	Pout 1dB (dBm Min.)	VSWR (In / Out)	Model	Freq. (Ghz)	Noise Fig. (dB Max.)	Gain (dB Min.)	Gain Flat (±dB Max.)	Pout 1dB (dBm Min.)	VSWR (In / Out)
BZ1840MC1	18 - 40	5.0	28	2.5	17	2.5:1 / 2.7:1	BZP118MB1	0.1 - 18	3.5	17	1.5	17	2.3:1 / 2.3:1
BZ2535MC1	25 - 35	4.5	30	1.8	20	2.0:1 / 2.3:0	BZ0218MD1	2 - 18	4.5	30	2.5	23	2.3:1 / 2.3:1
BZ2030MC1	20 - 30	4.5	30	2.0	20	2.0:1 / 2.0:0	BZ0218MD2	2 - 18	6.0	20	2.0	25	2.0:1 / 2.0:1
BZP126MD1	0.1 - 26	5.0	26	2.0	13	2.5:1 / 2.5:1	BZ0618MD1	6 - 18	3.7	30	1.8	23	2.0:1 / 2.3:1
BZ0226MD1	2 - 26	5.0	28	2.0	17	2.5:1 / 2.5:1	BZ1218MD1	12 - 18	3.5	30	1.0	23	2.0:1 / 2.3:1
BZ0226MC1	2 - 26	7.0	15	2.5	20	2.5:1 / 2.5:1	BZP112MC1	0.1 - 12	2.0	32	1.5	15	2.1:1 / 2.3:1
BZ1826MC1	18 - 26	3.0	28	1.8	20	2.0:1 / 2.0:1	BZ0212MD1	2 - 12	3.3	30	1.5	23	2.0:1 / 2.3:1
BZP120MD1	0.1 - 20	4.8	28	2.5	20	2.5:1 / 2.5:1	BZ0212MC1	2 - 12	2.0	32	1.3	17	2.0:1 / 2.0:1
BZ0222MD1	2 - 22	6.5	20	2.0	23	2.3:1 / 2.3:1	BZ0412MD1	4 - 12	3.8	30	1.8	24	2.0:1 / 2.0:1
BZP118MC1	0.1 - 18	3.5	28	1.7	17	2.0:1 / 2.0:1	BZ0510MD1	5 - 10	3.6	32	1.5	25	2.0:1 / 2.0:1
BZP118MD1	0.1 - 18	4.5	30	2.5	20	2.3:1 / 2.3:1	BZ0408MD1	4 - 8	3.5	33	1.5	25	2.0:1 / 2.0:1

Wideband High Dynamic Range Amplifiers

Model	Freq. (Ghz)	Noise Fig. (dB Max.)	Gain (dB Min.)	Gain Flat (±dB Max.)	Pout 1dB (dBm Min.)	VSWR (In / Out)	Model	Freq. (Ghz)	Noise Fig. (dB Max.)	Gain (dB Min.)	Gain Flat (±dB Max.)	Pout 1dB (dBm Min.)	VSWR (In / Out)
BZP526HA1	0.5 - 26	4.5	10	1.2	10	2.3:1 / 2.3:1	BZ0618HA1	6 - 18	2.3	10	1.0	12	2.0:1 / 2.0:1
BZP626HB1	0.5 - 26	4.5	15	1.5	15	2.3:1 / 2.3:1	BZ0618HB1	6 - 18	3.5	17	1.0	20	2.0:1 / 2.0:1
BZP518HA1	0.5 - 18	2.3	10	1.0	10	2.3:1 / 2.3:1	BZP506HB1	0.5 - 6	2.0	20	1.2	20	2.2:1 / 2.2:1
BZP518HB1	0.5 - 18	3.2	17	1.3	17	2.0:1 / 2.0:1	BZ0510HB1	5 - 10	2.3	20	0.5	20	2.0:1 / 2.0:1

Waveguide Low Noise Amplifiers

Model Number	Frequency (GHz)	Noise Figure (dB, Max.)	Gain (dB, Min.)	Gain Variation (±dB, Max.)	Pout 1dB (dBm, Min.)	V.S.W.R Input / Output	Waveguide Flange	Outline Drawing
BZW-07250775-070830	7.25 - 7.75	0.7	30	1.0	8	1.5:1 / 1.5:1	WR-112	100132
BZW-07700850-070830	7.7 - 8.5	0.8	30	1.0	8	1.5:1 / 1.5:1	WR-112	100132
BZW-10751275-090830	10.75 - 12.75	0.9	30	1.0	8	1.5:1 / 1.5:1	WR-75	100133
BZW-1218-140830	12 - 18	1.4	30	1.5	8	1.5:1 / 1.5:1	WR-62	100134
BZW-17702120-140830	17.7 - 21.2	1.4	30	1.0	8	1.5:1 / 1.5:1	WR-42	100129
BZW-1826-160830	18 - 26	1.6	30	1.5	8	2.0:1 / 2.0:1	WR-42	100129
BZW-2640-280830	26 - 40	2.8	30	1.5	8	2.0:1 / 2.0:1	WR-28	100135

Note: Performance may degrade below 500 MHz for Wideband models

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Industry

The GEC Research Laboratories founded in 1924, later known as Hirst Research Centre (HRC), ceased operation in the early 2000s. Based on the development of the silicon point-contact receiver mixer diode during the 1940s, the R&D widened to a broad range of two and three terminal Si-, Ge- and GaAs-based devices, for many low and high power applications. The Centre was recognised as a principal contributor to microwave receiver technology via point-contact diodes, planar devices, MICs and MMICs, over the frequency range of 1 to 100 GHz. An MIC superheterodyne receiver integrated unit was demonstrated in a short range, operational, X-band link in 1968, believed to be a world first.

HRC was also a leader in its ability to integrate planar ferrite non-reciprocal devices in MICs. Following the merger of GEC and Plessey, the GaAs HRC and Caswell activities were consolidated at the Caswell site in 1990. Plessey Research (Caswell) Ltd., established in 1940, became GEC-Marconi Materials Technology Ltd. (merger of GEC and Plessey) in 1990, and is currently part of Bookham Technology plc.

Work on GaAs led to the world's first demonstrated GaAs FET in 1966, the announcement of the world's first commercial GaAs FET for microwave applications in 1970, and the publication of the world's first FET-based GaAs MMIC in 1976. In the 1980s it established a GaAs MMIC technology capability up to 100 GHz, and a MMIC foundry. The facility was later upgraded to handle 150 mm wafers for microwave and optical applications. Currently, the facility only processes InP for optical communication devices.

Standard Telecommunication Laboratories (STL), now Nortel Networks, commenced GaAs technology R&D in the 1960s and made important contributions to GaAs Transferred Electron Devices (TED). In 1971, the company demonstrated GaAs diode-based monolithic integrated circuits applied to millimetre-wavelengths. Involved in pioneering work on optical fibre transmission it moved its semiconductor interests to opto-electronics in the 1980s.

Mullard Research Laboratories (MRL), in association with Philips Semiconductors, later Philips Research Laboratories, is now known as Philips Research Redhill. During 2006, Philips sold 80 percent of its semiconductors business to a consortium of private equity partners, laying the foundation for an independent semiconductors company, Next eXperience (NXP). MRL developed the first European liquid helium MASER used to receive TV satellite signals across the Atlantic. The Department of Electronics at MRL now mainly focuses on wireless communication projects.

Marconi Research Centre Great Baddow, established in 1939, later BAE Systems Advanced Technology Centre, can trace its origins as a Marconi Research Department created in 1913. The Centre traditionally involved in state-of-the-art communications and radar studies embraces wider ranging

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	Description	Device	Frequency (GHz)	Gain (dB)	Gain Flatness (dB)	Noise Figure (dB)	Output P1dB (dBm)	OIP3 (dBm)	Bias (mA @V)	Package (mm)
5-10 GHz Mimix SmartSet	Buffer Amplifier	XB1007-QT	4.0-11.0	23.0	+/-1.5	4.5	+20.0	+30.0	100 @ 4.0	3x3
	Power Amplifier	XP1035-QH	5.9-9.5	26.0	+/-1.0	-	+29.0	+39.0	500 @ 6.0	4x4
	Power Amplifier	XP1039-QJ	5.9-8.5	15.0	+/-1.0	-	+34.5	+49.0	1150 @ 8.0	6x6
	Receiver	XR1011-QH	4.5-10.5	13.0	+/-1.0	1.8	+6.0	+16.0	130 @ 4.0	4x4
	Doubler	XX1002-QH	5.0-12.0 fout	16.0	+/-1.5	-	+16.0 Psat	-	125 @ 5.0	4x4
	Transmitter	XU1012-QH	5.0-10.0	-8.0	+/-1.0	-	+7.0	+17.0	120 @ 4.0	4x4
10-16 GHz Mimix SmartSet	Buffer Amplifier	XB1008-QT	10.0-21.0	17.0	+/-2.0	4.5	+19.0	+32.0	100 @ 4.0	3x3
	Power Amplifier	XP1042-QT	12.0-16.0	21.0	+/-1.0	-	+25.0	+38.0	500 @ 5.0	3x3
	Power Amplifier	XP1043-QH	12.0-16.0	20.0	+/-1.0	-	+30.0	+41.0	700 @ 7.0	4x4
	Receiver	XR1007-QD	10.0-18.0	13.5	+/-1.0	2.7	+5.0	+15.0	150 @ 5.0	7x7
	Doubler	XX1000-QT	15.0-45.0 fout	10.0	+/-2.0	-	+18.0 Psat	-	200 @ 5.0	3x3
	Doubler	XX1002-QH	5.0-12.0 fout	16.0	+/-1.5	-	+16.0 Psat	-	125 @ 5.0	4x4
	Transmitter	XU1014-QH	8.0-18.0	-10.0	+/-1.0	-	+2.0	+12.0	80 @ 4.0	4x4

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activities in the microwave/mm-wave/optical fields, with extensive on-site support resources. Currently the Centre delivers the frontline in technology innovation, acquisition, development and insertion for BAE Systems and its joint venture organisations.

ERA Technology Ltd., a UK Research and Technology organisation, provides the leading edge of advanced technology consultancy and design. The business was founded in the 1920s and during the 1970s it was involved in research of image line waveguiding systems for MICs. Today it provides specialist, high value-added, technology-based services including design and development, testing, assessment and expert advice, e.g. antennas for automotive and satellite communications.

Filtronics Ltd., established in 1977, went public in 1994, and is a spin-off from the University of Leeds. Originally recognised for producing filters for telecommunications, it has become a leading supplier of wireless infrastructure subsystem products, and is now involved in III-V compound semiconductors with related product R&D and manufacture; representing in the 2000s the only GaAs foundry within the UK (in March 2008 the compound semiconductor part of the business was acquired by RFMD).

English Electric Valves (EEV) Lincoln became Marconi Applied Technologies in 1999, and then in 2002 became part of e2v Technologies (UK) Ltd. The site under EEV was originally known for its glass-based receiving and transmitting valves and transmit/receive cell technology; in later years this incorporated solid-state power limiter/switch techniques. Now as e2v, it is possibly the only UK&RI centre for R&D and manufacture of GaAs two terminal devices, particularly the TED; the technology base being transferred from Marconi Electronic Devices (MEDL) and HRC.

Finally, M/A-COM, formerly Microwave Associates Ltd., has had an independent operation in the UK since the early 1960s, with early involvement in producing silicon point contact diodes. It has made many contributions in the R&D fields of microwave solid-state device, components and sub-systems. It is now located in a new facility at Milton Keynes, M/A-COM (Tyco Electronics Ltd.), where it supports three business units with continuing microwave interests (currently under agreement to be acquired by Cobham).

The MoD

The Ministry of Defence (MoD) support in R&D, both technical and funding, has been important. A very significant MoD establishment is the one at Malvern, originally Telecommunications Research Establishment (TRE), then Royal Signals Radar Establishment (RSRE), then the Defence Evaluation and Research Agency (DERA) Malvern, and now part of the QinetiQ organization [in 2001 DERA separated into two organizations; QinetiQ (independent science and technology company) and Defence Science & Technology Lab-

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oratory (DSTL), an agency of the UK Ministry of Defence]. The Malvern site has been involved in wide ranging microwave activities: Pioneering work on GaAs and InP transferred electron effects, development of key radars including solid-state, and more recently R&D of opto-microwave integrated circuits.

Universities

University College London (UCL) was possibly the founder, in 1945, of microwave engineering as a recognised UK&RI academic discipline; it played a leading role in the study of millimetric waveguide as a long distance communication medium. Since then, many universities established microwave activities including: University of Manchester Institute of Science and Technology (UMIST) merged with the Victoria University of Manchester to form the University of Manchester in 2004. From the 1970s it has provided support and now has become internationally recognised for its work on ferrite non-reciprocal devices. University of Leeds initiated work on microwaves in 1963, formed the Microwave Solid State Group in the mid-1970s and the current Institute of Microwaves and Photonics in 1997.

Other Universities include: Queen Mary & Westfield College (QMW) - antennas; University College Dublin (UCD) - nonlinear device modelling; University of Cork - millimetre-wave devices with spin off by Farran Technologies; Queen's University Belfast (QUB) - silicon technology for microwave and millimetre-wave devices; King's College London - heterojunction microwave and opto-electronic devices; University of York - low noise solid-state oscillators; University of Sheffield - early microwave semiconductor interests, e.g. TEDs.

Italy/*Roberto Sorrentino*

Marconi carried out his investigations into microwave frequencies from 1919 to 1931 with his first radio transmission experiments at microwave frequencies over the Tigullio Gulf on the Riviera Ligure taking place in 1931. The following year he realized the first ground link between Villa Mondragone (near Rome) and the Vatican.

Also at this time, the first theoretical studies on microwave propagation and the first experiments on the devices for microwave generation and detection took place. The term 'microwaves' was introduced by Nello Carrara while he was working at the Royal Electronic and Communication Institute (RIEC) of the Italian Navy at Livorno. The Institute, which was founded in 1916, hosted the first Italian research group in electronics and is where Italian microwave and radar techniques originated. An important role was played by U. Tiberio, who has been credited as one of the inventors of radar.

GaAs microwave technology in Italy started at CISE, Milan, in the late 1970s, where a MESFET process was first established. In 1980, the same group manufactured the first X-band coplanar monolithic GaAs balanced amplifier. The activity on GaAs continued at TELETTRA, where the

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first air-bridge gate FET technology for GaAs MMICs was developed in 1985. In 1990 the company, owned by FIAT, was acquired by Alcatel, now Alcatel-Lucent (2006).

Industry

Initially, microwave industrial activities in Italy were driven mainly by military needs, related to radar and electronic warfare applications with Selenia and Elettronica in Rome being leading players in this field. However, with the relative decline of the military market, microwave industrial activity was redirected toward civil applications, particularly communication services and space.

The largest Italian industries in the RF and microwave area are owned totally or partially by the Finmeccanica Group, a state-owned holding working in the field of aeronautics, space, energy and defence electronics, the last being developed within the SELEX family.

SELEX-Sistemi Integrati (founded in the early 1950s as Microlambda, later evolved into Selenia, then Alenia, later Alenia Marconi Systems) is mainly focused on the production of radars for both military and civil systems. Products range from microwave antennas to solid-state devices, tube transmitters, microwave components, and packaging from 1 to 100 GHz.

SELEX Communications is a supplier of advanced communication, navigation and identification systems operating in the areas of professional communications, avionics, military and space.

Thales Alenia Space-Italy, originally born out of Selenia, then an independent company with the name of Alenia Spazio, merged with Alcatel under the name of Alcatel Alenia Space. It is one of the leading space communication companies, with RF and microwave technologies as one of its major assets. Specializing in telecommunications, remote sensing, scientific satellites, and space infrastructures, the company pioneered Ka-band communication with on-board processing, and from the early 1970s became a leader in microwave technologies for space applications.

STMicroelectronics is one of the world's largest semiconductor companies. It was created in 1987 by the merger of SGS Microelettronica of Italy and Thomson Semiconducteurs of France. Currently, ST has a worldwide network of front-end (wafer fabrication) and back-end (assembly, packaging and test) plants. The company's principal wafer fabs are located in Italy in Agrate Brianza and Catania. Other main plants are located in Crolles, Rousset and Tours (France), Phoenix and Carrollton (US) and Singapore.

The explosion of the wireless market is also reflected in the activities of some industries owned by foreign companies, such as Ericsson. Ericsson Laboratory Italy develops equipment and systems for fixed and mobile networks.

Research

Until the early 1970s, four major research centres operated in Italy—at the University of Rome 'La Sapienza', at the University of Naples, at the Polytechnic Institute of Turin, and at

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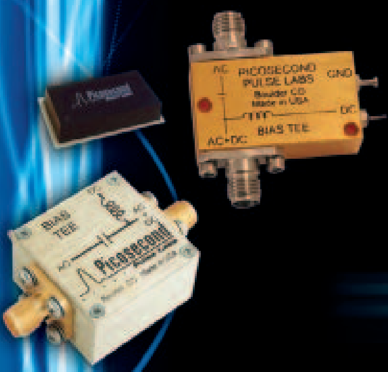

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5542	50 GHz	10 kHz	16 V	100 mA
5542K	40 GHz	12 KHz	16 V	100 mA
5542LL	>40 GHz	12 kHz	16 V	100 mA
5545	20 GHz	65 kHz	50 V	500 mA
5546	7 GHz	3.5 KHz	50 V	500 mA
5547	15 GHz	5 kHz	50 V	500 mA
5550B	18 GHz	100 kHz*	50 V	500 mA*
5575A	12 GHz	10 kHz*	50 V	500 mA*
5580	15 GHz	10 kHz	50 V	2 Amp
5585	18 GHz	2 GHz	100 V	6 Amps
5586	5 GHz	1 GHz	100 V	8 Amps
5587	2 GHz	200 MHz	100 V	6 Amps
5589	2.8 GHz	300 MHz	100 V	7 Amps
SM100	13 GHz	14 kHz	16 V	500 mA
SM101	15 GHz	7 kHz*	16 V	500 mA

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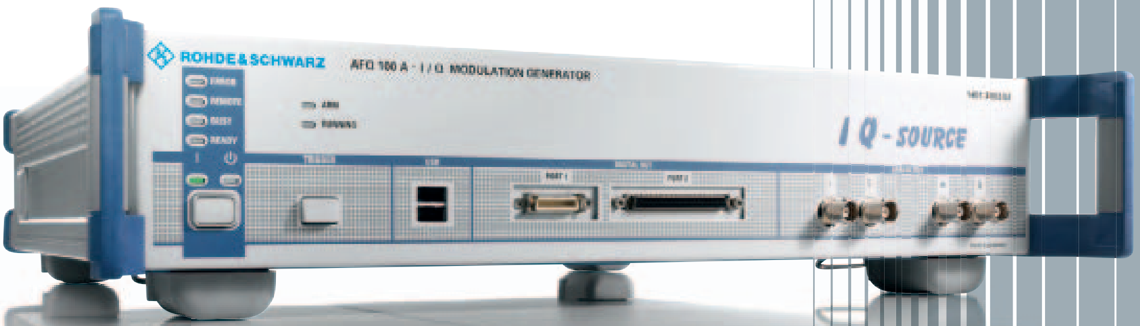

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the Research Institute of Electromagnetic Waves (IROE), formerly Centro Microonde, in Florence. Since then, the number of university laboratories involved in microwave research activities has increased significantly, now being about 40.

Italian researchers in the field of electromagnetics, mostly from academia, but also from industry and public research centres, formed the National Group on Electromagnetics (GEm) with the scope of co-ordinating their activities at a national level. Originally created in the framework of the National Research Council, the group formed SIEm, the Italian Electromagnetic Society, in 2002, grouping all university centres active in this area and containing about 200 members.

Inter-university research consortia have also been formed to coordinate research activities in specific domains, such as: MECSA (microwave space activities) and ICEMB (electromagnetic-biological interactions). Many microwave activities have been sponsored by the Italian Space Agency (ASI), in the framework of national, European and international programmes.

France/*R. Quéré and G. Salmer*

The dramatic growth of RF and microwave applications in the telecommunications and radar domain has pushed continuous advances in research, development and education during the last 50 years in France. Similarly, research fields have evolved considerably due to the evolution of relevant technologies, starting from solutions of Maxwell equations in waveguides to the 3D electromagnetic analysis of passive and active circuits and antennas. In the active circuit domain, the transition from microwave tubes to solid state devices has driven important research efforts on new transistor technologies (FET and HBT) and on GaAs and InP for low noise, power generation and high bit rate communications.

Recently efforts have been focussed on the development of GaN technology through several national and European collaborative programmes such as KORRIGAN funded by seven European MoDs. European and National Space Agencies are also pursuing extensive programmes with wide band gap technologies. The growth of Silicon-based microwave and RF technologies (SiGe and CMOS) with two major players in France—STMicroelectronics and NXP— is also worth mentioning.

In the '70s, the French microwave community became structured under the auspices of various national research organizations like the Centre National de la Recherche Scientifique (CNRS) and the Centre National d'Etudes des Télécommunications (CNET), with the support from several ministries and national organizations in a national network of microwave research centres.

In terms of research, all areas of microwave technology are presently covered. In order to reach critical mass, the creation of large laboratories grouping more than 100 permanent researchers has been encouraged; Alcatel-Thales 3-5 Labs, Thales

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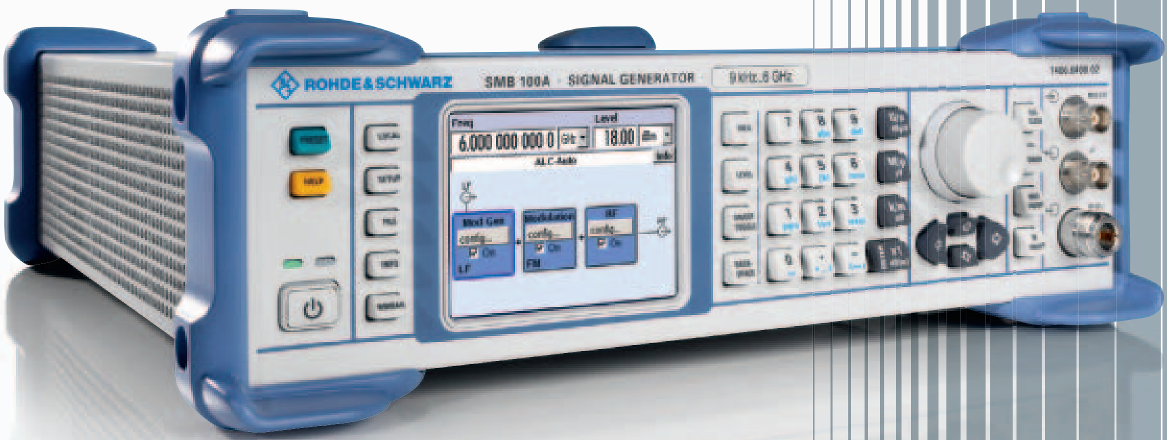

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Research and Technology (TRT), NXP, STMicro, Thales Alenia Space for industry, and IEMN (Lille), XLIM (Limoges), LAAS (Toulouse), IMEP (Grenoble), IMS (Bordeaux), Lab-STICC (Brest), IETR (Rennes) and FEMTO (Besançon) for academia.

Specific facilities for microwave measurements are available in all these laboratories, while TRT/3-5 Labs, NXP, IEMN and LAAS also possess device-processing facilities. Several cooperative research initiatives on microwave telecommunication systems were developed within the framework of the National Research Network on Telecommunications in the period from 1996 to 2006.

Nowadays cooperation between academic and industrial laboratories is being encouraged in French National Research Agency (ANR) programmes, which began its activities in 2007. Moreover the recently created competitive clusters facilitate academic and industrial research and development with strong involvement from SMEs. Although microwave activities are involved in a number of these clusters, only SYSTEM@TIC in Ile de France and ELOPSYS in Limousin have a specific microwave activity.

Industrial research centres (TRT, 3-5 Labs, UMS, NXP, Thales Alenia Space, Thales Aerospace-Air Systems-Land and Joint Systems) have mainly focused their activities on microwave devices, antennas, MMICs, millimetre-wave components and microwave subsystems. Cooperation with academic laboratories has often specialized in specific topics (for instance, IEMN on devices processing, simulation, and characterization; XLIM on microwave components and systems modelling and simulation; LAAS on noise; IMS on Silicon devices and reliability, Lab-STICC on filtering, etc.), enabling the French research community to achieve state-of-the-art results.

For example: LEP on high-efficiency IMPATT diodes in the 1970s; LEP and Thomson LCR on GaAs monolithic digital circuits in the 1980s; and, then, Alcatel Space in the field of 3-D MCM. More recently significant advances have been made in GaN technology at 3-5 Labs with the realization of power MMICs delivering up to 58 W with up to 36 percent power added efficiency in X-band.

Research covering a large range of microwave topics is advanced within the framework of national or European programmes, particularly the European Networks of Excellence. Three main NoEs have been dedicated to microwaves and RF: AMICOM (Lille, Toulouse, Limoges), which considered RF MEMS, ACE (Rennes, Marne La Vallée, Nice, Brest) dedicated to new antenna technologies and TARGET (Limoges, Toulouse, Lille) related to power amplifiers. Si RF activities are structured within the micro and nano technologies pole MINATEC in Grenoble in cooperation with CEA-Leti Labs and STMicro and in the IMS lab in Bordeaux.

Successful studies have also been performed by academic research groups on microwave radiometry and imagery in Orsay (LSS) and Lille (IEMN), in support of industrial and biomedical applications; and on radar

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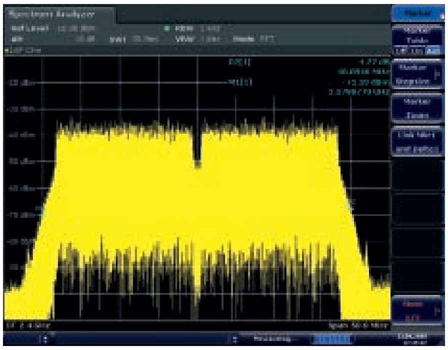

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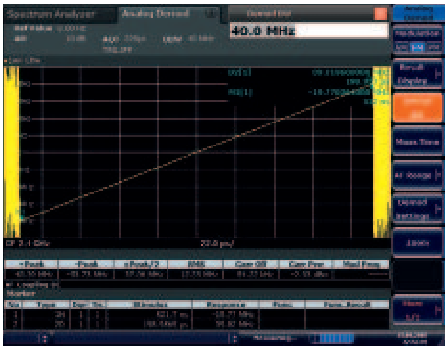

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polarimetry and telecommunications systems (Nantes). The French microwave community has played a very significant role in the field of submillimetre-wave devices and components for application to space-borne radiometers (for instance, EADS-ASTRIUM in Toulouse), and to radio astronomy research (DEMIRN, Observatoire de Paris).

In the past, the main microwave telecommunication systems research was undertaken by CNET (in Lannion and Paris); since 1996, CNET first became France Telecom R&D and is now Orange Labs. In the 1980s, they proposed and studied a number of very promising millimetre-wave systems. More recently, the network of telecommunication engineering schools (ENST) has contributed greatly to this sector.

Finally, over more than 15 years, a great deal of research has been undertaken in the field of microwave/optical devices, for applications such as local loops in telecommunication systems and phased-array antennas for radars. Such studies have been performed in cooperation between academic (Lille, Grenoble, etc.) and industrial groups (Alcatel, Thales). Very innovative solutions have been proposed both in terms of specific devices for detection (HBT) and in terms of millimetre-wave systems at 38 and 60 GHz. While the production of base stations for GSM and UMTS constitutes a very important market in the field of microwave telecommunication systems, the most advanced development activities concerns the millimetre-wave range (for instance, at Thales Land and Joint Systems).

In the space domain, Thales Alenia Space and Astrium working in cooperation with ESA and CNES have achieved international recognition, both in CAD and in the technology for space components, specific packages and 3-D assemblies. The emergence of the European Navigation System Galileo, military programmes like SYRACUSE III and long-term research into flexible payload satellites drive the French space microwave industry to a very high technical level. Thales plays a prominent role in microwave research and development and units such as Aerospace, Air Systems, Land and Joint Systems have developed large systems for civil and military applications: Radar, airborne, countermeasure systems, and telecommunications. They have reached a high international level, in terms of technology for passive and active circuits.

Civil applications have also been addressed with the development of front-end modules at 77 GHz for long range cruise control radars and at 24/79 GHz for short-range radars. United Monolithics Semiconductors (UMS)—a joint venture of Thales and EADS—has developed chipsets for such applications. At this stage it should be noted UMS (based in Orsay in France and Ulm in Germany) and OMMIC (based in Limeil-Brevannes, France), independent from the Philips group since 2007, are the only two commercial foundries for III-V MMICs in Europe, offering a wide range of different processes from low noise (0.1 μm PHEMT,

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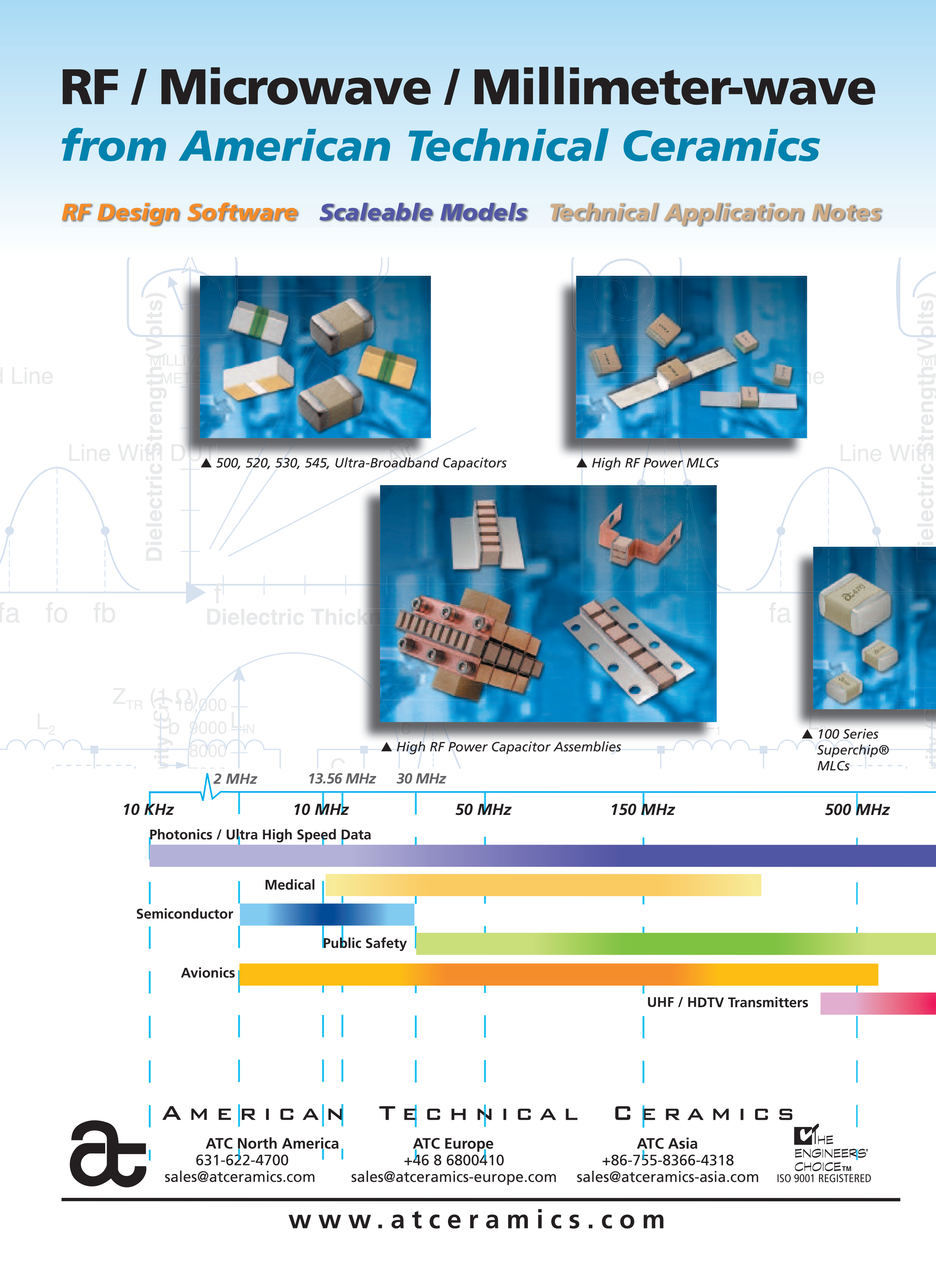
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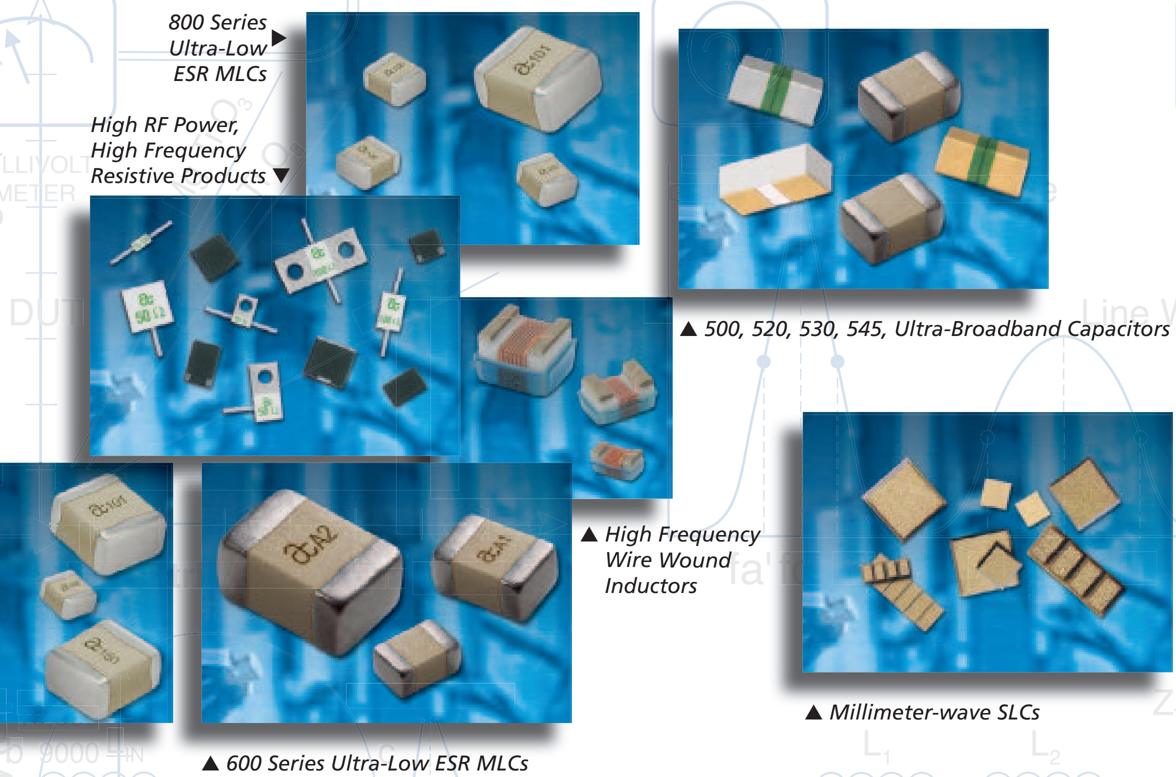

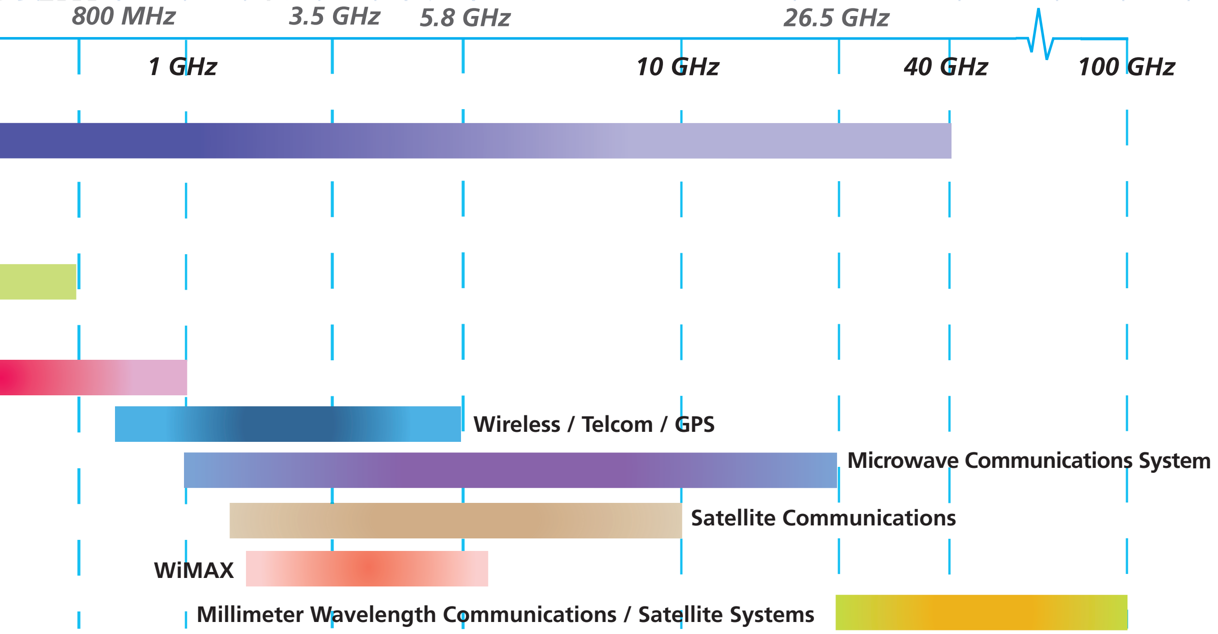

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Germany, Austria and Switzerland/*P. Russer*

Industry

The main microwave activity in Germany relates to public communication, broadcasting, sensing, traffic control and medical treatment, with applications in the commercial, consumer and military sectors. Microwave components, antennas and a variety of microwave systems and measurement equipment are manufactured. Leading players are Bosch, Continental-TEMIC, Daimler, EADS, EPCOS, Infineon, Rohde & Schwarz, Siemens and Spinner. In the 1990s, while the military sector decreased there was increased activity in the mobile communications and broadband optical communications sectors.

However, the last decade saw a decline in many RF and microwave oriented business segments with the communications segment of Siemens disappearing completely and the mobile communications production lines of some companies relocating to countries with low employment costs.

The wireless products business unit of Infineon Technologies is successful, producing semiconductor devices and complete system solutions for a range of wireless applications, including cellular and cordless telephone systems and devices used in connection with GPS. Products include standardized baseband ICs (logic and analogue), power RF and microwave transistors, and standardized and customized radio frequency ICs, including transceiver chip sets for mobile communications applications.

EPCOS emerged from the Siemens Matsushita Components joint venture and ranks as one of the world's largest manufacturers of passive electronic components. The company pioneered the field of miniaturized and innovative passive components and is playing a key role as a manufacturer of surface and bulk acoustic wave devices.

Daimler is a leading car manufacturer and supplier of electronic systems for safety and driving comfort. Micro and millimetre-wave techniques are the prerequisites for their security and safety systems, driver assist systems, and communication and entertainment systems.

The European Aeronautic Defence and Space Company (EADS) is a global company. The EADS Defence & Security Systems Division (comprises the former companies Telefunken, Dornier and MBB) is responsible for the majority of the company's microwave activities in the fields of radar, electronic warfare, navigation and communications for military and civil applications. These systems and related equipment are supported by UMS, a global semiconductor supplier and foundry.

Robert Bosch is a global supplier of technologies and services in the areas of automotive and industrial technology. Microwave technology is a key for their automotive electronics,

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driver assist systems, traffic monitoring and control systems, and car multimedia.

Rohde & Schwarz is a major supplier of radio communications, radio location, and broadcast equipment, and a manufacturer of test and measurement equipment.

Spinner is a manufacturer of passive microwave components, including waveguide components, coaxial connectors, cable assemblies, coaxial waveguide switches and optical waveguide components. The company also manufactures broadband optical transmission systems.

Universities

At German universities microwaves are mainly covered under High Frequency Engineering (Hochfrequenztechnik) within electrical engineering departments. The Fakultätentag für Elektrotechnik und Informationstechnik (FTEI), the Electrical Engineering and Information Technology Faculties assembly is a confederation of electrical engineering departments of German universities. The FTEI has the objective to achieve and maintain fundamental topics of education, research and academic self-administration.

There are 29 universities with electrical engineering departments with high frequency engineering or microwave engineering departments represented in the FTEI. Representatives of the electrical engineering departments of the Austrian universities Graz, Leoben, Linz, Vienna (Technische Universität Wien), and the Swiss Federal Institute of Technology Zürich are invited to the annual general meetings of the FTEI.

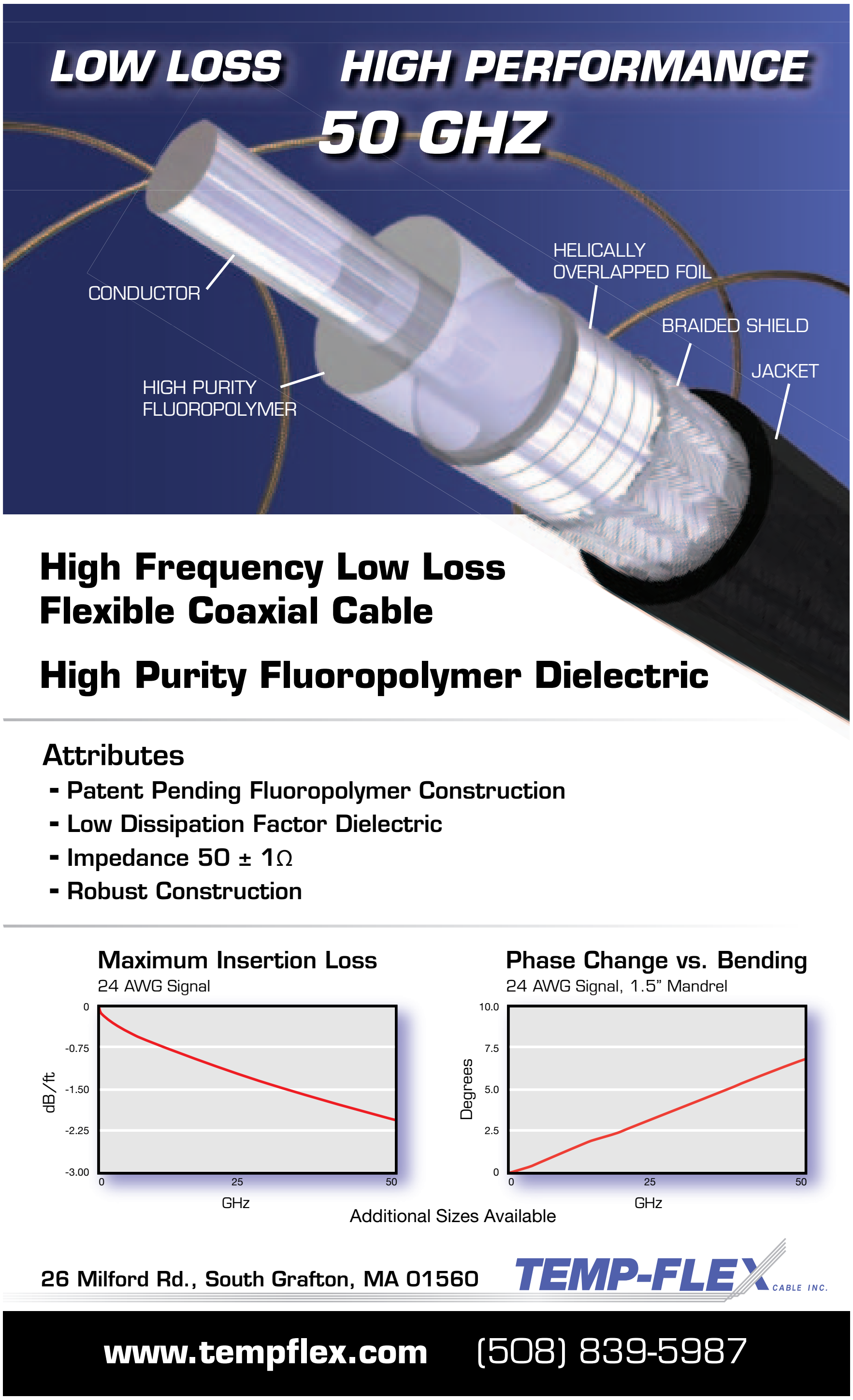
Government

In Germany the Bundesministerium für Bildung und Forschung (BMBF), the Federal Ministry for Education and Research, funds research projects at industry, research institutes and universities. The current priority programmes dealing with microwave topics are Mobile Communication Systems, Innovative Optical Communication Networks and New Areas of Technology, with the DFG being the central organization for supporting such projects.

A number of research institutes carry out microwave research. Major contributors are the Fraunhofer Institute for Applied Solid-State Physics (IAF) in Freiburg, the Ferdinand Braun Institute (FBH) and the Heinrich Hertz Institute, both in Berlin, the Institute for Semiconductor Physics (IHP) in Frankfurt/Oder and the Institute for Mobile Communications and Satellite Technology (IMST) in Kamp-Lintfort.

The German Aerospace Centre (DLR) as the national space flight agency manages German space programmes. The DLR Institute of Communications and Navigation pursues satellite communications, aeronautic communications, terrestrial radio systems, satellite navigation and traffic guidance systems.

The FGAN Research Institute for High Frequency Physics and Radar Techniques (FHR) develops concepts, methods and systems for electromagnetic sensors, particularly in



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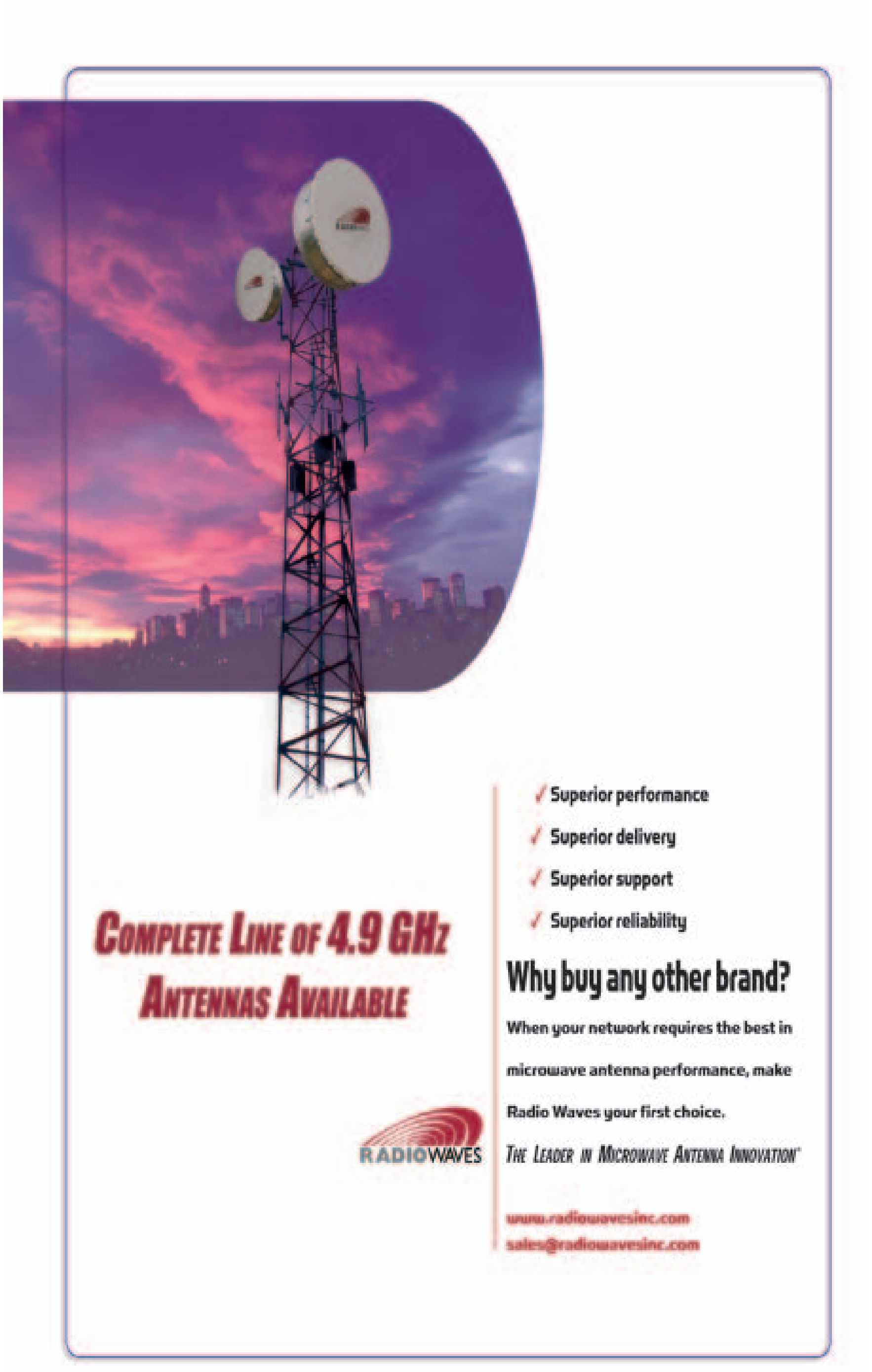
The Netherlands/*L.P. Ligthart*

Key players active in microwave theory and techniques are the Delft University of Technology (DUT), Eindhoven University of Technology (EUT), ESA-ESTEC, Applied Physics Research Organization TNO, NLR, Thales-Nederland, Dutch Space, CHL Netherlands, HITT, MESA at University Twente, WMC Institute, Philips, KPN and The Netherlands branches of large foreign telecom companies.

The International Research Centre for Telecommunications and Radar (IRCTR) of DUT focuses on the development of advanced RF front-ends (including antennas) for integration into novel microwave and millimetre-wave radar and radio systems and networks. Specific technologies and systems have been developed for ultra-wideband (UWB) array radar in various security related applications; breakthroughs are expected in Ground Penetrating Radar (GPR), Through-Wall Radar and Through-Dress Radar. Also, Doppler-polarimetric radar research has resulted in new developments in hybrid multi-beam antenna systems and new transmit/receive technologies allowing for simultaneous determination of all polarization characteristics of objects and media.



The Delft Institute of Micro-Electronics and Submicron Technologies (DIMES) has a specific microwave programme related to silicon-based UWB and cm/mm-wave radio system parts with realization of on-chip devices, and integration of MEMS circuitries using bipolar, CMOS, and BiCMOS technologies. EUT is involved in 60 GHz radio technologies for indoor communications and fibre to the home networks.

ESA-ESTEC is active in all areas of microwave circuits, devices and systems related to space applications, while NLR and Dutch Space are working in related areas. The Electro-Magnetic Division of ESA-ESTEC works closely in cooperation with IRCTR on antenna/front-end design and device diagnostics validated by UWB frequency and time-domain measurement techniques.

TNO has extensive programmes investigating MMIC design in various frequency bands for radar and telecommunications. Also noteworthy is that Thales-Nederland is developing highly integrated transmit/receive sub-systems in various radar bands as part of strategic modules in advanced phased-array radar.

Finland/*Antti Raisanen*

In 1924 the first professor of radio engineering was installed at the Helsinki University of Technology (TKK) and the Radio Laboratory established. Microwaves with regards to their applications to radar and radio links were first researched and taught in the 1940s; increasing in the 1950s, with the first thesis on a mobile radio appearing in 1949. In the 1960s, microwave techniques were often studied in connection with

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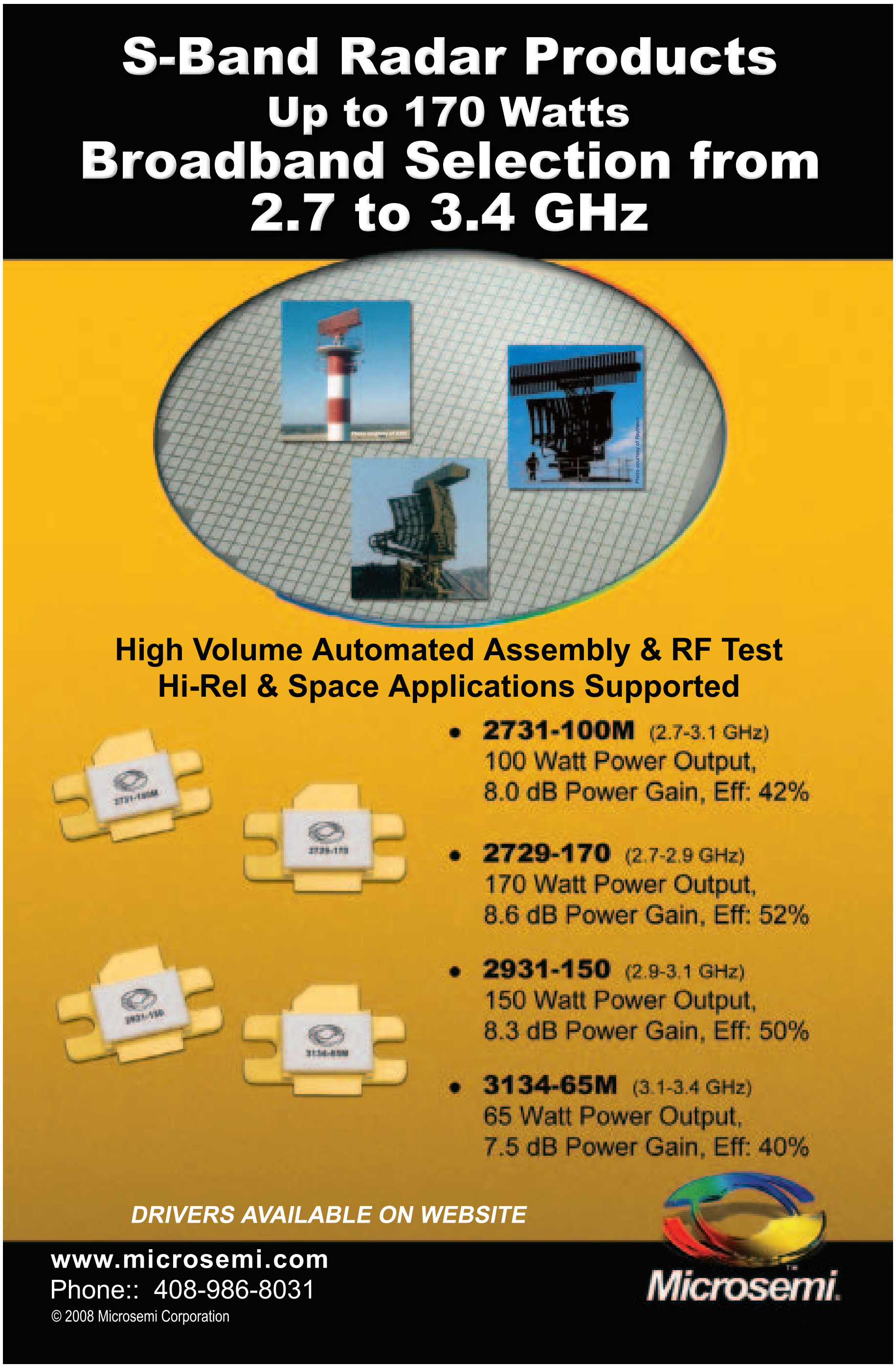
radio astronomy and, in the 1970s millimetre-waves were first applied. That decade also saw increased interest in the study of microwave sensors for industrial processes and microwave remote sensing.

The last 30 years have seen the evolution of radio communications. Today, a Finnish enterprise, Nokia, produces some 40 percent of mobile phones sold in global markets, which is a major contributor to the fact that currently the electronics and communications industry produces over 30 percent of Finnish exports.

Strong domestic industry has certainly been reflected in the education of microwave techniques, antennas and propagation. At TKK, microwave techniques and related topics such as electromagnetics, antennas and propagation, RF circuit design, circuit theory, microwave remote sensing, and radio communications are studied and taught, mainly at the Department of Radio Science and Engineering. The University of Oulu and the Tampere University of Technology also have research and teaching activities in these fields.



In 1995, TKK and VTT (the governmental research centre) established a joint research institute for millimetre-wave techniques, the Millimetre-Wave Laboratory of Finland—MilliLab, which has the status of a European Space Agency (ESA) External Laboratory.

Current microwave research activities are directed towards smart/adaptive radios and antennas, direct conversion receivers for WCDMA, improved models of RF components and circuits, radio channel modelling for future mobile radio systems, submillimetre-wave antenna measurements with holograms and synthetic aperture radiometry.

Poland, Czech Republic, Slovakia and Baltic Countries/*J. Modelski*

Poland

Polish microwave engineering activities date back to the late 1940s with the advent of the first Polish microwave tube; a pulse magnetron model M2 (600 MHz, 300 kW/imp), developed by the Telecommunications Research Institute (PIT) in collaboration with the Warsaw University of Technology (WUT). The manufacture of microwave tubes spread into the UNITRA establishments, OBREP and Lamina, from where new types of magnetrons, klystrons and TWTs emerged. At the same time, a radar technology unit was established at PIT, which developed its first NYSA radar.

The 1960s and 1970s were very productive. Several enterprises undertook microwave materials research and, subsequently, their production including the Institute of Electronic Materials (ITME), Polfer and the Institute of Electronic Technology (CEMI).

Microwave developments in Poland have been based on national research, with institutes supported by academia, mainly by the microwave departments within four universities: WUT, Technical University of Gdansk, Wroclaw University of Technology and Military University of Technology.

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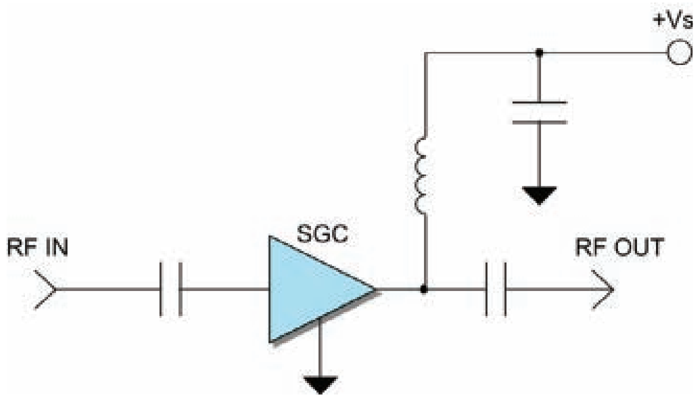

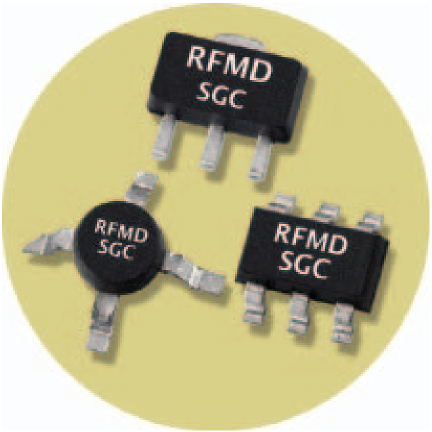

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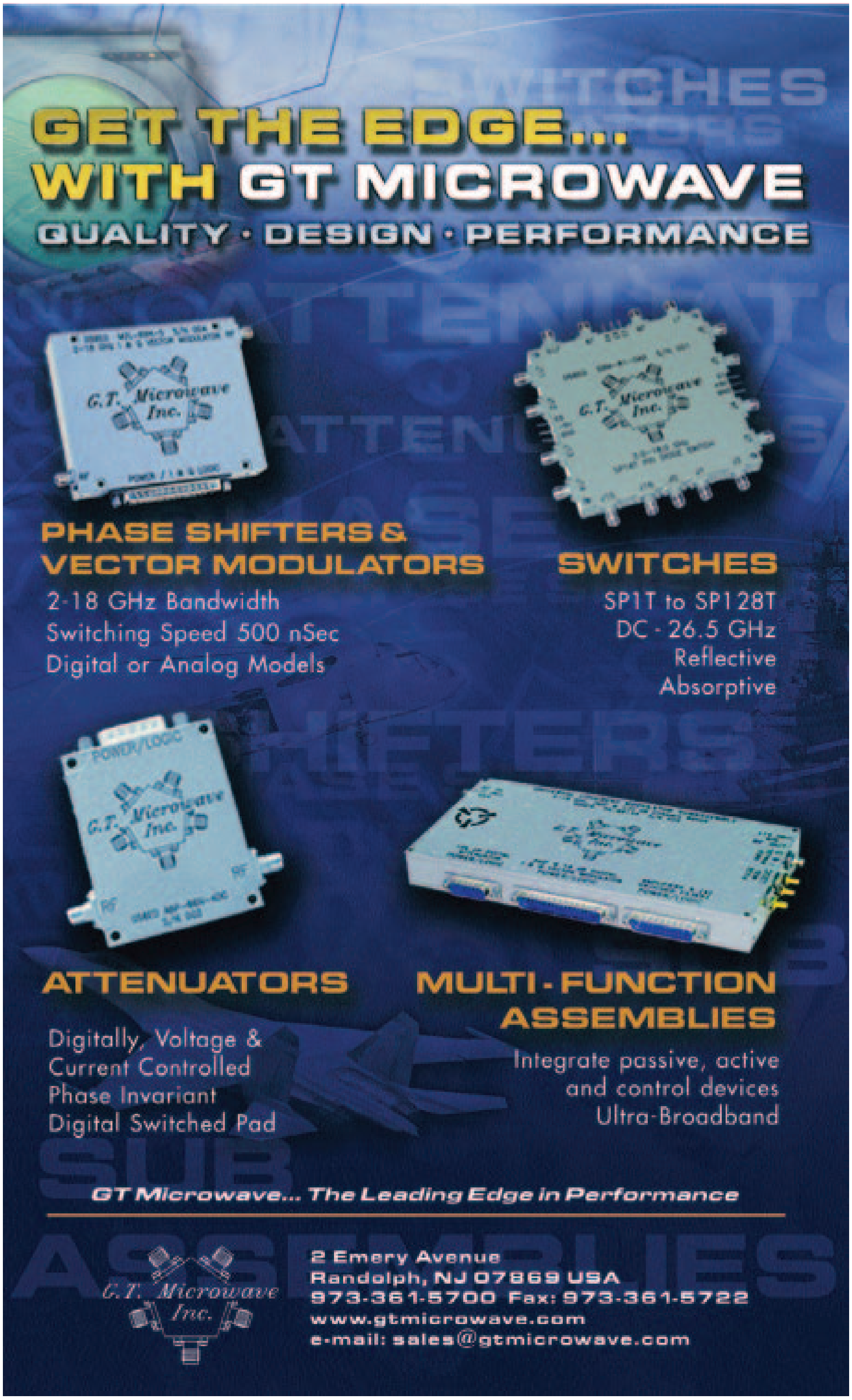
Unfortunately, the status of microwave research and industry in Poland has been heavily influenced by changes in the economy of the region, which led to many industrial establishments being closed down during the 1980s and 1990s. Similarly, governmental financing of research and education has been reduced significantly. Faced with the choice between a change of profession and a change of country, many Polish microwave researchers emigrated and now live and work abroad.

Today, though, PIT has the largest group of microwave and radar engineers in the country. It specializes in radar technology, and has gained international esteem for its radiolocation systems. Radwar continues the development and manufacture of civil radars. OBREP and Lamina produce amplitrons, reflex klystrons, gas-filled TR-tubes, and TWTs, while the latter is also working on new pulse tubes and BWTs.



With regards to microwave materials, ITME remains active and visible on the international arena, exporting silicon, GaAs and InP wafers, and epitaxial structures. It is also involved with optoelectronic and microwave devices and sensors. New private companies are being established, and some have already introduced their products onto the international market. Vector (Gdynia) manufactures cable television devices and telecommunication systems, Transbit (Warsaw) and Telemobile (Gdynia) microwave devices (filters, antennas) and digital communication systems and QWED (Warsaw) electromagnetic simulations software.

Czech Republic and Slovakia

The Czech Republic and Slovakia have experienced similar political and social-economic repercussions to Poland except that fewer workers emigrated. Until the upheaval of the 1980s, microwave technology in the former Czechoslovakia was relatively high. A key manufacturer of microwave equipment was TESLA, a brand name for radars operating from 10 cm to less than 3 cm, which also produced point-to-point radio links and nearly all associated components. The Czech Republic has been quite successful in developing passive radar technology (Ramona, Tamara).

Microwave systems were produced in southern Moravia (Let Kunovice). The Research Institute for Telecommunications developed and produced semiconductor diodes and transistors and the three Technical Universities of Prague, Brno, and Bratislava, the Military Academy, and the Institute of Radioelectronics of the Academy of Science provided background scientific support.

Since 1989 there has been a decline in the Czech Republic. Activity in the field of microwave technology has dropped and the market has been reduced by about a half. However, Prague, Pardubice and Kunovice, where the former large companies originally prospered, have become host to several new SMEs. For example, ERA makes passive surveillance systems, VERA and RAMET C.H.M. make police radars, Ramer and ALCOMA produce communication systems, and

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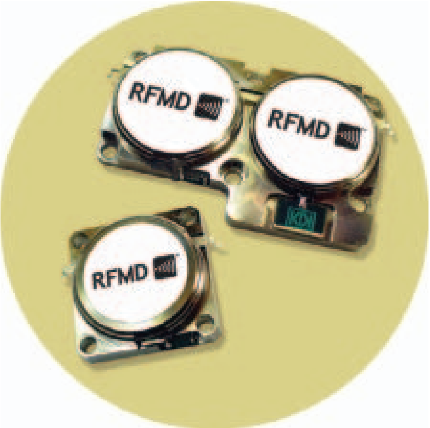

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PI0940AG-21H	920 to 960	< 0.2	> 20	> 20	-65
PI1843AG-21H	1805 to 1880	< 0.2	> 20	> 20	-70
PI1960AG-21H	1930 to 1990	< 0.2	> 20	> 20	-75
PI2140AG-21H	2090 to 2190	< 0.2	> 20	> 20	-75

PDxxxxAQ-21H SPECIFICATIONS

Part Number	Frequency Range (MHz)	Insertion Loss (dB)	Isolation (dB)	Return Loss (dB)	IMD (dBc) 2T x 37.5 Watts
PD0882AQ-21H	869 to 894	< 0.35	> 50	>20	-60 Forward and -90 Reverse
PD0940AQ-21H	920 to 960	< 0.35	> 50	>20	-60 Forward and -90 Reverse
PD1843AQ-21H	1805 to 1880	< 0.35	> 50	>20	-60 Forward and -90 Reverse
PD1960AQ-21H	1930 to 1990	< 0.35	> 50	>20	-60 Forward and -90 Reverse

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Retia makes special radar subsystems and C3I systems.

Slovakia is a different story as microwave production has virtually disappeared and while the three technical universities continue, research institutes have practically disappeared.

Baltic Republics

Since gaining independence the former Baltic Republics of the USSR have witnessed vast economical changes. In the USSR, some of the major RF and microwave enterprises were concentrated in Lithuania including the Vilnius Research Institute of Radio-Measuring Devices and a similar research institute, but with smaller scale microwave activities in Kaunas. After the collapse of the USSR both research institutes were liquidated and a number of private companies were established in their place. They are engaged in applied research: Elmika on passive devices and microwave measuring instruments; Geozondas on microwave measuring equipment for antennas and radars; Hybridas on thick-film substrates and hybrid circuits; and Keturpolis on panoramic-parameters measurement systems.

Russia/*Yury Kuznetsov*

Marconi is universally recognized as being the first to demonstrate the practical application of electromagnetic waves. However, the year before Marconi's patent application, Alexander Popov demonstrated a wireless receiver consisting of a metal 'coherer'—a device that detects electromagnetic waves—an antenna, a relay, and a bell to signal the presence of these waves. Although not initially intended as a means of transmitting information, Popov's device proved that radio communication was feasible.

More recently Zhores Alferov, together with Herbert Kroemer, received the 2000 Nobel Prize for Physics, "for developing semiconductor heterostructures used in high-speed electronics and optoelectronics." He effectively invented the heterotransistor.

Industry

Some years ago the Government of Russia developed a strategy for utilising the production of high technology equipment and systems (specifically microwave information and communication technology) for military and civil purposes. As a result some specialized federal corporations were founded, with many active in microwave R&D.

Phazotron—NIIR Corp. is a leader in the development and production of radars and radar weapon and defence control systems. Modern airborne radars produced by the corporation are multifunctional, quasi-continuous, pulse-Doppler, multimode systems.

The Joint-Stock Co., the 'Almaz-Antey' Industrial Concern, is one of the largest Russian military-industrial organisations specializing in the development, manufacture and export of high-technology products for military and non-military applications. It incorporates seventeen manufacturing enterprises, design bureaus and

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scientific research institutes located in different regions of Russia.

Also, the Scientific-Research Institute of Instrument Design (SRIID) is one of Russia's leading scientific-research institutions dedicated to the development of mobile medium range air defence missile systems and aircraft weapon control systems.

Radiotechnical and Informational Systems is a research association, which includes large defence and industry organisations including the Institute of Radio Engineering n.a. Academician Mints A.L., JSC, Scientific Research Institute of Telecommunication, Research and Production Complex, JSC. It oversees work on the development of information systems for ground-based missile defence, the organization of technical maintenance of operating systems for missile attack warning, outer space control and antimissile defence.

Research

The Russian Foundation for Basic Research (RFBR) is a self-governing non-commercial government organization whose main goal is to provide support and assistance to research work in all areas of fundamental science on a competitive basis.

Since 2004, it has been competitively targeting fundamental research aimed at selecting and funding those projects aimed at the development of break-through technologies and new materials in priority areas.

Also, the Institute of Radio Engineering and Electronics (IRE) of the Russian Academy of Sciences carries out fundamental research. Some of its microwave R&D activities include: EM wave propagation in complicated media and structures; EM scattering by complex objects; new types of waveguides and waveguide elements; and antennas for DBS, communications and radars (ranging from 0.5 to 150 GHz).

Technological Testimonies

While focusing on individual countries offers an insight into their respective achievements and activities, it does not give an overall picture of the vital contribution that Europe as a whole has made to the microwave technologies that have defined the 20th century and will shape the 21st.

The continent plays a key role in all sectors including industrial, biomedical, military aerospace and emerging wireless technologies. Since there is such a broad range of sectors, in Part II we will only focus on the technological development in Europe of two sectors: satellite communications from the launch of Sputnik and microwave radar. ■

ACKNOWLEDGMENTS

The author would like to thank all of the European Microwave Association contributors for their time and effort and for sharing their knowledge and expertise.

Reference

1. R. Sorrentino, T. Oxley, G. Salmer, et al. *Microwaves in Europe IEEE Trans. Microwave Th. and Tech., Special Issue*, Vol. 50, No. 3, March 2002, pp. 1056

Broadband Amplifiers by AML Communications

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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.

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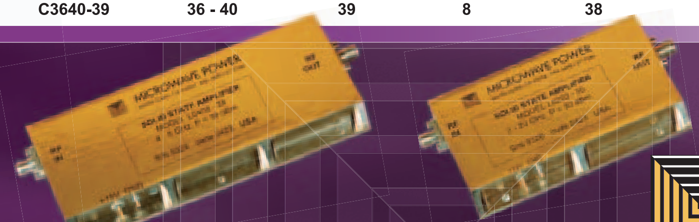
Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Gain (dB)	DC Current(A) @ +12V or +15V
Broadband Microwave Power Amplifiers						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	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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mmWave Devices for PTP Radio and VSAT Ground Terminal Applications

Description	*Frequency Range (GHz)*	*P1dB (Psat) / OIP3 (dBm)*	*Gain (dB)*	*NF / PAE (dB) (%)*	*Voltage / Current (V / mA)*	*Package Style*	*Part Number*
HPA	7 - 8.5	(38) / –	21	– / 42	7 / 2000	Die	TGA2701
Driver Amp, SB	11 - 17	17 / –	23	6 / –	6 / 75	SM-06-12	TGA2507-SM
HPA	12 - 19	29 / –	25	–	5 - 7 / 435	SM-06-12	TGA2508-SM
2W HPA	12.5 - 16	(32) / 37	32	–	6 - 7 / 680	SM-01-24	TGA2503-SM
2W HPA	12.5 - 17	(33.5) / –	25	– / 25	7.5 / 650	SG-A1-6	TGA2510-EPU-SG
4W HPA	13 - 15	(36) / 41	25	–	7 / 1300	FL-A1-10	TGA8659-FL
6.5W HPA	13 - 16	(38) / –	24	–	8 / 2600	FL-A2-10	TGA2514-FL
2W HPA	13 - 17	(34) / 40	33	–	5 - 8 / 680	SG-A1-6	TGA8658-EPU-SG
Doubler with Amplifier	16 - 30	20 / –	18	–	5 / 150	SM-011-16	TGC4403-SM
1W HPA, PD	17 - 20	30 (32) / 42	20	–	5 - 7 / 825	Die	*TGA4530**
1W HPA, PA	17 - 20	29 (31) / 41	21	–	6 / 825	SM-A4-20	*TGA4530-SM**
Driver Amp	17 - 24	22 / –	19	4 / –	5 / 270	SM-09-16	TGA2521-SM
HPA, AGC, PD	17 - 24	(29) / 38	22	–	5 / 712	SM-010-20	TGA2522-SM
HPA	17 - 27	29 (31) / 37	22	–	7 / 760	Die	TGA4502-SCC
Upconverter	17 - 27	– / 28	13	–	5 / 425	SM-011-16	TGC4405-SM
Gain Block & 2x/3x Multi	17 - 40	18 (22) / 24	22	7 / –	5 / 140	SM-A3-16	TGA4031-SM
HPA	25 - 31	35.5 (36) / –	22	–	6 / 2100	CP-A1-8	TGA4905-CP
MPA	25 - 35	25 / –	18	–	6 / 220	SM-A4-20	TGA4902-SM
7W HPA	26 - 31	(38.5) / –	22	–	6 / 4200	CP-A3-8	TGA4915-EPU-CP
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	SM-A4-20	TGA4509-SM
4W HPA	28 - 31	36 (36.5) / –	22	– / 22	6 / 1600	Die	TGA4906
7W HPA	28 - 31	(38.5) / –	22	– / 20	6 / 3200	Die	TGA4916
Driver Amp	29 - 31	16 (17) / 22	15	–	6 / 60	SM-A4-20	TGA4510-SM
MPA	33 - 47	27 (27.5) / 36	18	–	6 / 400	Die	TGA4522
HPA	36 - 40	30 / –	14	–	6 - 7 / 500	Die	TGA1171-SCC

NOTES: * = New, SB = Self Biased, PD = Power Detector

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WELCOME TO EUROPEAN MICROWAVE WEEK 2008

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As Amsterdam is renowned for its vast network of canals and the bridges that cross them, it is not surprising that Bridging Gaps is the theme of the 11th European Microwave Week that takes place at the city's RAI Centre from 27 to 31 October. However, the reference is not to the spanning of the Amstel,

but to the vital building of links between research and development, leading to commercial implementation. EuMW's four focused conferences and associated workshops and short courses, alongside Europe's premier RF and microwave trade exhibition, attract the cream of academia and industry from Europe, North America and Asia, making the Week the ideal medium for bridging gaps and forging relationships.

EuMW 2008 will focus on the needs of engineers and researchers for the creation of innovative applications, products and services by providing an inspiring environment for discussion between academia and industry. We hope to enable the two communities to share the latest trends and developments that are widening the field of application of microwaves. Microwave devices, systems for telecommunications (both terrestrial and space-borne), transportation, medical, radar as well as new fields of application are all being addressed and special attention has been given to the coordination of areas of common interest between

RICHARD MUMFORD
Microwave Journal *European Editor*

Another Major Breakthrough in VCO Technology

by Dr. Mahadevan Sridharan PHD, Z-Communications, Inc.

Modern digital communication systems using complex modulations including OFDM 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, 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 ability to detect weak signals.

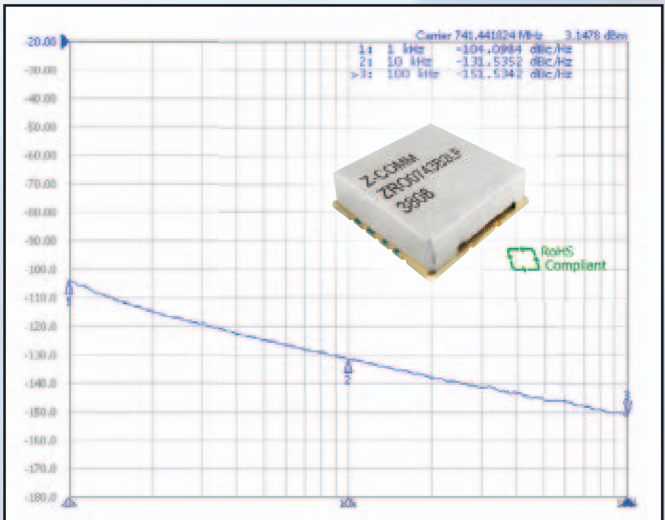
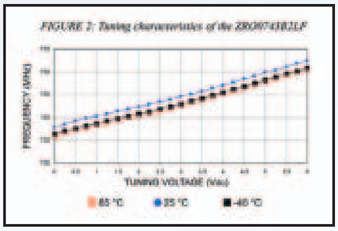
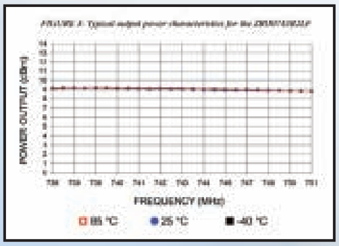


FIGURE 1: Typical phase noise of the ZRO0743B2LF

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. So it is 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.



The first VCO of this series is the ZRO0743B2LF, which has an excellent typical phase noise performance of -131 dBc/Hz @ 10 kHz offset and -151 dBc/Hz @ 100 kHz offset in a frequency range between 738 and 748 MHz (see figure 1).

The ZRO0743B2LF has excellent tuning linearity over the tuning range from 0V–6V (see figure 2) with a typical tuning sensitivity of 2 MHz/V. It also offers excellent 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 the frequency and temperature. 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"x0.75"x0.22" and Z-COMM's industry standard MINI-16 package which measures 0.5"x0.5"x0.22" Both packages are surface mount and manufactured to meet the European RoHS directive.

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Specification	ZRO0743B2LF	ZRO0915C2LF
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Tuning Voltage	0-6 Vdc	0-11 Vdc
PN @ 10 kHz	-131 dBc/Hz	-128 dBc/Hz

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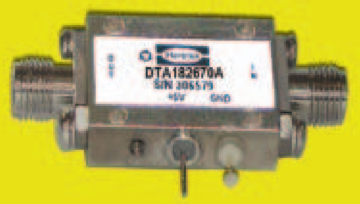

MODEL	FREQ RANGE (GHz)	MIN VOLTAGE SENSITIVITY K (mV/uW)	TYP TSS (dBm)
DTA1-1860A	1-18	10	-60
DTA1-1870A		100	-70
DTA1-1880A		1000	-80
DTA182660A	18-26	10	-60
DTA182670A		100	-70
DTA182680A		1000	-80
DTA264060A	26-40	10	-60
DTA264070A		100	-70
DTA264080A		1000	-80
DTA184060A	18-40	10	-60
DTA184070A		100	-70
DTA184080A		1000	-80

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the different conferences, workshops and short courses.

The four conferences—the 38th European Microwave Conference (EuMC), the 3rd European Microwave Integrated Circuits Conference (EuMIC), the 1st European Wireless Technology Conference (EuWiT) and the 5th European Radar Conference (EuRAD)—specifically target ground breaking innovation in microwave research through a call for papers explicitly inviting presentations on the latest trends driven by the industry roadmaps. The result is a total of 528 papers over 108 sessions, complemented by 183 poster papers, 12 interactive poster presentations and 16 keynote speakers who will focus on new trends and state-of-the-art innovations.

Just how far down the road of innovation the industry has travelled will be demonstrated by the three-day European Microwave Exhibition, which has established a reputation as the essential platform for key players, not just from Europe but from across the globe, to showcase their wares to a wide and focussed audience. It is a trade exhibition that companies target to launch new and significant products, offer technical advice, discuss possible future developments and get feedback from customers.

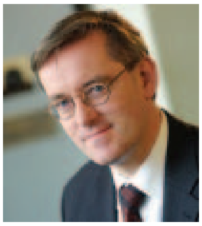
Bridging the gap between theory and practice, there are associated workshops and short courses on various subjects that offer the opportunity to get hands on experience and guidance direct from the experts. Also, the siting of conference Poster Sessions, including new Interactive Posters, in the exhibition halls on all three days sets the current academic research amongst the exhibitors who have the commercial expertise to make the concepts a reality.

The EuMW Welcome Reception epitomises the organiser's ongoing endeavours to encourage the interaction between industry and academia, having become established as a social event that is both convivial and conducive to networking. Indeed, mixing business and pleasure can be enjoyed throughout the week through the strong calendar of social events that has been organised.

Like the industry it serves, European Microwave Week has to be innovative and forward thinking; therefore, three new initiatives have been introduced this year. For the first time, IQPC's Military Radar Conference will be collocated and accessible to EuMW delegates, with forum and panel discussions organized on topics of special interest. A Women in Engineering event will focus on and debate the contribution and role of women in our industry. Thirdly, the EuMW 2008 Student Challenge aims to bridge the gap between university and industry. This competition challenges students and young researchers to test their technical and application-oriented innovation skills. The competition complements the 2008 Tutorial Seminars for Young Engineers aimed at stimulating and encouraging the next generation that was successfully launched last year.

Such initiatives take time and effort to bring to fruition and the Local Organizing Committee would like to express its gratitude to the international Technical Programme Committee and more than 300 hundred reviewers who worked hard to shape the conference programmes. We would also like to acknowledge those who organized the workshops, the focussed sessions, the short courses and the special events that are essential elements for a successful event. Thanks also goes to the Horizon House staff assigned to EuMW for their invaluable support in organising this major international event, as well as their contribution to the staging of a world-class exhibition. Last but not least, we acknowledge the financial and in-kind sponsorship of many industrial enterprises and other organisations.

Due to all of their efforts the 11th European Microwave Week will not just bridge the gap between the 10th and the 12th, but aims to be a significant catalyst in developing relationships, forging alliances, and moving the microwave and RF industry positively and productively forward.



Welcome from Frank van den Bogaart, general chairman of EuMW 2008, and Ivar Bazzy, president, Horizon House Publications. ■

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P1dB*	750 mW/mm
PAE (peak)*	51%
Gm (peak)	400 mS/mm

* f=10 GHz, Vdg=7 V, Ids=160 mA/mm

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ATTENDING EUROPEAN MICROWAVE WEEK 2008

From 27 to 31 October, the RAI Centre in Amsterdam will play host to European icrowave Week for the third time. The previous two events have been landmarks of innovation with 1998 being the very first EuMW and 2004 seeing the original three conferences and associated workshops, short courses and trade exhibition augmented by EuRAD, which has become a successful conference in its own right. Not to be outdone, this year's organisers have instigated not just one but THREE new initiatives (see ***Figure 1***).

Strengthening EuRAD even further, the Military Radar Conference of the International Quality and Productivity Centre (IQPC) in London will for the first time be collocated within the Week, with its own programme on the Tuesday and Wednesday. Delegates can visit the European Microwave Exhibition and participate in the EuRAD sessions as well as the conference workshops. Likewise, participants of EuMW can register for IQPC's Military Radar Conference at a reduced rate.

Fig. 1 Three new initiatives will be implemented this year to extend the conferences.

The second innovation recognises the increasing role that women are playing in the RF and microwave industry with a free to attend Women in Engineering event, which takes place on Wednesday evening after the conference sessions and is sponsored by the Netherlands National Science Foundation STW. There will be presentations on gender issues and the making up of careers, followed by discussions and networking. Although the focus is on the female perspective it is hoped that the broader issue of co-working of genders will be considered and both women and men are encouraged to participate.

Last but not least, this year's event is looking to encourage and nurture the future of the industry with the introduction of the EuMW 2008 Student Challenge, where participating students are asked to present a poster during the lunch break on Thursday related to ideas

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Microwave Journal *European Editor*

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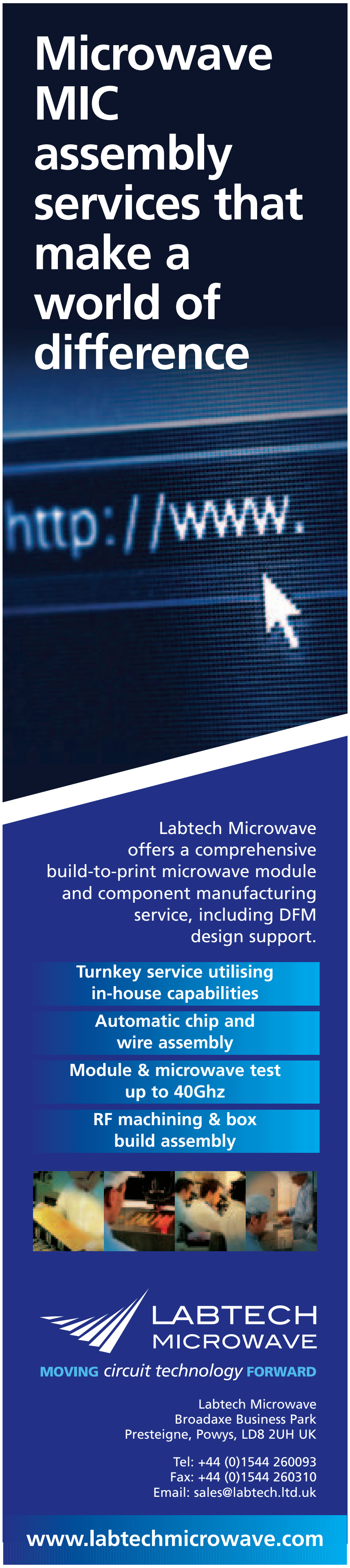

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and results that came up during the Week and inspired by EuMW presentations. The posters will cover topics that have been supplied by the organization. The competition is sponsored by Thales Nederland and organized by PhD students. The best presentation will receive a prize worth €1,500.

The Challenge will complement the Agilent sponsored Tutorial Seminars for Young Engineers, which was such a success when launched in 2007 that the company will also introduce the Agilent Technologies University Innovation Award this year. Showing commitment to university research and development in Europe, the Award recognises that access to instrumentation and expertise is often an obstacle for research and so will provide such access to a single person project or research group, which could enable them to take their project to the next level. The prize consists of a week of access to the RF Measurement Lab in Miplaza Eindhoven. The winner will be decided by the EuMW committees and presented during the Welcome Reception (see Social Events).

All of these new innovations serve to add to the content and reach of an event that is well established as the premier event in the RF and microwave calendar in Europe and is viewed as an essential destination for around 4,500 attendees—comprising delegates, exhibitors and visitors. The aim, as always, has been to create four focused conferences that reflect the groundbreaking and innovative work currently being undertaken in the RF, microwave, integrated circuit, wireless and radar sectors. For the fourth year running there were more than 1000 paper submissions, enabling the Technical Programme Committee to fashion a high-level programme, with 528 oral papers, 183 poster papers and 12 interactive poster presentations, complemented by a wide range of workshops and short courses.

The commercial reality of much of that research and development will be showcased during the European Microwave Exhibition, which continues to expand with more than 250 exhibitors spread over more than 6,000 m^2 (gross). Over the three days visitors can see first hand the latest innovations and new product introductions, discuss specific areas of interest with development engineers and find the right products for their specific applications.

The official European Microwave Week opening ceremony on Tuesday morning is open to delegates from all conferences, while the Tuesday evening sees the EuMW Welcome Reception (see Social Events), which has become a highlight of the week. Other social events have been organised throughout the Week and although convivial interaction is essential to a successful event, of course, the main focus is to provide visitors with the opportunity to discover the latest trends and innovations and to network, exchange ideas and do business. To help you to achieve most, if not all, of these goals, the following quick reference guide is designed to complement the Conference Programme and Exhibition Catalogue, where you will find more detailed information.

CONFERENCES

There are four separate conferences that are scheduled throughout the Week as follows:

- 3rd European Microwave Integrated Circuits Conference (EuMIC) - Monday 27 and Tuesday 28 October
- 1st European Wireless Technology Conference (EuWiT) - Monday 27 and Tuesday 28 October
- 38th European Microwave Conference (EuMC) - Tuesday 28 to Thursday 30 October
- 5th European Radar Conference (EuRAD) - Thursday 30 and Friday 31 October

Onsite registration begins on Sunday 26 October (16:00 - 19:00) and commences at 07:30 each morning from Monday 27 to Friday 31. The registration area and delegate bag collection are located in the Main Foyer of the RAI. Delegates should register for one, two, three or all four of the conferences. Registration at one conference does not allow access to other conference sessions, but those who register for two or more conferences will receive a discount.

Those wishing to participate in the Military Radar Conference should register at the IQPC registration desk in the Main Foyer near the entrance.

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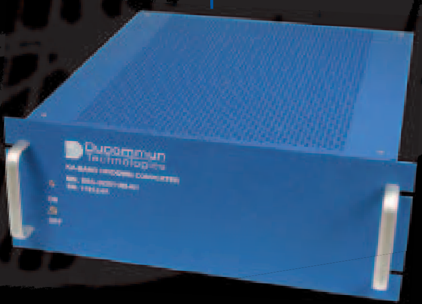

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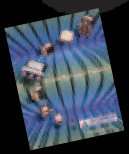

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EUROPEAN MICROWAVE INTEGRATED CIRCUITS CONFERENCE

This conference is the successor to the well-known GAAS symposium. Since 2007 the conference has been organized under the umbrella of both the European Microwave Association and GAAS® Association. There will be four plenary presentations and more than 130 technical papers, distributed across more than 25 sessions as well as seven workshops and one short course. A significant number of these sessions and workshops are joint sessions with the EuMC and the EuWiT conference, demonstrating the strong interaction between these conferences.

The plenary invited talks reflect the state-of-the-art in different areas. Dr. Mehmet Souyer from IBM will share the latest SiGe-development for integrated microwave circuits, while Dr. Thijs de Graauw of SRON will present the status of the European space instrument, HIFI, for space research. Professor Gabriel Rebeiz will share the recent development of SiGe and CMOS-based phased arrays up to 60 GHz at UCSD, and Dr. Bill Deal from Northrop Grumman will present the latest results from the new 1 THz f_{max} InP HEMT device and circuits.

This year the emphasis is for the programme to interest both industry and academia, with a large number of focussed sessions ranging from phased-array technology, millimetre-wave IC-design for commercial applications, sub mm-wave circuits, linear receiver design, advanced power amplifiers, to active device modelling.

PRIZES AND AWARDS

To acknowledge the high quality of papers presented the Best Paper Prize (€3,000) and a Young Engineer Prize (€2,000) will be awarded. The winners receive a certificate commemorating their achievements and, in addition, the GAAS Association will provide three student fellowships of €5,000 each.

EUROPEAN WIRELESS TECHNOLOGY CONFERENCE

Formerly known as the European Conference on Wireless Technology (ECWT), the EuWiT conference is an integral part of EuMW and is a forum for the presentation and discussion of new developments in the field of wireless communication technologies. With research and development on beyond 3G in full swing, wireless technology is a rapidly expanding field with many new challenges, products and services, in particular for systems such as WLAN, cognitive radio, UWB, wireless ad-hoc networks, 4G, RFID, local positioning, digital audio, video broadcasting, etc.

The first EuWiT conference will bring together researchers and product developers from all over the world to update and share their knowledge. The new conference topic, Quality of Life, will be addressed from the Body Area Networks point of view. In the plenary sessions, which are open to all EuMW participants, keynote speakers will address the present trends in wireless communications.

There will be the regular podium and poster paper contributions, joint sessions with EuMC and EuMIC, and three focussed sessions on cognitive radio and networks, adaptive spectrum access in cognitive radio and intelligent wireless transceivers. Workshops on safety-of-life communications, mobile communications and intelligent transportation systems, how will SDR change the future of radio communication?, and emerging technologies for hybrid terrestrial wireless and mobile satellite communications have been scheduled, while a workshop on reconfigurable RF systems has been organized jointly with EuMC and EuMIC.

PRIZES AND AWARDS

To acknowledge the high quality of papers presented the Best Paper Prize (€3,000) and a Young Engineer Prize (€2,000) will be awarded.

EUROPEAN MICROWAVE CONFERENCE

The EuMC is the largest conference of the Week. It covers a broad range of technological and engineering themes in passive and active components, circuits and sub-systems. Many common topics with all of the other three conferences underline the synergy in microwaves. In the Electromagnetism and the Microwave Systems and Applications themes, attention is paid to medical and biological effects, extending to quality of life, which will be the subject of several focussed sessions and in the opening session keynote address. Homeland security is also a newcomer, with a focussed session, common with

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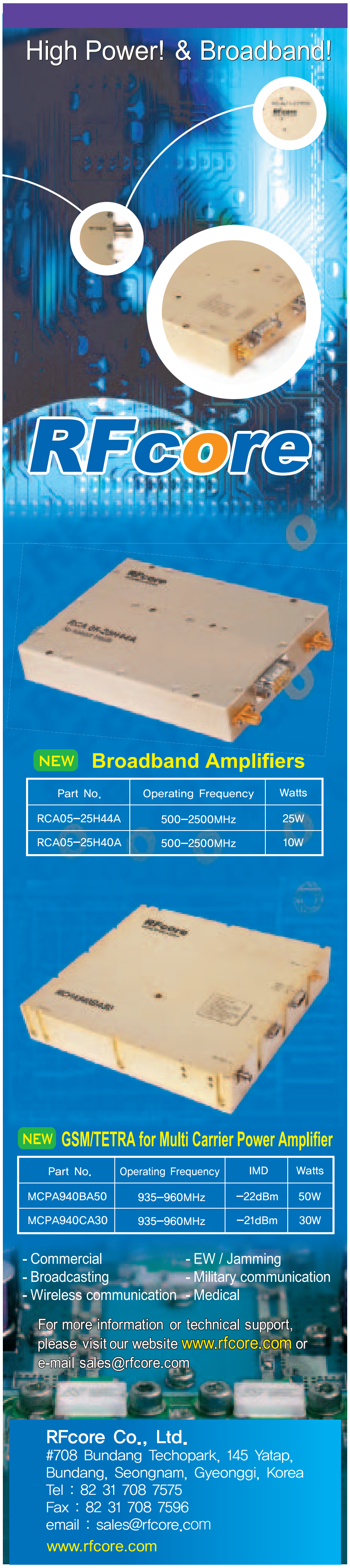

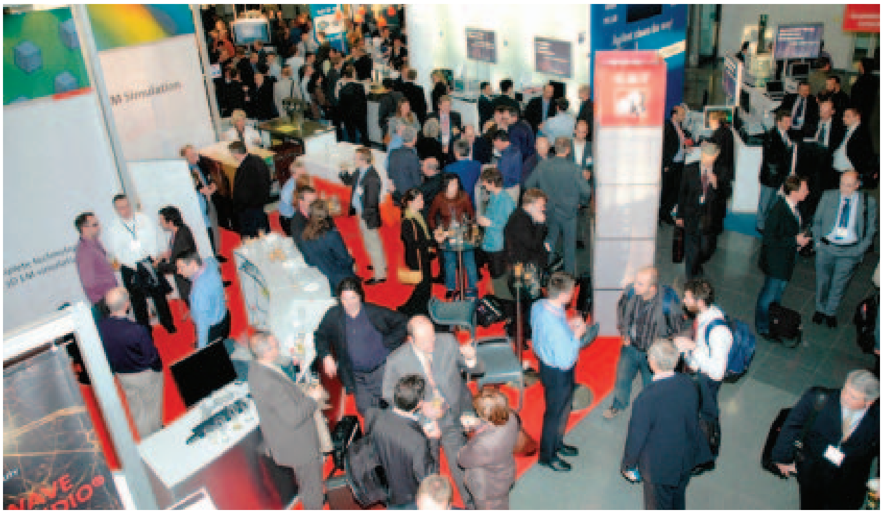

▲ *Fig. 2 The exhibition typically attracts over 250 companies.*

EuRAD, on the European Stand Off Surveillance and Target Acquisition Radar (SOSTAR) system.

PRIZES AND AWARDS

The EuMC Best Paper Prize of €5,000 will be awarded to the paper that best advances the state-of-the-art in radar. Two Young Engineer Prizes of €2,000 each, sponsored by EADS, will be awarded to a young engineer or researcher who has presented an outstanding paper at the conference. Also, the best innovative demonstration prize (joint with EuRAD) of €1,000 will be awarded by Thales Nederland to the best presentation at the Interactive Poster Session.

EUROPEAN RADAR CONFERENCE

EuRAD started in Amsterdam five years ago and has developed into one of the largest radar events. This year there were over 160 abstracts submitted to the conference, not only from Europe but also from the US, Asia and Africa. They cover a wide range of radar topics, including technology, signal processing, system design and evaluation, and various applications. Also included are environmental remote sensing systems for hazard prevention and monitoring applications, homeland security and military related systems as well as radars for surveillance, transport guidance and control. The programme focuses on modern developments in radar, including active phased arrays and ultra-wideband technology as well as their applications in high-resolution and imaging radars, advanced signal processing for target tracking, and classification and radar sensor networks.

The conference programme combines oral sessions, joint sessions with the EuMC, a poster session and an interactive poster session. The programme will give a wide overview on the most recent advances in radar and radar applications. In the opening session a discussion on future radar developments in the US will be complemented with an overview of one of the most successful recent radar projects in Europe—the PAMIR active phased-array system. At the closing session the Dutch Government-Industry approach towards long-term radar innovations will be presented.

PRIZES AND AWARDS

The Eu*M*A EuRaD Radar Prize and Young Engineer Prize, which are both sponsored by Raytheon will be presented. The Radar Prize of €3,000 is awarded to the paper that best advances the state-of-the-art in radar. The Young Engineer Prize of €2,000 is awarded to a young engineer or researcher who has presented an outstanding paper at the conference. Also, the best innovative demonstration prize (joint with EuMC) of €1,000 will be awarded by Thales Nederland to the best presentation at the Interactive Poster Session.

EXHIBITION

Established as the premier RF and microwave tradeshow in Europe, this FREE to enter exhibition (see ***Figure 2***) showcases the latest products and services. Over its three days it is

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THE EXHIBITION

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THE CONFERENCES

Choose from four separate but complementary conferences

- European Microwave Integrated Circuits Conference (EuMIC) – 27-28 October 2008
- European Microwave Conference (EuMC) – 28-31 October 2008
- European Wireless Technology Conference (EuWiT) – 28-29 October 2008
- European Radar Conference (EuRAD) – 29-31 October 2008

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The 1st European Wireless Technology Conference

EuRAD 2008
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▲ *Fig. 3 Country/regional pavilions have been successful with three to look out for in 2008.*

the focus of activity, offering visitors the opportunity to discover what's new, identify trends, network and do business. The exhibition is also targeted by many companies as the place to launch new products or introduce them onto the European stage for the first time.

It is a reflection of the industry with companies large and small, established and newcomers and from all corners of the globe participating. As always, Europe and North America are well presented and the Asian presence continues to grow as companies endeavour to demonstrate their capabilities to a wider audience, penetrate new markets and build business relationships.

Each year the EuMW host country attracts local interest as smaller companies and distributors that band together in a pavilion that gives them a collective presence. Such has been their success over recent years that these pavilions are sustained year on year and travel with the exhibition to the next venue with the RAI playing host to Dutch, German and French Pavilions this year (see ***Figure 3***).

Free exhibitor workshops offer the opportunity for visitors to gain hands-on experience of the latest products, while the Agilent Technologies Tutorial Seminars for Young Engineers that were successfully introduced in 2007 continue. Focussing on the application of test and measurement, the seminars are an investment in the RF and microwave industry's future and aim to help young engineers along their chosen career paths.

As well as being a shop window for the latest innovations, the European Microwave Exhibition embraces the EuMW 2008 Bridging Gaps theme by acting as a focal point where academia and industry can come together. The exhibition halls will host the conference session coffee breaks, provide Internet access via the popular CST sponsored Cyber Cafés, and generate debate and discussion during the Poster Sessions.

As well as the normal poster sessions, this year sees the introduction of an Interactive Poster Session on the Thursday. It is designed to enable authors to present their results interactively, which could be via a live computer demonstration, a real measurement set-up to show a newly discovered effect or via a demonstration of a newly developed device/system.

Exhibition Hours

Tuesday 28 October: 09:30 - 17:30
(followed by the Welcome Reception)
Wednesday 29 October: 09:30 - 17:30
Thursday 30 October: 09:30 - 16:30

GETTING TO THE RAI

The conference and exhibition centre is situated next to the A10 orbital motorway, exit S109. There is a stop for Tram 4 in front of the building and Amsterdam RAI railway station is within walking distance. Amsterdam Schiphol Airport is less than 15 minutes away by car or public transport.

BY TRAM AND BUS

From Amsterdam Central Station take the Amstelveen express Tram 51 (journey time: 12 minutes, stopping at Amsterdam RAI station) or Tram 4 (journey time: 30 minutes, stopping at the RAI Europaplein). From Amstel station take the Amstelveen express ingun®

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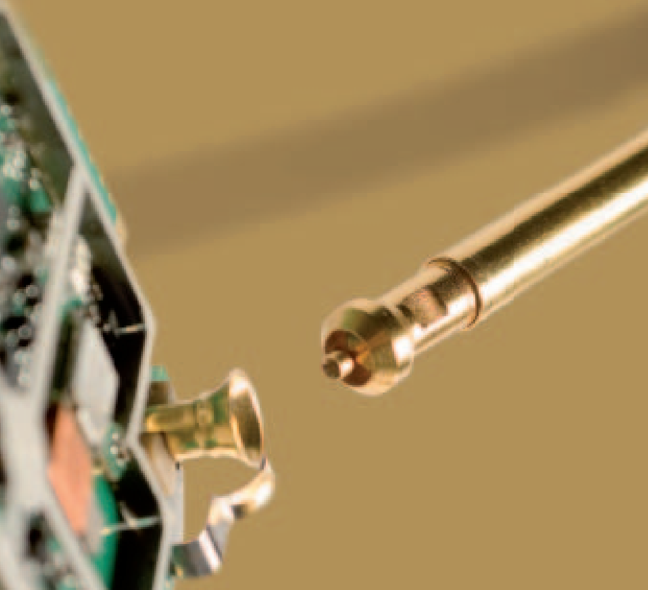

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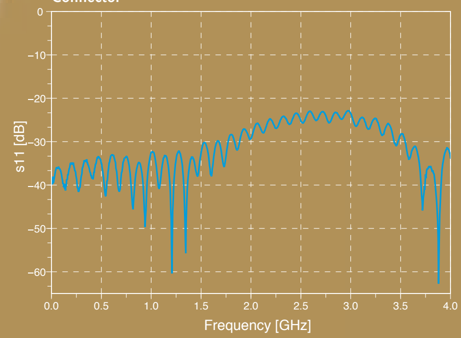

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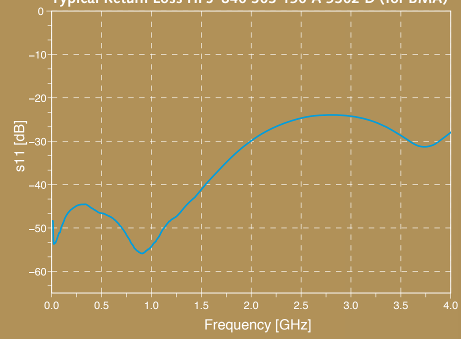

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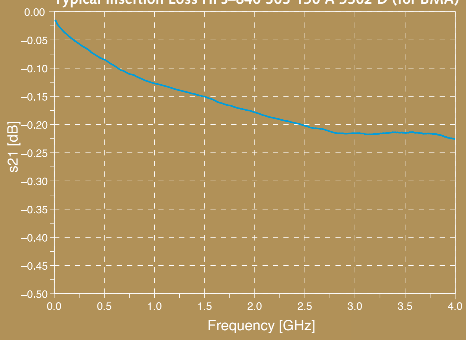

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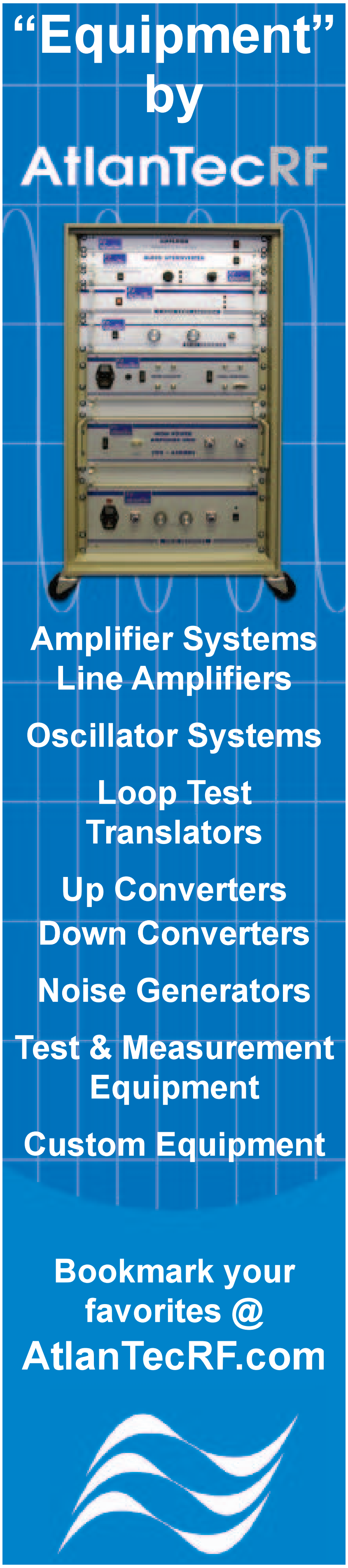

Tram 51 (journey time: five minutes) or the bus routes 15, 69 or 169 (journey time 10 minutes). From Amsterdam Sloterdijk station, take express Tram 50. Tickets for trams and buses must be purchased before the journey at stations, kiosks or ticket machines.

BY TRAIN

The Amsterdam RAI railway station is 300 m from the RAI and has regular connections to all parts of the Netherlands, including Schiphol, Rotterdam, Utrecht and The Hague, and is also linked to the international train network. Train tickets must be purchased before the journey from ticket machines, which are situated at all stations.

HOTEL RESERVATIONS

If you require hotel accommodation during your stay in Amsterdam, the RAI Hotel & Travel Service booking agency makes reservations at reduced rates in various 2, 3, 4 and 5 star hotels, free of charge. For more information contact either RAI Hotel & Travel Service on +31 20 549 1927 or visit www.eumweek.com and click on the Accommodation page.

SIGHTSEEING

The facts state that Amsterdam has 51 museums, 141 galleries, 755 restaurants, 1,402 cafes and bars, six nightclubs, six windmills, 1,281 bridges, 200 km of canals and 600,000 bicycles. It is one of the most colourful and diverse cities in the world, with its famous diamond factories, cosy pubs, fun shops and flower markets. It has all the advantages of a big city—culture, history, entertainment and good transport but is relatively small, quiet, and, thanks to its canals, has little road traffic.

Delegate bags will contain guides for shopping and sightseeing and there will be a help desk in the registration area to provide support in booking tourist trips, purchasing public transport tickets, etc. For even more sightseeing ideas, including where to eat and shop, see the Guide to Amsterdam in this issue.

SOCIAL EVENTS

The Week begins in style on the Monday evening when all conference delegates are invited (advance registration is mandatory) for a Rembrandt Style Dinner when the world of Holland's greatest painter can be experienced. In keeping with Rembrandt being a man of very good taste, only the finest foods will be offered with meat roasters, fish mongers and cooks on hand to serve wonderful food. An authentic atmosphere will be provided by musicians and the drinks (soft and alcoholic) will flow.

The following evening (Tuesday 28) the Agilent Technologies sponsored EuMW 2008 Welcome Reception will take centre stage in the Onyx Lounge at the RAI. The reception has become more than just a social event as it offers the unique and invaluable opportunity for industry and academia to meet network and establish relationships. All registered conference delegates from all four EuMW conferences, as well as delegates from the IQPC Military Radar Conference and representatives from the companies participating in the exhibition are invited.

The evening will begin with a champagne drinks reception at 18.00 followed by an address by the Platinum sponsor Agilent Technologies and announcement of the winners of the Grand Prize Draw. The company's European general manager, Benoit Neel, will also announce the recipient of the new Agilent Technologies University Innovation Award. The reception will continue with an Italian and Indonesian buffet dinner and the chance to combine good food, drink and conversation.

Also, a lively partners and social programme has been organised throughout the Week. The first trip is the Amsterdam City Tour on Monday (27 October) followed by a round trip to typical Dutch Windmill villages the next day. On Wednesday there is the unique opportunity to tour Amsterdam Homes and Gardens, which are normally not open to the public. On Thursday the destination is the famous Rijksmuseum and on Friday there is a trip to the typical Dutch villages of Marken and Volendam.

GENERAL INFORMATION

In advance, take time to familiarise yourself with the event and plan your visit by logging onto the show web site: www.eumweek.com. ■

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AMSTERDAM: BRIDGING THE CULTURAL DIVIDE

With its Bridging Gaps theme, the 11th European Microwave Week couldn't be held in a more suitable city than Amsterdam. Known as the 'Venice of the North', the canals that give it that name are spanned by 1281 bridges. They range from the famous Magere Brug (Skinny Bridge; see ***Figure 1***), a traditional double-leaf, Dutch draw-bridge connecting the banks of the river Amstel, to the snake-like red steel Pythonbrug (Python Bridge). This mixture of old and new epitomises the city that manages to blend history with modern day living and embraces the 21st century without sacrificing its heritage. You will find striking modern architecture among the museums and palaces.

Fig. 1 The famous Skinny Bridge is one of the 1281 bridges in Amsterdam (courtesy of Amsterdam Tourism and Convention Board).

Amsterdam has a rich cultural heritage, which is diverse and creative. There is a high quality of life with a diverse population from various backgrounds enjoying a broad range of arts and culture. Holland is renowned as an all inclusive, tolerant country; what it no longer tolerates, however, is the smoking of tobacco in public places, including cafés, bars and restaurants. The ban, which came into force on 1 July, is not as strict as in many other European countries as it does permit smoking in segregated smoking areas where staff are not required to enter.

The ban should not spoil your enjoyment, of course, as Amsterdam has so much to offer, so take some time out during European Microwave Week to discover just how vibrant and diverse the city is. To help you do so here is some advice of how to get the best out of the city.

CITY LAYOUT

Amsterdam's system of one-way roads, canals and bridges may not seem easy to navigate at first, but it can be simplified if you think of the layout as half of a bicycle wheel: the old, medieval city is centred around the Centraal Station—the hub, with roads, smaller canals and the Amstel River spreads out from it like spokes. The ring of concentric canals date back to the 17th century, bordered by the Singelgracht. Approxi-

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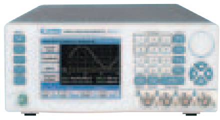

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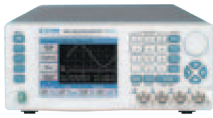

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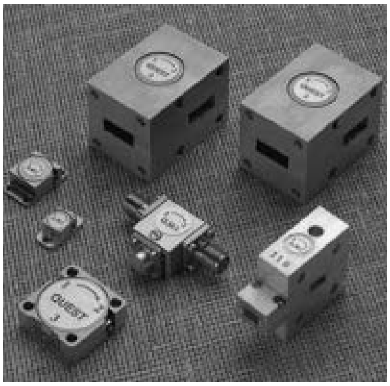

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mately five minutes from Centraal Station you will find Dam Square (see ***Figure 2***), the centre of Amsterdam. Within walking distance from the train station you can also explore Leidseplein (see ***Figure 3***) and Museumplein (see ***Figure 4***) for culinary and cultural activities or Rembrandtplein for a night out.

▲ *Fig. 2 Dam Square is the center of Amsterdam (courtesy of Amsterdam Tourism and Convention Board).*

▲ *Fig. 3 Terraces at Leidseplein (courtesy of Amsterdam Tourism and Convention Board).*

▲ *Fig. 4 Sample the relaxed café culture (courtesy of Amsterdam Tourism and Convention Board).*

GETTING AROUND

With most major sites located in or near the city centre, the best and most convenient way to enjoy the city is on foot. If you are feeling energetic, however, join the Dutch in their preferred way to travel and experience the city by bike.

For those preferring motorised transport, GVB (www.gvb.nl) provides integrated metro, tram and bus services throughout Amsterdam and its surrounding areas. Twenty-four, 48 and 72 hour GVB passes allow for unlimited travel on all trams, buses, the Metro and night buses, and provide the most economical way for visitors to explore the city. Alternatively, 'strippenkaarten' charge travellers per trip according to the number of zones passed through to reach their destination and are available at kiosks, stations and tobacconists in strips of 8, 15 and 45. Single trip tickets can be bought onboard from GVB drivers and conductors and are relatively expensive.

TRAMS

Trams provide the best way to get around Amsterdam and run regularly until 00:15 am. City buses are primarily used to reach outlying suburbs and after the trams have stopped running. Night buses run from midnight until 07:00 with routes connecting to Centraal Station, Rembrandtplein and Leidseplein. The Metro is fast, but is mostly of use if you need to travel a fair distance from the city centre.

CANAL BOATS

The Canal Bus (www.canal.nl) runs every 40 minutes from 09:50 until 19:25 with 14 stops along three different routes throughout the city. Day passes cost €16 and are valid until 12:00 the next day. All of Amsterdam's major attractions are on the route and historical commentary is provided along the way.

TAXIS

There are Taxi stands at most tourist hubs, including Leidseplein, Dam Square and Centraal Station (see ***Figure 5***). Hailing a taxi is quite difficult and virtually impossible on weekends, but the taxi service is generally prompt if you call ahead (city cab: 0900 677 7777). As well as the taxi sign on top of the roof, Amsterdam taxis can be recognized by the blue license plates with black letters and digits.

Taxi trips are costly and must normally be paid in cash, although sometimes credit cards are accepted. The maximum rate for four passengers is calculated as follows: a maximum call out charge of €7.50, including the first two kilometres. Starting from the third kilometre the charge is up to €2.20 per kilometre. If you keep a taxi waiting, up to €33 per hour will be charged. A 5 to 10 percent tip is expected.

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BICYCLES

Some 600,000 bicycles travel around the streets of Amsterdam, contributing to the city's unique charm. Cyclists have their own lanes (coloured red), separated from pedestrians, but you should be aware that mopeds and scooters also use these lanes. A number of companies offer bicycle rentals for around €8 per day with discounts for longer rentals

You'll need some form of ID and a deposit. Take out the insurance for a little extra, because the city's bike thieves are ingenious.

These include:

Macbike Leidseplein,
Weteringschans 2 (next to Paradiso)

Mr. Visserplein 2 (Waterlooplein)
Centraal Station, Stationsplein 12
Tel: 020 620 0985

Bike City
Bloemgracht 68-70 (Westerkerk)
Tel: 020 626 3721

Damstraat Rent a Bike
Damstraat 20-22
Tel: 020 625 50 29

▲ *Fig. 5 Try riding a taxi bike (courtesy of Amsterdam Tourism and Convention Board).*

WHAT TO DO AND SEE

Anne Frank's House, Westerkerk

Described as a normal girl in exceptional circumstances, Anne Frank and her family hid from the Nazis for two years during World War II in the rear of their house at Prinsengracht 263. The entrance was hidden by a revolving cupboard, which was made especially for that purpose. In this hiding place Anne chronicled her experiences in her famous diaries. Go early or late to avoid the queues.

Rijksmuseum, Museumplein

One of Amsterdam's most famous museums is currently undergoing the biggest rebuilding, renovation and modernization programme in its history. During this period the finest works from the 17th century, including Rembrandt, Vermeer and Van Hals will continue to be on view under the title The Masterpieces. The redesigned Philips Wing will house various pieces, including Rembrandt's Night Watch, which has rarely left the main building since it opened in 1885. For more information, visit www.rijksmuseum.nl.

Stedelijk Museum of Modern Art

Also due to renovation this museum is temporarily located on the second and third floor of the Post-CS building (next to Centraal Station) on the Oosterdokskade in the intriguing area between the new and old Amsterdam. The museum offers a diverse exhibition programme, including highlights from the main collection of modern and contemporary art, photography, applied art and design after 1968. For more information, visit www.stedelijk.nl.

Van Gogh Museum, Museumplein

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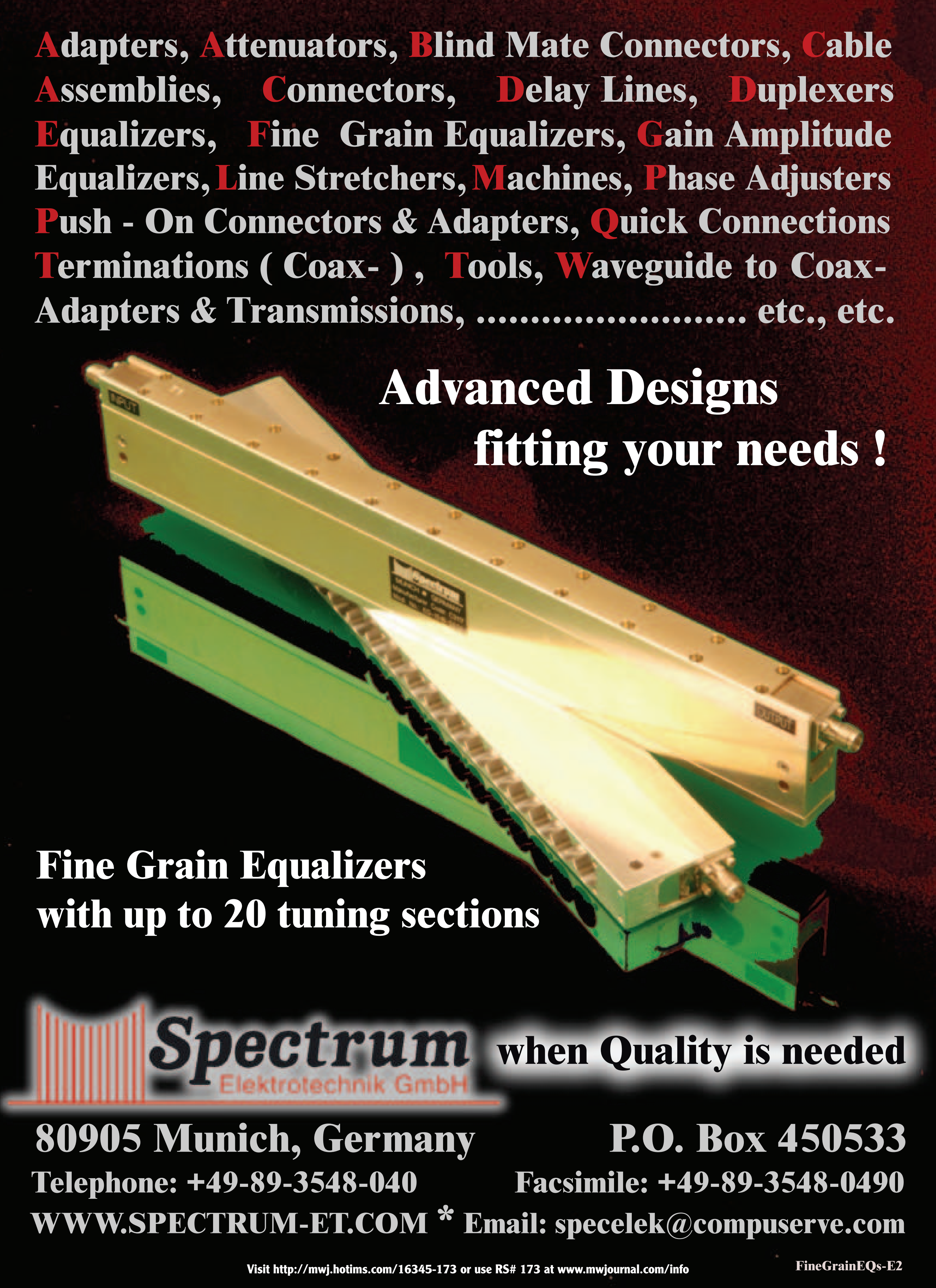
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museum is a must for any visitor to Amsterdam. It contains more than 200 paintings, 500 drawings and 700 letters as well as the artist's own collection of Japanese prints.

Hortus Botanical Gardens, Plantage Middenlaan 2A

Known as 'the town's pride and joy', the gardens offer the opportunity to commune with nature in tranquil surroundings in the very centre of the bustling city. Established in 1638 as a herb garden for Amsterdam's doctors and pharmacists, the Hortus has evolved into a live museum with a unique range of plants from all continents.

Heineken Brewery, Stadhouderskade 78

What used to be a brewery until a few years ago is now a museum and visitor centre, which has been completely renovated. Now called the Heineken Experience, this multimedia event acquaints you with the world of the world's largest beer exporter. You can take a moving seat on the 'Bottle Ride' and follow the route that each bottle in the brewery follows. However, for traditionalists the historic brewery has retained its own atmosphere, with the original brewing room, for instance, having had its impressive hop boilers preserved.

Houseboat Museum, Prinsengracht opposite number 296, facing Elandsgracht

Many people in Amsterdam live permanently on water. You can see their houseboats all over the city. But how does it feel to live in one? How much space do you actually have? The museum shows you a snugly furnished, traditional Amsterdam houseboat.

NEMO, Oosterdok 2

A must if you have children to entertain during European Microwave Week or if the curiosity of the engineer gets the better of you. NEMO is the biggest science museum in the Netherlands. Discover the world of science and technology in the stunning copper-clad building designed by Renzo Piano.

Eating and Drinking

With more than 1000 restaurants to choose from, Amsterdam offers something for everyone, including vegetarians. Dining ranges from fast food to haute cuisine with most nationalities represented. The city boasts top quality restaurants as well as traditional cafés, Dutch pancake houses, steakhouses, seafood outlets, etc. It is advisable to reserve a table, particularly in the city centre. Also note that the Dutch eat early, so some restaurants may close earlier than you might expect. Addresses and phone numbers are given, but if calling from outside the Netherlands, use the International Dialling Code: +31 and omit the first zero. In Amsterdam the city code (020) is not required.

Dutch

Die Port van Cleve

The restaurant of this 4-star hotel is the place to try the authentic cuisine of the Netherlands in stylish and sophisticated surroundings.

Nieuwezijds Voorburgwal
176-180 (Dam)
Tel: 020 624 0047

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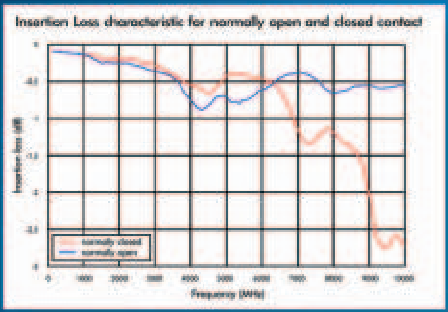

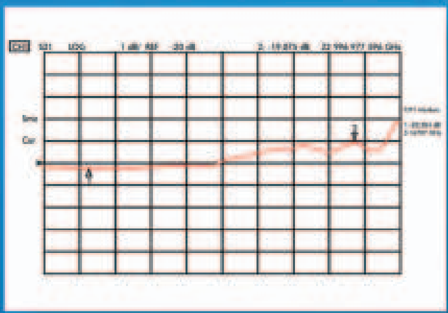

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Leidsegracht 84
Tel: 020 6260802

Chinese

Nam Kee

In the heart of Amsterdam's small but growing Chinatown, the restaurant's many Chinese visitors are a testimony to its authentic Chinese kitchen. More of a Chinese-style 'diner' it has expanded its seating space over the years, but its popularity means that sharing a table with others is the norm, rather than the exception.

Zeedijk 111 (Nieuwmarkt)
Tel: 020 639 2848

French

De Belhamel

Decorated in Art-Nouveau style with many original details, the restaurant offers splendid views over two of Amsterdam's most beautiful canals. The cuisine has French-Italian origins, but the menu also offers traditional Dutch dishes. The food is original, of high quality and pleasantly priced.

Brouwersgracht 60
(Beginning of Herengracht)
Tel: 020 622 1095

Greek

De Twee Grieken

This restaurant offers a traditional Greek atmosphere in which to eat good food at reasonable prices.

Prinsenstraat 20 (Westerkerk)
Tel: 020 625 5317

Italian

Cinema Paradiso

As the name suggests, this restaurant used to be a cinema. The former auditorium is now the main dining area of the restaurant, with an open kitchen to one side. It is only possible to book a table for parties of eight persons or more.

Westerstraat 184- 186 (Jordaan)
Tel: 020 623 7344

Pasta e Basta

The name means as much as pasta and don't nag. The dining experience in this beautiful building is not restricted to good pasta and fine wine as the staff will reveal themselves as good singers and dancers too as they perform at your table. Early booking required.

Nieuwe Spiegelstraat 8
Tel: 020 422 2222

Toscanini

Although this authentic restaurant prides itself on home-style regional Italian cooking, prepared in an open kitchen, the one thing that you won't find is pizza. Book early to ensure getting a table.

Lindengracht 75 (Jordaan)
Tel: 020 623 2813

Japanese

Tokyo

This large all-in-one restaurant offers a sushi bar, teppanyaki tables and traditional Japanese cuisine, providing a unique taste of the Orient.

Spui 15
Tel: 020 489 7918

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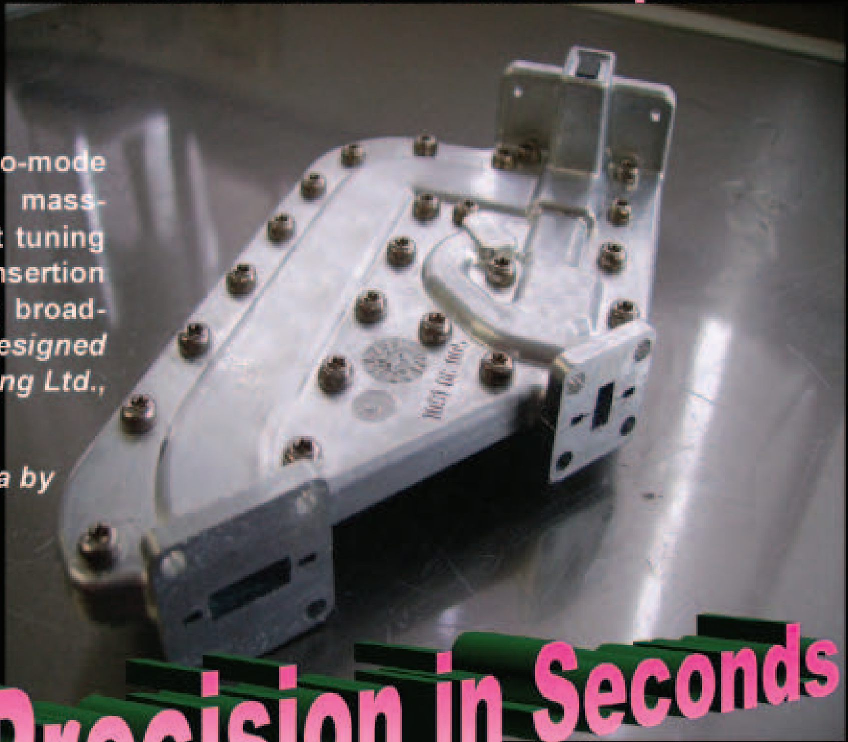
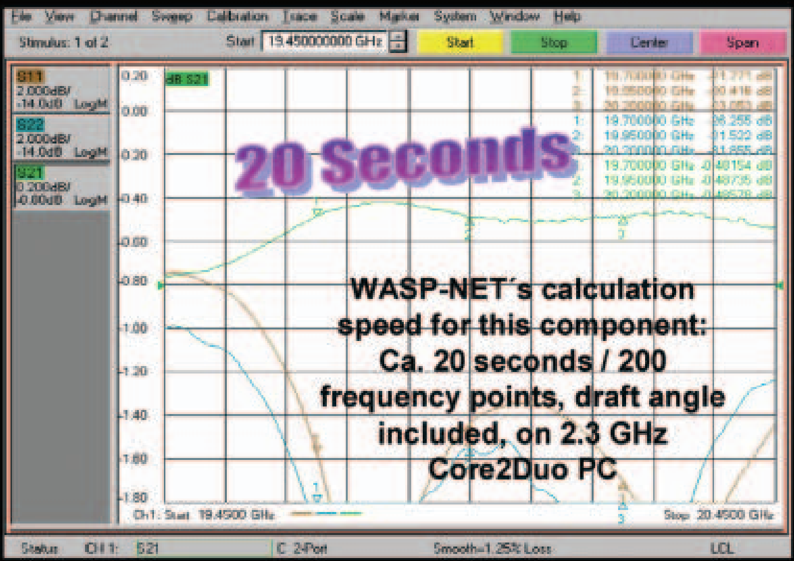


Example: K/Ka dual-band ortho-mode transducer (OMT) in low-cost mass-production casting technique without tuning screws (>20dB return loss, <0.5dB insertion loss, >90dB isolation), for domestic broadband satellite internet applications. *Designed and fabricated by RAVEN Manufacturing Ltd., UK,* www.raven.co.uk

Photograph and measurement data by courtesy of RAVEN.

EM CAD Precision in Seconds



WASP-NET´s pioneering hybrid CAD engine uniquely exploiting four EM solvers, utilizes automatically the most efficient and appropriate method for every part of the structure (i.e. MM for waveguides, MoM for antennas, for more general 3D portions MoM, FE or FD), and yields precise EM design optimizations, which are up to three orders of magnitude faster than more standard approaches.

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Mexican

Rose's Cantina

Located on the street that runs parallel to the floating flower market, the restaurant opened in 1980 with seven tables and an old piano. The piano has gone and it can now seat up to 280 people, but the atmosphere is still lively and the food is authentic.

Reguliersdwarsstraat 40
(Flower Market)
Tel: 020 625 9797

Spanish

Centra

Located in the red light district, Centra is a very good restaurant offering traditional food at reasonable prices with the paella being a speciality.

Lange Niezel 29
Tel: 020 622 3050

Vegetarian

De Bolhoed

The long established and bohemian 'Bowler Hat' restaurant has a picturesque canal-side location and endeavours to serve organic food, where possible, in an amiable and relaxed atmosphere. The food is decidedly modern, with tasty stir-fries and burritos, etc., on offer.

Prinsengracht 60 (Jordaan)
Tel: 020 626 1803

Vliegende Schotel

One of the healthiest places to eat in Amsterdam, the 'Flying Saucer' restaurant offers an extremely varied, mainly vegetarian menu with most tastes catered for. Vegans are welcome and there are even fish dishes for non-vegetarians. All food is freshly prepared from fresh produce.

Nieuwe Leliestraat 162-168
(Jordaan)
Tel: 020 625 2041

International

Take a culinary trip around the globe without leaving the city boundaries.

Dam Plaza

Conveniently located on the busy Damrak, just opposite the famous Bijenkorf Department Store, and close to Dam Square and the Royal Palace, this restaurant offers a wide range of popular dishes from fish 'n chips, steaks and pasta dishes, to light meals and snacks.

Damrak 98
Tel: 020 626 22 00
Hemelse Modder

Oude Waal 9 (Old Centre)

Tel: 020 624 3203

De Ondeugd

Ferdinand Bolstraat 13
Tel: 020 672 0651

Kort

Amstelveld 12
Tel: 020 626 1199

Unusual Locations

For those who like to eat somewhere different, Amsterdam has a few that might fit the bill.

1e Klas
(First Class)

This 'grand cafe' style restaurant in Centraal Station's former first class buffet, which has been restored to its original late 19th century splendour, offers French cuisine at moderate

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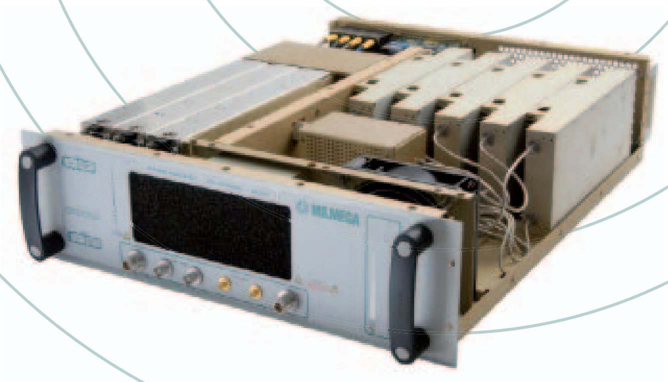

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▲ *Fig. 6 De Waag, a stunning middle-age weigh-house (courtesy of Amsterdam Tourism and Convention Board).*

prices. It has a beautiful interior with large windows and a monumental bar with mirrors and tall porcelain vases.

Platform 2b, Centraal Station
Tel: 020 625 0131

Pier 10

A former shipping line office with some tables that have dramatic harbour views (ask for them when you book). The seasonally adjusted fish and meat menu features dishes ranging from classical French to typically Dutch.

De Ruiterkade
Steiger 10, Pier 10 behind
Central Station
Tel: 020 624 8276

In De Waag

The location is a stunning middle-age Weigh-House. This magnificent historic building with its constrained yet informal interior design is lit by 300 candles, which adds to the dining experience (see ***Figure 6***).

Nieuwmarkt 4 (Old Centre)
Tel: 020 422 77 72

As this guide illustrates, Amsterdam has a great deal to offer. Use it to have a good time away from the show and enjoy your visit. ■

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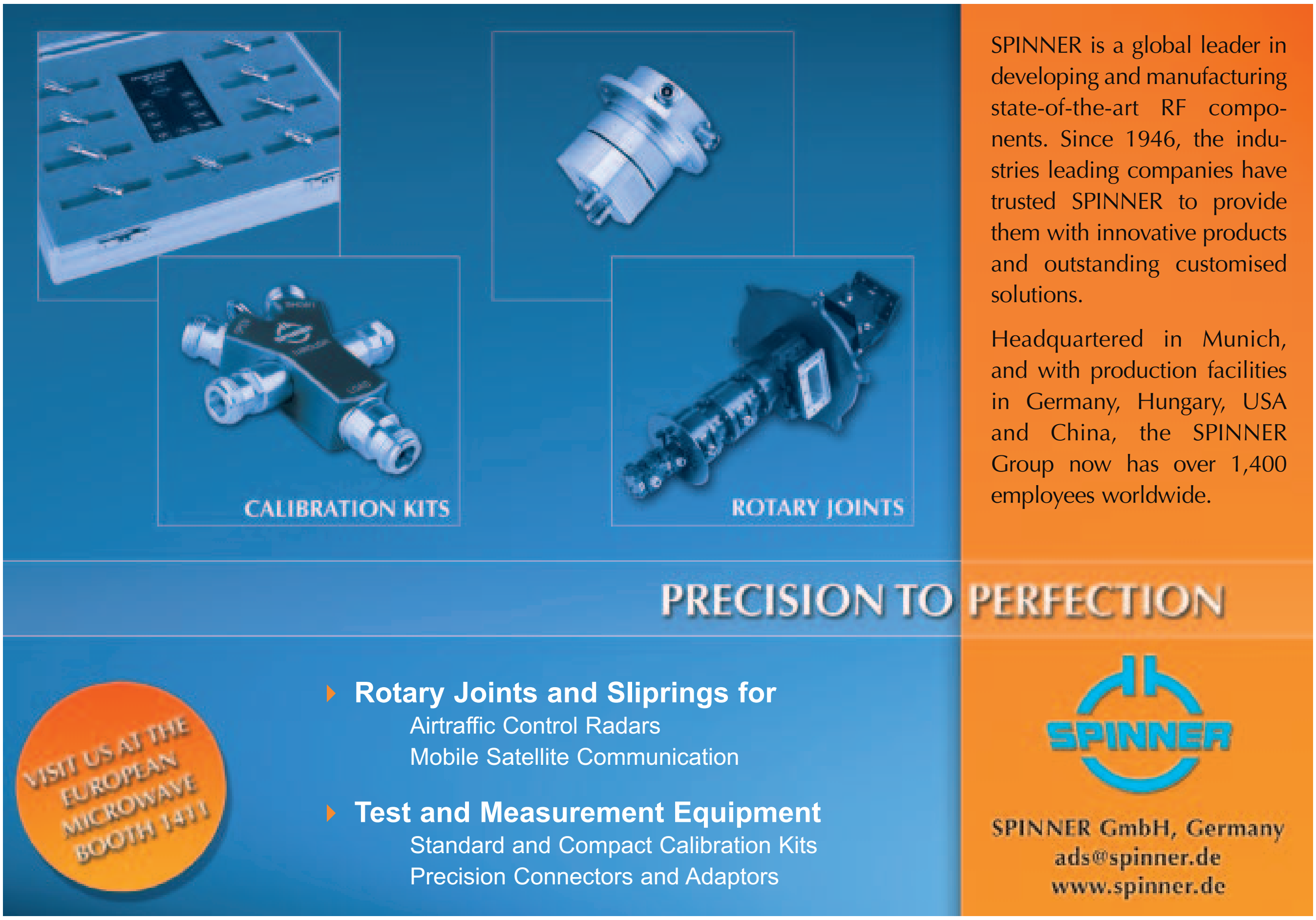

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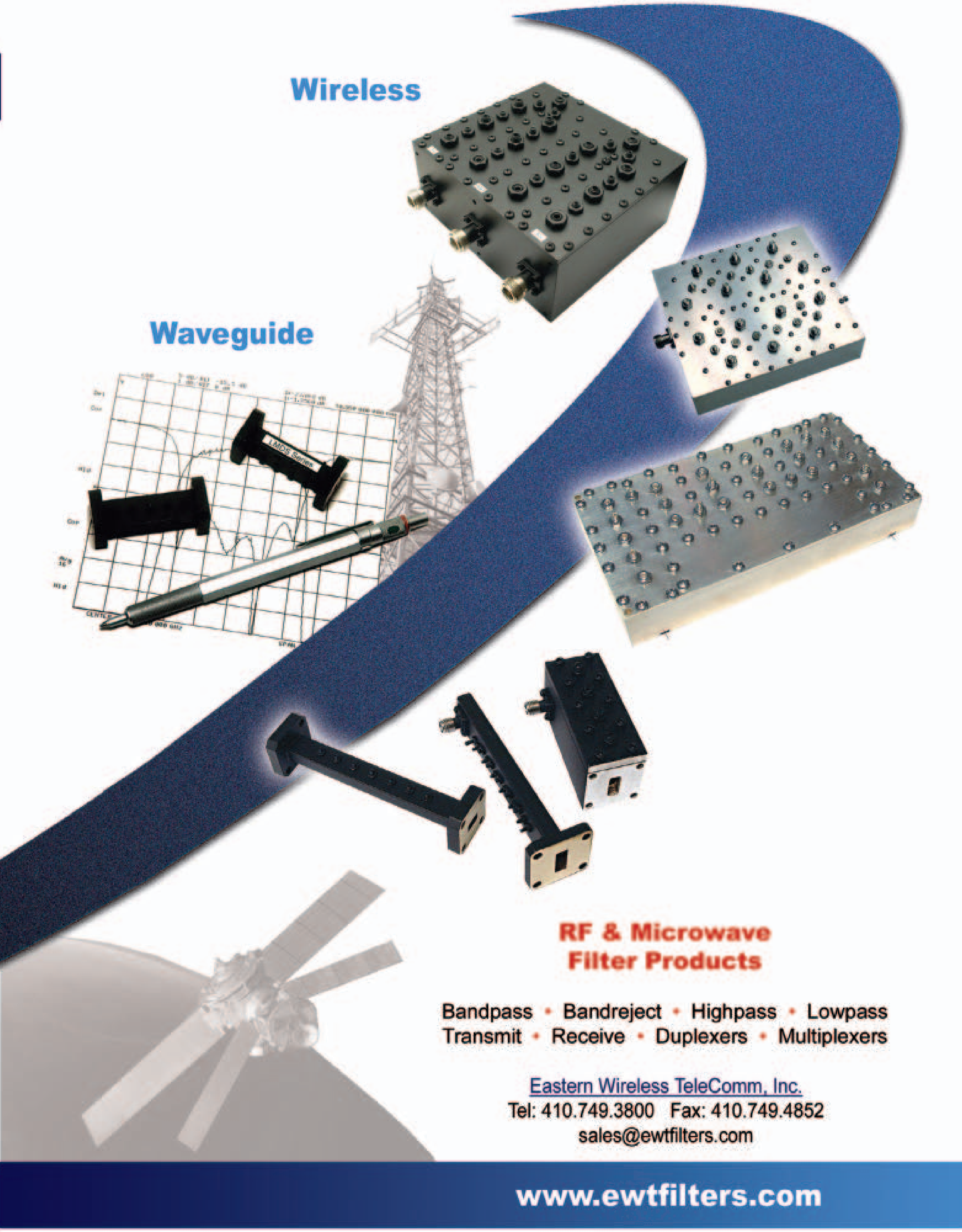

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The History and Evolution of European Microwave Week

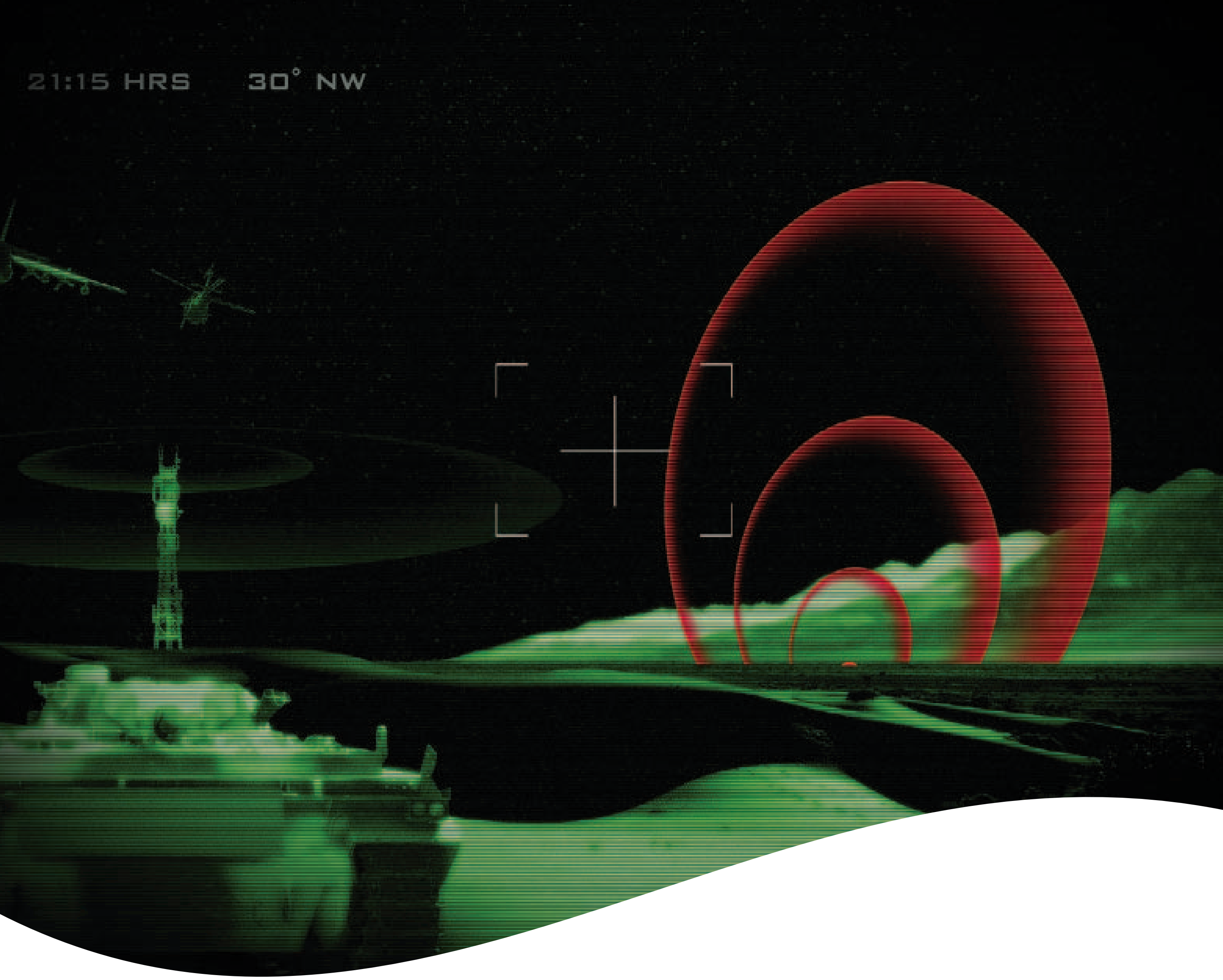
As European Microwave Week (EuMW) returns to its inaugural host city of Amsterdam, we would like to take the opportunity to outline the history of EuMW, the role of the European Microwave Association (Eu*M*A) and the latest developments. The story starts with Peter Clarricoats who, on joining GEC in 1953, began work on microwave ferrite devices and continued to do so when entering the university arena in 1959. However, at that time, there was also interest in gaseous plasmas in the context of the re-entry of manned space vehicles that lost communication signals during a critical period. There was a suggestion that the application of a magnetic field could, as with ferrites, change the properties of the plasma and allow signals to propagate and communication to be restored.

Because of the similarities between ferrites and plasmas, Clarricoats suggested to the IEE, now the IET, that an international conference should be held. In the early 1960s, an international conference was a totally new idea for the IEE, but Clarricoats' powers of persuasion prevailed, and he organised and chaired the International Conference on Ferrimagnetics and Plasmas. It was a success, attracting some of the most famous microwave names of the day from both the US and Europe.

In 1967, when the IEE committee came to review the concept of a second conference on ferrimagnetics and plasmas, Clarricoats suggested that they should hold an International Microwave Conference instead. Another member of the committee, Eric Ash, went a stage further and suggested a European Microwave Conference. The Committee Chairman and natural microwave leader in the UK at that time was Professor Harold Barlow of University College London, and he was designated as Conference Chairman. Later, Ash became co-chairman. The members of the Organising Committee represented various institutions, with large numbers of corresponding members, resulting in an impressive group of individuals. The opening ceremony of the 1st European Microwave Conference (EuMC) was held in September 1969 at the IEE, Savoy Place, London (see ***Figure 1***). Interestingly, the conference fees were £15 for members of sponsoring bodies for the five-day conference.[1]

The conference was a success and the IEE made the decision to take the next EuMC to Stockholm, Sweden, in 1971. It is worth mentioning that in those days there were two chairmen: the General Chairman and the TPC Chairman. The former took care of everything, in-

Roberto Sorrentino and André Vander Vorst
European Microwave Association, Belgium



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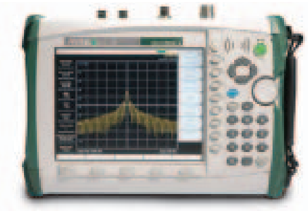

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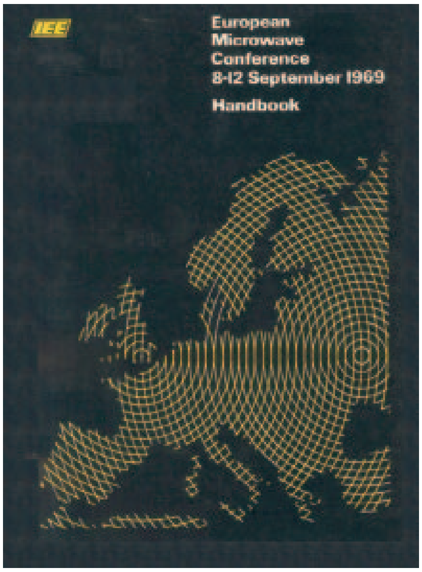


Fig. 1 The first EuMC handbook from 1969.

cluding the receptions, general organization, hotels, etc., while the TPC Chairman was, together with his committee, in charge of the 'scientific part'—evaluating the paper submissions, selecting the accepted papers, organizing sessions, appointing session chairs, etc.

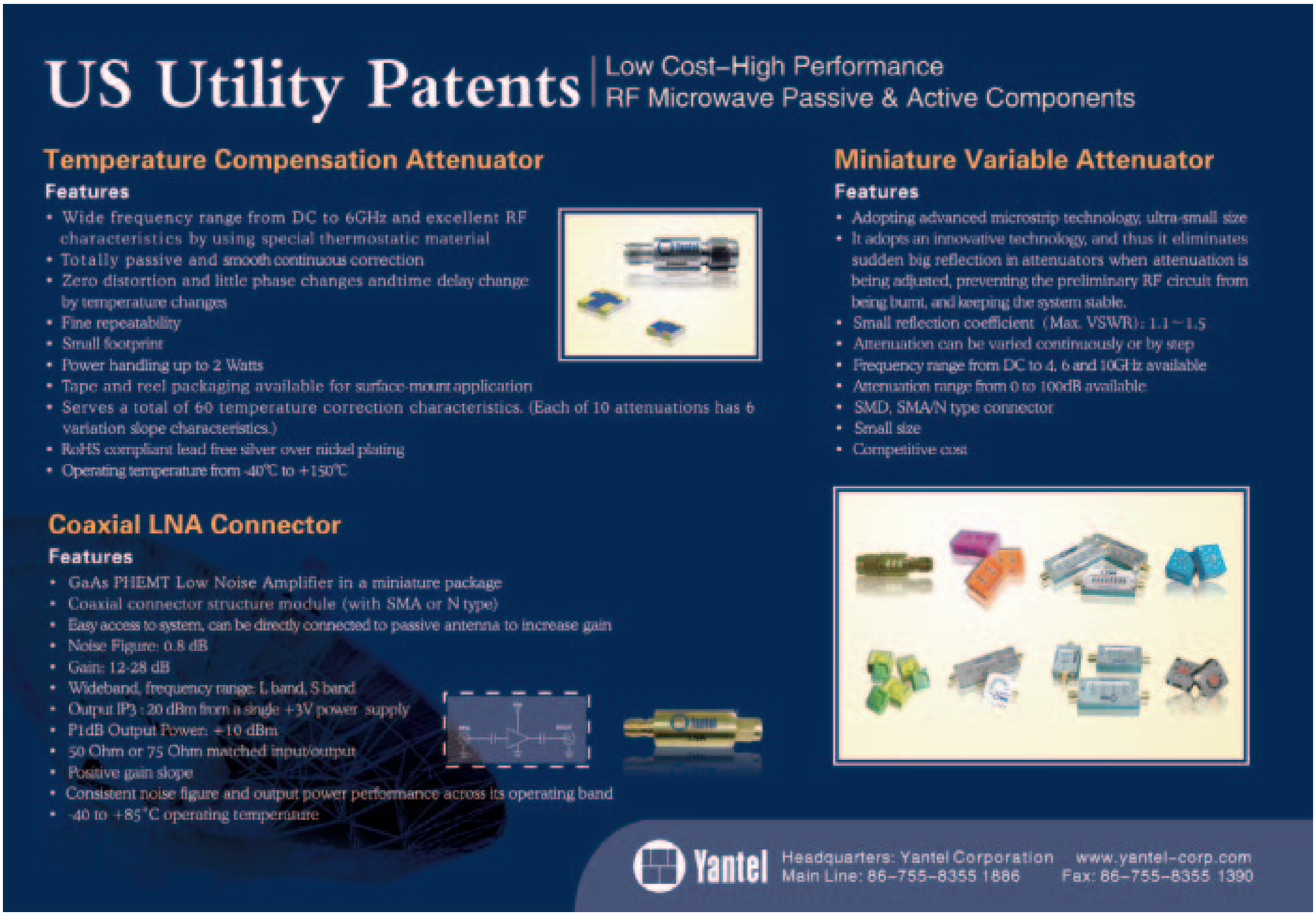
During the conference in Stockholm, it was proposed to host the EuMC in Brussels, Belgium, in 1973. R. Marriott offered its services to set up an exhibition and organize the conference, which came to fruition in Montreux, Switzerland, in 1974, and is described in detail in this referenced article.[2] The EuMC had now become an annual event and was organized with the support of a professional conference manager (MEPL), in association with an exhibition of manufacturers of microwave components, systems and test equipment.

Looking back, it is amazing to see how just a few dedicated people were able to set up the EuMC, especially when you realise that in Brussels in 1973 there were more than 700 registrants. The EuMC was very successful, very quickly. When we consider that today European Microwave Week attracts around 4,500 attendees—delegates, exhibitors and visitors—it is even more successful now.

There are certainly many reasons for such success. Besides, of course, the importance of microwave research and industries in Europe, one reason is certainly that the founders of the EuMC based the organizing structure of the conference, i.e. its Management Committee, on a strong and wide European representation, with members selected by a variety of organizations such as national societies, national committees of URSI and IEEE/MTT Society chapters.[3] The other key to its success is the combination of a high level and selective scientific conference with a technical exhibition, that was originally held every second year in conjunction with the EuMC.

A somewhat declining period began in the early 1990s with the reduction of investments in the military sector worldwide. After Roger Marriott withdrew and the professional organization of EuMC was put in the hands of other companies, the attendance started to decrease.

In 1995 the EuMC was held in Bologna, Italy, under the efficient chairmanship of Vittorio Rizzoli, but



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with virtually no exhibition. The Management Committee (MC) then decided to take suitable actions for the revival of the conference. It thus appointed a task force made up of four people (Vander Vorst, Raisanen, Madjar and Landstorfer) who drew the lines for putting the EuMC back on track and strengthening its role. Basically, a six-member Steering Committee (StC) to be elected by the MC (with one exception) was established as a more agile governing body; the EuMC was to be held only in five large European cities/countries with a significant microwave industry.

One member of the first StC was to be appointed by the Administrative Committee of the IEEE MTT Society, with the scope of establishing a good cooperation with MTT.

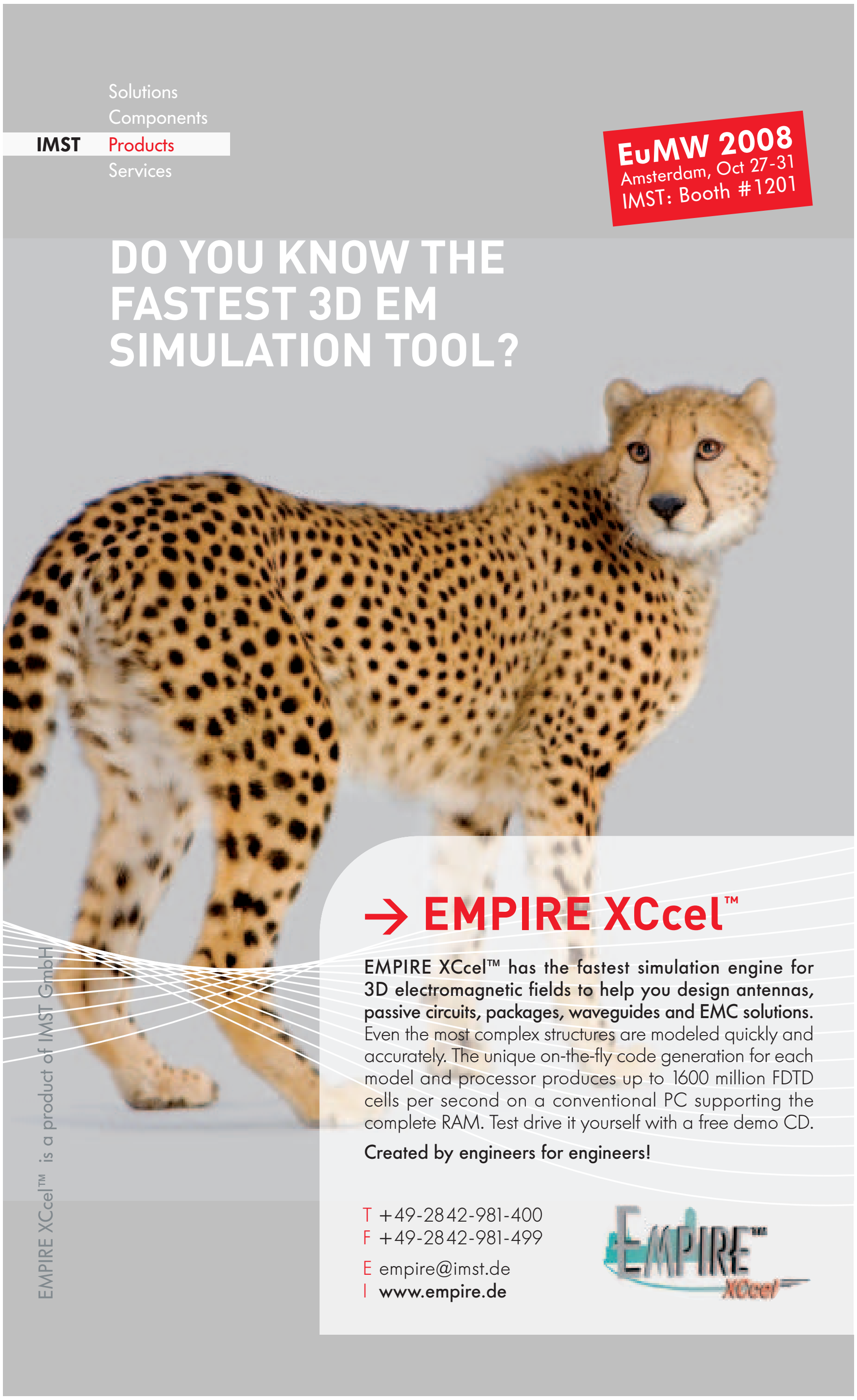
The first StC was formed in summer 1996. Leo Ligthart, Asher Madjar, Holger Meinel, Steve Nightingale and Roberto Sorrentino, the last as the Chairman, were elected by the MC, while Rolf Jansen was appointed by MTT. He resigned after one year and was replaced by André Vander Vorst.

One of the significant initiatives agreed by the MC was to organize a European Microwave Week, the core being the EuMC. The first European Microwave Week was held in Amsterdam in 1998 by adding to the well established EuMC two additional conferences in related areas, the Gallium Arsenide Application Symposium (GAAS) and European Wireless. After 10 years EuMW is recognized as the most important microwave event in Europe and the second in the world. It presently comprises the European Microwave Conference, the European Microwave Integrated Circuits Conference, organized in collaboration with the GAAS Association, the European Wireless Technology Conference, organized in collaboration with the IEEE-MTT Society, and the European Radar Conference, as well as tutorials, workshops and the European Microwave Exhibition.

EuMW is organized on a five-year cycle throughout Europe. The IQPC Military Radar Conference will be collocated with the EuMW in Amsterdam in 2008 and Horizon House is organizing the event, in conjunction with the Eu*M*A, for the sixth year.

The minutes of the StC meeting held in Munich, Germany, on 25 January 1997, record that, "The Chairman reported that he had discussed the creation of a legal entity for EuMC with Professor Vander Vorst. He intended to discuss this further and report back to the Committee at its next meeting." This was the beginning of Eu*M*A.

In 1998 the European Microwave Association was officially founded in Belgium as an international association with a scientific, educational and technical purpose. The aim is to develop on a non-profit basis, in an interdisciplinary way, education, training and research activities with the following goals: To promote European microwaves, to network and unite microwave scientists and engineers in Europe, to provide a single voice for European microwave scientists and engineers in Europe, to promote public awareness and appreciation of microwaves, to attain full recognition of microwaves by the European Union,



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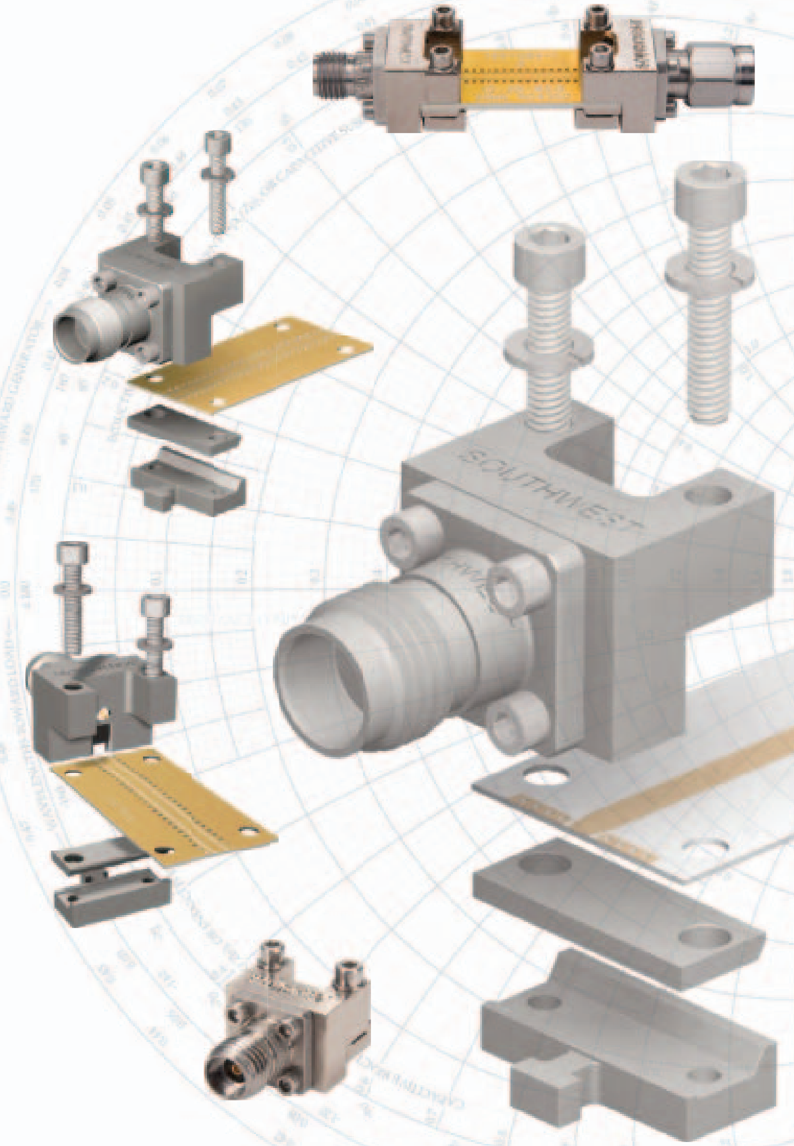

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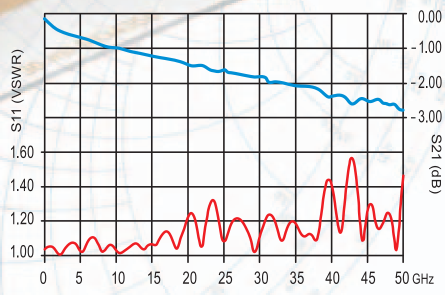

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to organize European Microwave Symposia and, in particular, the EuMC, as well as the EuMW and all the associated events, and to circulate information among European microwave scientists and engineers (www.eumwa.org).

The General Assembly is the highest governing body of the EuMA. Since 1998 the number of members has been increased to take national developments into consideration. It has recently been decided to include representatives from North America and Asia Pacific. This is a first step towards the creation of a truly trans-national association. We expect that this move will trigger similar and coordinated actions by other technical communities in Europe with whom EuMA has various collaborations.

Also, since its inception, EuMA has undertaken initiatives for better serving the microwave community worldwide. In 2003 the Association was opened to general membership, so that microwave engineers from all over the world could join as Members or Student Members. As a result, many EuMA members now come from the US and Asia. Members are entitled to discounted fees for attending EuMA and EuMA sponsored conferences and workshops, participate in EuMA activities, receive the EuMA Newsletter, and pay a discounted price both for the two EuMC DVD Archives that include all papers from the EuMC (1969 to 2003 and 2004 to 2008, respectively) and subscription to the *EuMA Proceedings*, a quarterly peer-reviewed journal, which is currently being revamped.

During European Microwave Week, EuMA is proud to acknowledge those individuals who have made exceptional contributions to the microwave community. In 2004, the Distinguished Service Award was established to, "recognize an individual who has given outstanding service for the benefit of the European microwave community and, in particular, for the advancement of the European Microwave Association." In addition, a new award, the Outstanding Career Award, will be presented for the first time in 2008 to recognize an individual, "whose career has exemplified outstanding achievements in the field of microwaves." Both awards will be presented during the opening ceremony of EuMW 2008.

As well as recognising the achievements of individuals, the EuMA also acknowledges the important position that European Microwave Week has established within the RF and microwave community and will endeavour to see it evolve and develop to meet the future needs of the industry. ■

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3. A. Vander Vorst and R. Sorrentino, "The European Microwave Association," *IEEE Microwave Magazine,* February 2006, pp. 54-56.

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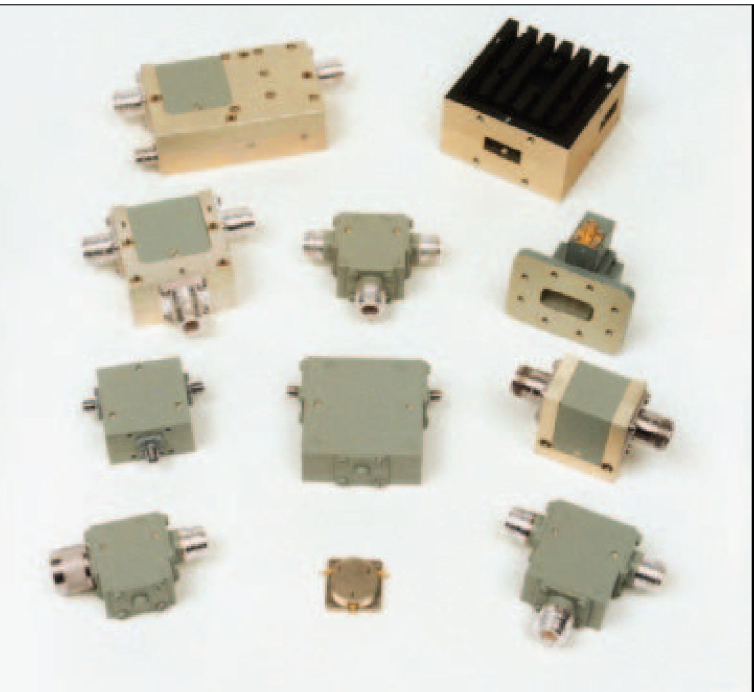

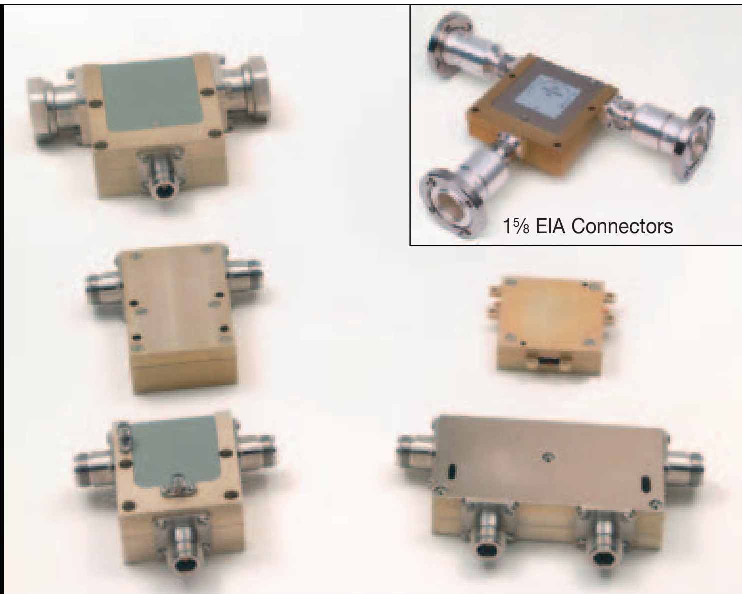

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CFS	L - K	1 Hz	2	-62	-75	-85	-89	-97	-110	14.84 GHz	13
Ku3LS	X - Ku	1 kHz	2.2	-62	-70	-75	-85	-97	-115	12.50 GHz	13
C3LS	C	1 kHz	1.1	-63	-88	-90	-100	-100	-115	5.50 GHz	13
UWB	S - K	1 kHz	Multioctave	-60	-71	-80	-90	-96	-105	12 GHz	13
MOS	VHF - K	1 kHz	Multioctave	-55	-65	-75	-85	-90	-100	20 GHz	13
SLS	L - Ku	125 kHz	1	-70	-80	-86	-88	-105	-115	3.3 GHz	13
SLFS	VHF - Ku	100 kHz	2	-70	-75	-80	-90	-115	-125	5 GHz	13
LFTS	VHF - Ku	100 Hz	1	-78	-88	-98	-98	-110	-130	350 MHz	13
VFS	L - Ku	>25 MHz	1.5	-60	-80	-110	-115	-115	-130	12.5 GHz	13

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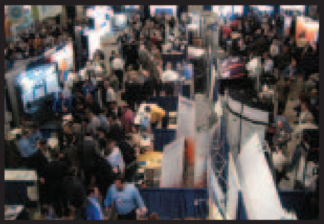
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CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
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CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Harris Corp. Conducts Successful Demonstration of Networked Maritime Radio

More than 50 representatives of the US Navy and industry attended a live, "over-the-ocean" demonstration of Harris Corp.'s new SeaLancet™ RT-1944/U tactical radio—designed to provide network-centric communications to both ground- and air-based networks. During the three-day series of demonstrations, Harris successfully showcased the radio's high-throughput, long-range network-centric IP communications capabilities. The demonstrations featured an aircraft simulating an unmanned aerial vehicle and three boats off the east coast of Florida as unmanned surface vehicles and tactical maritime platforms. Attendees witnessed real-time results of the radio's high-throughput transmission of voice (VoIP), data, files, chat and digital streaming video from multiple platforms to the simulated Littoral Combat Ship (LCS) radio room and command center. Network IP traffic was demonstrated between up to five nodes and at data throughput rates as high as 54 Mbps, and at distances between nodes of greater than 100 nautical miles. This also successfully demonstrated the ability to relay communications between surface modules at distances greater than 200 nautical miles via an airborne relay.

SeaLancet™ was designed to communicate high-volume sensor data from Navy platforms to distant tactical ships, such as LCS. Applications include anti-submarine warfare, mine warfare, anti-surface warfare, maritime interdiction, ship-to-ship communications and wireless pier capability. The highly ruggedized radio can survive submersion in water up to 1 meter and operate at high altitudes. In addition to its use onboard LCSs, the compact radio can be applied to a wide range of Navy platforms, including ships, aircraft, unmanned vehicles, gateway buoys and distributed sensors. It also addresses the needs of similar maritime missions for the Department of Defense (DoD), the US Coast Guard and international military forces.

Northrop Grumman's GPS OCX Team Completes CMMI Appraisal Method

The Northrop Grumman Corp. Global Positioning System Next Generation Ground Segment (GPS OCX) team recently completed the Standard Capability Maturity Model Integration (CMMI) Appraisal Method for Process Improvement (SCAMPI) software assessment, passing another significant milestone for the multi-billion dollar program and continuing Northrop Grumman's enterprise-wide audit successes.

GPS OCX will revolutionize the operations concept for command and control of existing GPS II and future GPS III satellites. OCX will provide new GPS mission planning, constellation management, ground antenna, monitoring station and satellite command and control capabilities benefiting GPS users worldwide. OCX will deliver a flexible architecture scalable to new missions, cutting-edge warfighting and civil net-centric capabilities and enhanced multi-level information assurance to address the growing cyber threat. None of these new mission capabilities is achievable with the current ground control system. The government uses SCAMPI appraisals to identify strengths and weaknesses of software, engineering and management processes and to reveal acquisition development risk for corrective action. These appraisals are frequently used as part of a process improvement program or for rating prospective prime contractors and their key subcontractors. The US Air Force GPS Wing concluded a multi-week, comprehensive software appraisal, thoroughly examining more than 1000 documents and measuring them against hundreds of criteria.

"The Northrop Grumman GPS OCX team in recent weeks has marched steadily forward in achieving major milestones under a stringent and thorough back-to-basic acquisition process established by the Air Force customer," said Steve Bergjans, GPS OCX vice president and program manager for Northrop Grumman.

Northrop Grumman is one of the two teams currently under contract to perform systems engineering and integration; architecture design; communications and network engineering; information assurance and security; modeling and simulation; network management; software development; support, maintenance and implementation; and test and evaluation. The Air Force is expected next year to choose one company to continue the program through development, deployment and sustainment.

Lockheed Martin Successfully Tests Common Electronics Warfare System for Navy

Lockheed Martin Integrated Common Electronics Warfare System (ICEWS)—a single enterprise solution designed to scale across all ship classes in the US Navy's surface fleet—performed successfully during a series of just-completed demonstrations conducted by the Navy. The at-sea demonstration of ICEWS, held beginning in June, followed recent land-based testing and further validates the enterprise approach that Lockheed Martin has taken in developing sensor systems for US Navy vessels.

Lockheed Martin's ICEWS electronic warfare (EW) solution will compete for the upcoming Surface Electronic Warfare Improvement Program (SEWIP) Block 2 contract award for the Navy's next generation upgrade to the AN/SLQ-32 (V) Electronic Support Measures system. SEWIP Block 2 will upgrade the receiver and antenna capabilities, as well as the combat system interface, of the legacy surface EW system. Lockheed Martin was specifically designed to provide a sensors capability upgrade, as well as built-in system commonality, to the AN/SLQ-32 (V) system. The modular ICEWS—which use common electronics across the enterprise system—will provide the Navy with the latest surface EW capabilities, as well as enhanced agility to upgrade technology as it becomes available to address changing and emerging threats. ICEWS will also provide proven cost savings and ease of maintenance through the use of COTS components.

Raytheon's SLAMRAAM Completes System Field Integration Testing

Raytheon Co.'s Surface Launched Medium Range Air-to-Air Missile (SLAMRAAM) successfully completed system field integration testing at White Sands Missile Range, NM, demonstrating interoperability with both Patriot an Avenger weapon systems. "Successful integration testing will help put this much-needed air defense capability into our warfighter's hand," said Pete Franklin, vice president for Raytheon Integrated Defense Systems, National and Theater Security Programs. "Interoperability is the key to enhanced situational awareness." SLAMRAAM demonstrated its ability to form a network of sensor elements tracking live targets and providing each battlefield element with a common air picture with fire quality data. Avenger fire units with Stinger missiles under SLAMRAAM command and control received targeting data directly from the SLAMRAAM system, allowing precise slew-to-cue of the gunner turret to targets. SLAMRAAM and Patriot exchanged and displayed unit position and air track data to form a common operational air picture between the two air defense systems.

SLAMRAAM interoperability testing demonstrated that these systems could work together to cover a large battlespace and allow the most appropriate weapon to engage a particular threat. SLAMRAAM also demonstrated the ability to communicate while on the move, maintaining both ground situational awareness and a live air picture at fire units to support hasty emplacements and engagements. "This was a great collaborative effort from the SLAMRAAM contractor and government team, demonstrating a distributed network in a field environment as we move away from stovepipe systems to a system that is interoperable with other air defense systems," said Susan Christiansen, the Army's SLAMRAMM deputy product manager. SLAMRAAM is a tailorable, state-of-the-art defense system that can defeat current and emerging cruise missile threats and a wide range of air breathing threats. It provides the warfighter with a system of highly mobile battlefield elements networked and geographically distributed to provide integrated fire control capability against airborne threats. ■

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Semiconductor Makers Team Up for eWLB Technology

STMicroelectronics (headquartered in Switzerland), STATS ChipPAC (Singapore) and Infineon Technologies AG (Germany) have signed an agreement to jointly develop the next-generation of embedded Wafer-Level Ball Grid Array (eWLB) technology, based on Infineon's first-generation technology, for use in manufacturing future-generation semiconductor packages.

ST and Infineon, two of the world's leading semiconductor makers, have joined forces with STATS ChipPAC, a leader in advanced 3D packaging solutions, to fully exploit the potential of Infineon's existing eWLB packaging technology, which has been licensed to ST and STATS ChipPAC. The new R&D effort, for which the resulting IP will be owned by the three companies, will focus on using both sides of a reconstituted wafer to provide solutions for semiconductor devices with a higher integration level and a greater number of contact elements.

The eWLB technology uses a combination of traditional 'front-end' and 'back-end' semiconductor manufacturing techniques with parallel processing of all the chips on the wafer, leading to reduced manufacturing costs. This together with the increased level of integration of the silicon's overall protective package, in addition to a dramatically higher number of external contacts, means the technology can provide significant cost and size benefits for makers of cutting-edge wireless and consumer products.

ST's decision to work with Infineon to jointly develop and use this innovative technology marks an important milestone for eWLB on its way to becoming an industry standard for cost-efficient and highly integrated wafer-level packages. The company plans to use the technology in several products in wireless and other application markets, with first samples expected by the end of 2008 and production capability by early 2010.

£236.5 M Investment in UK Science and Technology

The UK's Science and Technology Facilities Council (STFC) has earmarked £236.5 M for investment to develop large-scale research facilities and projects in its science portfolio. The investment, which was announced by the Department for Innovation, Universities and Skills (DIUS), is being made available through the UK Government's Large Facilities Capital Fund.

The approved projects include: £30 M for a new Detector Systems Centre based jointly at the STFC's Daresbury and Harwell Science and Innovation Campuses; £25 M for ISIS Target Station 2, STFC's world-leading pulsed neutron and muon source facility at the Rutherford Appleton Laboratory; £92.5 M for the Diamond Light Source, in which STFC has an 86 percent shareholding, for the design and construction of an additional ten beam lines; £15 M for the Square Kilometre Array to develop the first prototype phase of this next generation global radio telescope; £50 M for the Hartree Centre, an advanced computational science centre at Daresbury; and £24 M for a new Imaging Solutions Centre based at Harwell.

In collaboration with key stakeholders, STFC will now develop a detailed science and business case for each approved project for endorsement by Research Councils UK (RCUK) and submission to DIUS prior to funds being formally committed.

Commenting on the announcement, STFC's chief executive, professor Keith Mason, said, "The announcement of £236.5 M is a major addition to STFC's three-year investment programme of £1.906 B and will further ensure the UK remains at the forefront of international scientific research."

EADS to Aid German Armed Forces and NATO Modernisation

EADS Defence & Security (DS) will modernize the identification systems of the German Armed Forces and of NATO's early warning aircraft in order to meet the latest air traffic control standards and to increase safety in air traffic. Defence Electronics (DE), an integrated activity of DS, has been awarded a contract covering the modernisation of approximately 600 STR2000 transponder systems in order to comply with the new international Mode S standard.

The 'transponders' on board aircraft and helicopters emit flight data regarding the course, speed, etc. to ground stations or other aircraft thus enabling precise identification and flight control. This facilitates air traffic control and helps to avoid collisions. Pursuant to international regulations, all aerial vehicles of the German Armed Forces need to be equipped with this new technology by April 2009 at the latest. STR2000 ensures the identification of not only civil but also military aircraft.

In addition to the STR2000 emitters, DE also produces the 'interrogators' in the form of the Monopulse Secondary Surveillance Radar (MSSR) 2000 I secondary radars, which are used as receivers on the ground or on board ships and form an air traffic control network together with the transponders.

"Air traffic, especially in Europe, has become so dense," explained Bernd Wenzler, CEO of Defence Electronics, "that air traffic control can no longer manage without automatic identification systems. In this way, our transponders are making an important contribution to the safety of our citizens in everyday life."

BAE Systems Extends Royal Navy's Radar Capability

In a contract worth £100 M, the UK Ministry of Defence has selected the Advanced Radar Target Indication Situational Awareness and Navigation (ARTISAN) 3D radar to provide the next generation of medium range radars (MRR) for the majority of the current Royal Navy (RN) surface fleet and for the Future Aircraft Carriers.

ARTISAN 3D is the culmination of a three-year industry private venture programme to develop a new generation of radar that builds upon a family of mature technology from the BAE Systems existing portfolio of radars. It will replace the RN's legacy Type 996 surveillance and target indication radar.

The ARTISAN 3D Radar Team comprises BAE Systems, QinetiQ and Roke Manor Research and thus comprises the core of UK industry's surface radar research. These three companies have a pedigree and heritage at the very heart of UK radar development epitomised by the established relationship on the UK ARTIST programme.

ARTISAN 3D will improve the performance of the RN's primary sensing capability, particularly in terms of meeting the challenges posed when operating in a complex littoral environment. When integrated into the overall combat system, ARTISAN 3D will enable marked improvements in the platform's overall situational awareness and exploit the full capabilities of the updated Seawolf system.

Nokia and Qualcomm Enter New Technologies Agreement

Nokia and Qualcomm have entered into a new agreement covering various standards, including GSM, EDGE, CDMA, WCDMA, HSDPA, OFDM, WiMAX, LTE and other technologies.

Under the terms of the new 15-year agreement, Nokia has been granted a license under all Qualcomm's patents for use in Nokia's mobile devices and Nokia Siemens Networks' infrastructure equipment. Further, Nokia has agreed not to use any of its patents directly against Qualcomm, enabling the company to integrate Nokia's technology into its chipsets.

The financial structure of the settlement includes an up-front payment and on-going royalties payable to Qualcomm. Nokia has also agreed to assign ownership of a number of patents to Qualcomm, including patents declared as essential to WCDMA, GSM and OFDMA.

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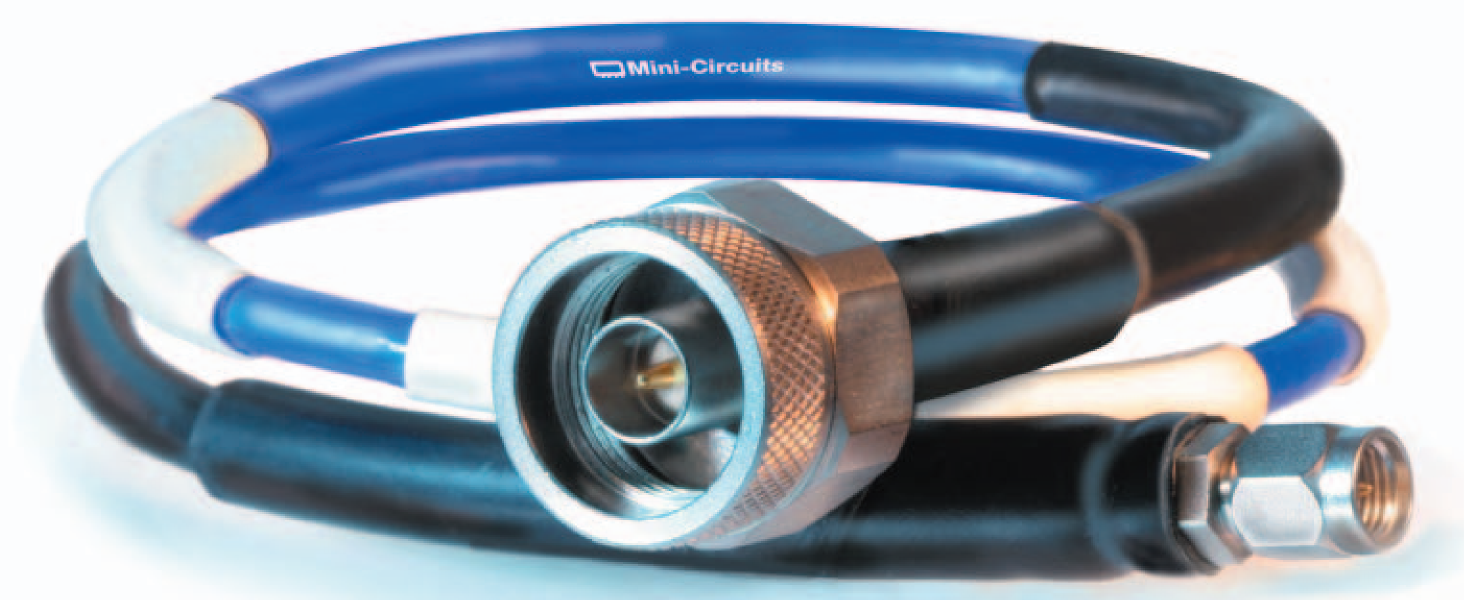

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CBL-5FT-SMSM+	SMA	5	2.5	27	77.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
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-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					
CBL-3FT-SFSM+	SMA-F to SMA-M	3	1.5	27	93.95
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
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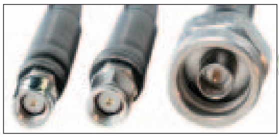

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High-power RFIC Markets Exceeding Even the Most Optimistic Forecasts

The penetration of high-powered RF integrated circuits into the mobile wireless base station market has surpassed even ABI Research's optimistic forecasts of last year. "The level of penetration of high-powered RFICs into the mobile wireless base station market right now exceeds what most observers would even suspect," says research director Lance Wilson. "It is a major force in the device market for base stations. These parts are shipping in the millions. The accepted wisdom about high-power RFICs simply no longer applies."

Over the past several years, this new breed of high-powered RFICs—primarily geared for use in base stations for cellular and other wireless infrastructure—has been quietly grabbing significant market share and will continue to do so at an increasing pace. The enthusiastic adoption of these ICs is due to three factors. Compared to the discrete devices they can replace, high-power RFICs are smaller; they are easier to use; and they cost the same or slightly less. This is a remarkably consolidated market. Between them, the three largest vendors have over 95 percent market share. In fact, cautions Wilson, "One major supplier controls so much of the RF high power amplifier RFIC market that there is a risk of permanent market distortion."

ABI Research's new report, "High-power RFICs," identifies the factors driving the RFIC market, discusses the device technologies and the vendor landscape, explains this technology's disruptive potential and contains new, accelerated forecasts. It forms part of two ABI Research Services: RF Power Devices and Wireless Semiconductors.

'Mobile Video' Includes 'Internet Video', but Operators Can Fulfill Needs

In the past year, two forces have emerged to radically change the definition of "mobile video," reports In-Stat. First, Internet delivery of user-generated and professionally produced content is moving viewers from their living rooms to their computers, the high-tech market research firm says. Second, high-quality mobile devices that use wireless networks (such as Apple's Wi-Fi iPhone and iPod Touch) are improving mobile access to the Internet in general. As a result, "Internet video" increasingly means "mobile video".

In-Stat identified two potential models for mobile TV viewing: "waiting room" and "leisure time" with very different requirements. David Chamberlain, In-Stat analyst, points out, "Personal devices such as cellphones and personal media players are preferred for the waiting room scenario. However, if there is more time available, survey respondents preferred larger screens on products such as mobile Internet devices or ultra-mobile PCs."

Recent research by In-Stat found the following:

- Mobile operator offering both 3G and out-of-band video content (such as MediaFLO, DVB-H or 1-Seg) have the near-term advantage fulfilling both leisure time and waiting room usage models.
- Over half of the respondents to an In-Stat US consumer survey reported watching Internet video in the previous 30 days.
- There is a strong preference for full-length shows rather than selected highlights tailored for mobile viewing.
- US survey respondents prefer monthly subscription fees to the purchase of video devices.

The research, "US Consumers Weigh in On Mobile Video Content Choices," covers the US market for mobile video. It provides analysis of a US consumer survey about mobile video. Data and analysis about how consumers perceive mobile video and their attitudes about different types of mobile video service are included.

Home Network Technologies Will Coexist, Not Compete

Consumer electronics products no longer exist in a vacuum: increasingly they are linked to each other via a number of short-range radio technologies. CE vendors, faced with a series of overlapping use-cases, network areas, standards and technologies, need to understand the applications best suited to each, and how they relate to each other.

Fortunately, short-range networking technologies are settling into more or less clearly defined roles, and will by and large complement each other rather than competing. "Technologies like Bluetooth, Wi-Fi, UWB, 60 GHz and ZigBee will not compete within the home," says ABI Research senior analyst Douglas McEuen, "but will be used in coordination, overlapping and coexisting for full wireless network coverage. Each of these technologies has a sweet spot or specialty. Bluetooth is the driving technology in the personal area network (PAN) and may see some success in remote controls, especially for gaming. Wi-Fi will be the key technology for wireless Local Area Network (LAN). UWB and 60 GHz respectively will be specialized for home office peripherals, and for wireless HDMI (uncompressed video sent from a set-top box to a high-definition TV) ZigBee stands apart, as home automation technology."

There are a few competitive counter-trends worth noting. Recently, Intel and OZMO Devices announced a program that uses standard Wi-Fi protocols to handle PAN tasks such as syncing notebooks with various PC peripherals and wireless consumer electronics. The Radio Frequency for Consumer Electronics (RF4CE) industry consortium has been formed recently to develop a new protocol for radio frequency remote controls that would compete with

Bluetooth to replace IR remote controls for audiovisual equipment. However, these are the exceptions that prove the rule. A new Research Brief from ABI Research, "Short-range Wireless in the Home Networking Environment," describes the landscape and examines the opportunities in the home networking market environment for the short-range wireless technologies. It forms part of two ABI Research Services: Short-range Wireless and Mobile Devices.

Weak Signals Do Not Work for Data

In-Stat reports that cellular infrastructure is usually not one of the most exciting topics to discuss in wireless, but that has started to change. As wireless operators have begun to deploy 3G and other wireless broadband technology, they have discovered that the grid of cell towers that worked fine for voice are not an ideal solution for data. The reasons are numerous and complex, but the top reasons are the higher frequencies which most wireless broadband technologies are using and which do not penetrate buildings as well as the lower frequencies, and the higher signal to noise requirements these technologies have if subscribers are to get data speeds anywhere near those advertised by operators.

A voice call that is suffering from a poor signal will usually stay connected until the signal is so bad that the call is dropped. The user might not get an indication that the signal is waning until the end when the caller's voice starts to break up and the inevitable drop call occurs. With a wireless data connection, a weak or noisy signal results in a slower data connection. As long as a voice call stays connected, the voice user feels like he or she is getting his money's worth, but the data user who is getting a 50 Kbps data rate instead of the advertised 1.5 Mbps may not be very happy and his impression will be that his service is not living up to that advertised.

Operators are aware of this problem, but getting a strong signal everywhere is much easier talked about than accomplished. In 2007, wireless operators worldwide spent on average $74 US on total infrastructure costs per cellular customer. Micro and picocell base stations can get the signal closer to the user and will be used more in the future, but while the base stations themselves are much cheaper than a macro base station, their capacity and coverage are much less. Still, operators may not have a choice once wireless data use becomes much more widespread. Another option that the operators can take advantage of is femtocells. These devices, installed in a home by the subscriber, can support three or four simultaneous subscribers, while the subscriber foots most of the backhaul costs, an operator's dream. ■

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2-32	30 ± 1	0.10	1.10:1	100w	C30-104-481/2*
2-32	50 ± 1	0.06	1.10:1	2500w	C50-101-481/1N
0.5-50	50 ± 1	0.10	1.10:1	2000w	C50-100-481/1N
0.5-100	30 ± 1	0.30	1.15:1	200w	C30-102-481/2*
0.5-100	40 ± 1	0.20	1.15:1	200w	C40-103-481/2*
20-200	50 ± 1	0.20	1.15:1	500w	C50-108-481/4N
20-400	30 ± 1	0.30	1.15:1	50w	C30-107-481/3*
100-500	40 ± 1	0.20	1.15:1	500w	C40-105-481/4N
500-1000	50 ± 1	0.20	1.15:1	500w	C50-106-481/4N

Directivity greater than 20 dB
* Available in SMA and N Connectors

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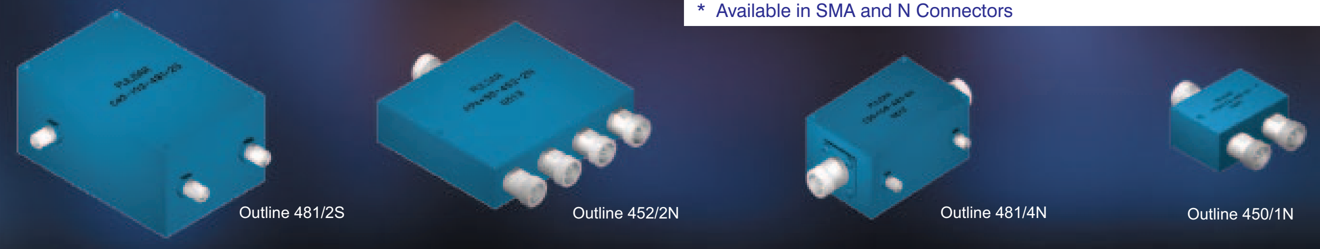
Freq. Range (MHz)	Isolation (dB)	Insertion Loss dB max.	Total Input Power max.	VSWR max.	P/N
2-Way					
800-1000	25	0.3	100w	1.20:1	PPS2-12-450/1N
800-2200	18	0.5	100w	1.40:1	PPS2-10-450/1N
1700-2200	20	0.4	100w	1.30:1	PPS2-11-450/1N
10-250	25	0.5	200w	1.20:1	PP2-13-450/50N
250-500	20	0.3	100w	1.30:1	PPS2-16-450/20N
500-1000	20	0.3	100w	1.30:1	PPS2-15-450/20N
4-Way					
20-400	20	0.6	400w	1.30:1	PP4-50-452/2N
100-700	25	1.2	25w	1.40:1	P4-P06-440
30-1100	20	1.5	25w	1.50:1	P4-P09-440
5-1500	20	1.5	25w	1.50:1	P4-P10-440

* Available in SMA and N Connectors



Outline 481/2S Outline 452/2N Outline 481/4N Outline 450/1N

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INDUSTRY NEWS

■ **Autoliv**, the world's largest maker of air bags and seat belts, announced it has agreed to buy the automotive radar sensors business of **Tyco Electronics** for $42 M. This part of the business unit designs and manufactures active radar proximity and attribute sensor systems used in vehicle driver assist and safety applications for the global automotive market. Based in Lowell, MA, US, and Schweinfurt, Germany, the business includes approximately 115 employees. It is Autoliv's expectation that the sales of the acquired business will approach $100 M within three years. In 2009, Autoliv expects the business will have an accretive earnings per share effect and should be accretive to operating margin and return on capital in 2010. Autoliv said it expected the deal to close by the end of this month.

■ **CAD Design Software**, a supplier of new technology EDA layout tools, and **CADParts & Consulting**, a provider of PCB design services, announced that CADParts & Consulting has entered into a VAR agreement with CAD Design Software to sell and support CAD Design Software's line of design and layout tools, with a focus on PCB, RF/microwave, flex and hybrid/MCM (LTCC) technologies. Additionally, CADParts & Consulting is integrating several seats of CAD Design Software's Electronics Packaging Designer (EPD) into its development flow to further support their design customers.

■ **COM DEV International**, a global designer and manufacturer of space hardware subsystems, announced it has opened a new state-of-the-art engineering and production facility in El Segundo, CA. The 46,000 sq. ft. COM DEV USA (CDU) headquarters is located at 2333 Utah Avenue in El Segundo, CA. Currently, 100 employees have been assembled to support the design, production and testing of space hardware. Company representatives estimate that a total of 200 new jobs will ultimately be created as a result of the new facility.

■ The enhanced capabilities of a new global satellite communications (SATCOM) system were successfully tested recently by **MIT Lincoln Laboratory**, representing a major step forward in improving communications among US Department of Defense commands around the world. In March, Lincoln Laboratory completed its portion of the on-orbit testing of the first Widespread Global Satellite Communications (WGS) system, a constellation of geosynchronous satellites orbiting 22,300 miles above the equator, which provides worldwide high-capacity military satellite communication capabilities. The WGS system improves upon the X-band capability (between 7 and 9 GHz) of the current Defense Satellite Communications system to include "Ka-band" service (30 GHz ground to satellite, 20 GHz satellite to ground). These sophisticated new broadcast capabilities were tested in orbit by a ground-based Large Aperture Ka-band Test Terminal (LAKaTT), developed by Lincoln Laboratory.

■ MTNet, the CDMA Certification Forum (CCF) accredited conformance test lab established within the Ministry of Information Industries of the People's Republic of China, has standardized on the **Aeroflex** 6402 AIME CDMA test platform for 1xEV-DO Rev A and A-GPS testing. MTNet selected Aeroflex following a recent public tender to upgrade its CDMA test capability to include 1xEV-DO Rev A protocol testing as well as A-GPS protocol and minimum performance testing.

■ **Lenthor Engineering**, a California-based designer, manufacturer and assembler of RIGID-FLEX and FLEX printed circuit boards, announced the successful completion of its **Lockheed Martin** corporate audit resulting in Lenthor Engineering's approval for and addition to the Lockheed Martin corporate AVL. This approval solidifies Lenthor Engineering's position as a strategic defense industry supplier of flex and rigid-flex fabrication and assembly.

CONTRACTS

■ **Alion Science and Technology**, an employee-owned technology solutions provider, has been awarded a $7 M contract to perform a wide range of RF spectrum services at the National Oceanic and Atmospheric Administration (NOAA). The three-year contract was awarded by the Defense Technical Information Center through the Modeling and Simulation Information Analysis Center (MSIAC). Under the contract statement of work, any NOAA office can utilize Alion's expertise in RF propagation, satellite orbital dynamics, RF spectrum management, RF systems testing and specifications, antenna siting and analysis, and other areas that support RF.

■ **Endwave Corp.**, a provider of high frequency RF modules for telecommunications networks, defense electronics and homeland security systems, announced the award of an 18-month production contract from the **Boeing Co.** to supply broadband frequency converters used in the modernization of the United States Air Force's Airborne Warning and Control System (AWACS) 3035 system. AWACS provides survivable airborne surveillance, command, control and communications functions and early warning detection and tracking of low-level targets at extended ranges over land and water.

■ **OEwaves Inc.** has been awarded a contract by DARPA to develop a multi-function and reduced SWAP optical SIGINT receiver prototype that will significantly improve system configurability and platform compatibility for future SIGINT and EW systems. OEwaves will develop the photonic receiver front-end, and in collaboration with **ITT**, demonstrate the receiver system that will meet the stringent performance and SWAP requirements in the DARPA contract.

■ **LadyBug Technologies LLC** announced that the company has received additional, follow-on orders from the US Government for its PowerSensor+™ line of

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Features

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- > Wide Bandwidth
- > Good Amplitude / Phase Unbalance
- > Rugged Welded Construction
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RoHS COMPLIANT

Model #	Z Ratio (50:Z)	Frequency (MHz)	Schematic
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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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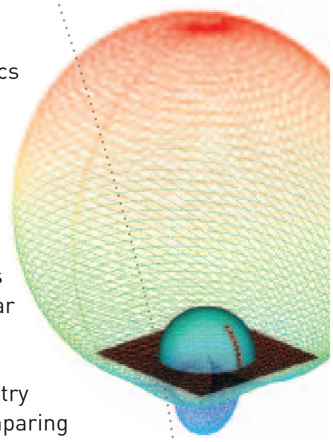
- Powerful parametric solvers

Other benefits:

- Incorporated Physical Optics (PO) along with the Moment Method
- Only tool in the market that handles Highly Lossy Materials
- Built-in FFT solver, for electrically large problems
- Accurate calculation of near field distribution
- Field distribution with any arbitrary, free form geometry
- Excellent match when comparing software results with experimental results



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miniaturized USB power meter-sensors. The most recent orders included LadyBug models LB479A and LB579A.

FINANCIAL NEWS

■ **RF Micro Devices Inc.** reports sales of $240.5 M for the fiscal 2009 first quarter ended June 28, 2008, compared to $211.6 M for the same period in fiscal 2008. Net loss was $24.1 M ($0.09/per diluted share), compared to a net income of $23.6 M ($0.11/per diluted share) for the first quarter of last year.

■ **Mimix Broadband Inc.**, a fabless semiconductor company, announced that it has secured $10 M of additional investment in its fourth round of institutional financing. The investment from **GaAs Labs** and participation in the round by existing investors will allow Mimix to pay off debt and provide working capital to the company for further growth in the diversified microwave and millimeter-wave marketplace.

NEW MARKET ENTRY

■ **AmpTech Inc.** announced availability of contract manufacturing foundry services at the company's fabrication facility in Milpitas, CA. The company offers Gallium Arsenide (GaAs) and Indium Phosphide (InP) processes targeted for RFIC and Optoelectronics applications. AmpTech operates a four-inch wafer fabrication line in a 15,000 square foot clean room within the company's headquarters facility. AmpTech has production-qualified processes for GaAs MESFETs and InGaP HBTs.

PERSONNEL

■ Ansoft Corp. founder, chairman and chief technology officer **Zoltan Cendes** received the Institute of Electrical and Electronics Engineers (IEEE) Antennas and Propagation Society (AP-S) Distinguished Achievement Award. The award, given to Cendes for his "contributions to the widespread use of user-friendly software tools for electromagnetic analysis and design," recognizes outstanding career achievements by an individual in the field of antennas and propagation. In addition to his responsibilities at Ansoft, Cendes is an adjunct professor at Carnegie Mellon in Pittsburgh, PA.

■ TriQuint Semiconductor announced that **Steven R. Grant** has joined the company as vice president of worldwide operations. Grant will be responsible for TriQuint's global manufacturing including purchasing, manufacturing quality and supply chain operations. Grant, who spent the last 27 years at Intel Corp., was most recently vice president of Intel's Technology and Manufacturing Group in Oregon. During his Intel tenure, he managed the Fab manufacturing network and was key to driving the manufacturing structure and efficiency improvements to record performance levels.

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- ✓*High 1 dB compression, up to +23 dBm*
- ✓*Extremely low conversion loss, from 6.3 dB*

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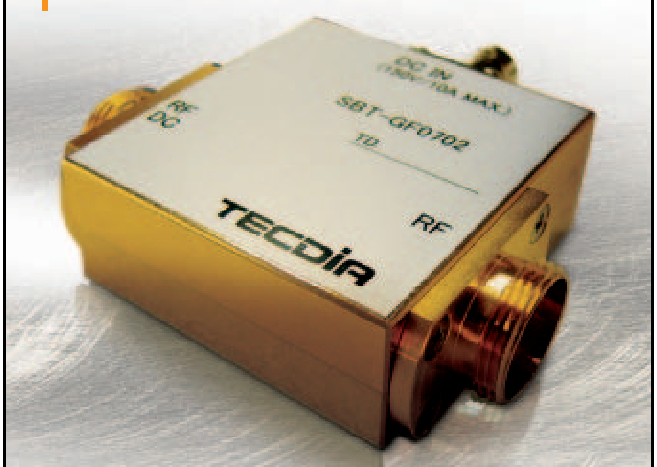


SBT-GF0702 BIAS-T

Tecdia introduces the SBT-GF0702 high voltage Bias-T.

The SBT-GF0702 is capable of handling up to 10 amps of DC current at 150V to apply bias to RF signals within the range of 2~7 GHz.
For many years Tecdia has produced top of the line high current (5, 10 and 20A) bias tee models capable of handling a DC bias voltage of 30V, and RF power of 50W. Now, to meet the higher voltage and power requirements of GaN devices, Tecdia is introducing this new design that has the following specifications :

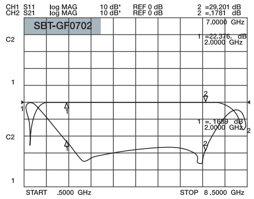
SPECIFICATION

Series		SBT	
Model		SBT-GF0702	
Frequency Range		2~7GHz	
Insertion Loss		0.5dB max.	
VSWR (Return loss)		1.22 max. (20dB min.)	
Connectors	RF	APC-7	
	DC	BNC-R (Female)	
RF Power		50W max.	100W max.
Bias Current		20A max.	10A max.
Bias Voltage		30V max.	150V max.
Dimensions (mm)*		50 x 52 x 20	
Weight		200g	

* Excluding Connectors

Typical VSWR & Insertion Loss

SBT-GF0702
These Bias-Ts are the optimum choice for measurement of high-power devices.



www.tecdia.com


▲ Eric Mariette

■ Radio Frequency Systems (RFS) has appointed **Eric Mariette** to the key role of vice president of global marketing and strategy. Mariette assumes responsibility for ensuring that RFS's comprehensive portfolio of RF solutions is fully visible to the global wireless sector, and that the company's rapidly expanding solution-set meets the varied demands of the industry. Mariette comes to RFS with 20 years' experience in sales, marketing and business operations in the telecommunications and IT sector, a great many of those years with communications solutions group, Alcatel-Lucent.

■ Tampa Microwave, a designer and manufacturer of RF and microwave communications and test equipment for various commercial and government applications, announced the appointment of **Obie Johnson** as vice president of new business development. Johnson will have responsibility for product marketing in addition to domestic sales development, key account support and management of the sales representative network. Prior to joining Tampa Microwave, Johnson was president of Intelligent Systems, Solutions and Services, St. Petersburg, FL.

■ Ducommun Technologies (DTI) announced that **Tommaso Pusateri** has joined its team as director of business development-millimeter products. He will be responsible for the global sales and marketing of the millimeter-wave products for DTI. Pusateri has a broad background in millimeter-wave technology with extensive experience in military applications, satellites, commercial communications, avionics, RF microwave and electronics markets. He was most recently with Crane Aerospace and Electronics in Chandler, AZ, as the company's director of business development where he was responsible for millimeter-wave sales and strategy.


▲ Bob Betz

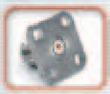
■ Smiths Interconnect, part of the global technology business Smiths Group, announced the addition of **Bob Betz** to its sales and marketing staff as senior applications engineer. Betz brings over 25 years of industry-related connector experience to Sabritec. His expertise is in the area of fiber optics, flex PCB termination, technical support and sales application engineering. Most recently, Betz was the regional sales manager for a major military aerospace connector manufacturer in southern California. Betz will be working closely with the company's customers and sales representatives to further strengthen its high speed copper, fiber optic, filtered and non-filtered multi-pin connector product lines. Betz can be reached by phone at (949) 250-1244 or e-mail: bbetz@sabritec.com.

REP APPOINTMENTS

■ **Digi-Key Corp.** and **Laird Technologies** announced that the companies have entered into a global distribution

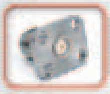
Field Replaceable SMA

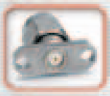

2 Hole, .625", with Ground Plane


4 Hole, .500", with Ground plane


2 Hole Diamond with Ground Plane


2 Hole, .550" with EMI Gasket


4 Hole, .500" x .375" with EMI Gasket


2 Hole, .625", Male, with EMI Gasket


Female Thread Mount


Male Thread Mount

Many other configurations available. Please specify .012", .015", .018" or .020" pins.

Performance

Frequency Range:	DC to 27 GHz
Voltage Rating:	335 V RMS (sea level)
Nominal Impedance:	50 ohms
DWV:	1000 V RMS @ 60 Hz (sea level)
Insulation Resistance:	10,000 megohms
Temperature Range:	-65°C to +165°C

Materials

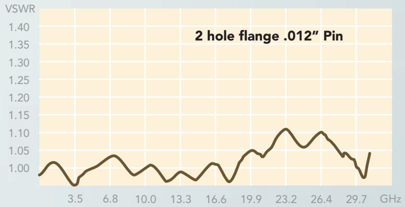
Dielectrics:	PTFE Fluorocarbon
Center Contacts:	Beryllium copper
Bodies:	SS303
EMI gaskets:	Silver filled Fluorosilicone rubber

Plating

Center Contacts:	Gold
Bodies:	Passivated

Pimp your components

Trick out your next design in one easy step with new, innovatively engineered field replaceable SMAs from San-tron. This simple switch will give you a boost in available frequency range—in some cases up to 31 GHz! When combined with VSWR performance of 1.07:1 from DC to 18 GHz and 1.25:1 or better through 26.5 GHz, your circuits will be fueled like never before.



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agreement. Laird Technologies products stocked by Digi-Key are featured in its print and on-line catalogs and are available for purchase directly from Digi-Key. The terms of this new distribution agreement will enable Digi-Key to fulfill the prototype as well as the production quantity needs of its very diverse customer base.

■ **Vishay Intertechnology Inc.** announced that it has signed a distribution agreement with **Yosun**, a major Asian distributor of electronic components. Under the terms of the agreement, Yosun will carry the complete line card of Vishay semiconductor and passive components, with the exception of foil resistors.

■ **Computer Simulation Technology** (CST) has appointed **AgetoMTT** as the company's sales representatives in Scandinavia. With offices in Sweden and Finland, AgetoMTT currently represents over 38 manufacturers within the field of RF and microwave products and services and will be utilizing its expert local sales and support to distribute CST's products in Sweden, Norway, Denmark and Finland.

■ **ClearComm Technologies LLC** announced the appointment of **Conifer RF Sales** headquartered in Olympia, WA. Conifer RF will cover the entire states of Washington and Oregon. This group brings a broad experience and complimentary products to ClearComm. ClearComm is a manufacturer of filters, duplexers, diplexers and RF assemblies covering the frequency range of 10 MHz to 18 GHz. Contact Conifer RF Sales at (360) 350-4720, e-mail: mark@coniferrf.com or visit www.coniferrf.com. To reach ClearComm Technologies, call (410) 860-0500 or e-mail: sales@clearcommtech.com.

■ **California Eastern Laboratories** (CEL) has signed **Amtele AB** to represent its growing line of ZigBee/IEEE802.15.4 radio modules. Based in Stockholm, Amtele will be the exclusive source for these CEL products throughout Sweden, Finland and the Baltics.

■ **W.L. Gore & Associates**, a leader in providing innovative technology solutions for the electronics industry, will supply GORE™ Camera Link® High Flex Flat Cable for use in Infini Flex™ Cable Assemblies manufactured by **Intercon 1**, a division of Nortech Systems Inc., and major global supplier of machine vision analog and digital video cable assemblies. Intercon 1 will be an exclusive reseller in North America and Europe for GORE Camera Link High Flex Flat Cables.

■ **Peregrine Semiconductor Corp.**, a supplier of high performance RF CMOS and mixed-signal communications ICs, announced that it has signed **Rich-Power Electronic Devices Co. Ltd.**, a member of WPG Holdings, to market and sell Peregrine's line of UltraCMOS™ RFICs throughout the Asia Pacific region, including Taiwan, China, Korea, India and the ASEAN.

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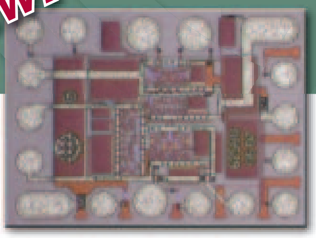

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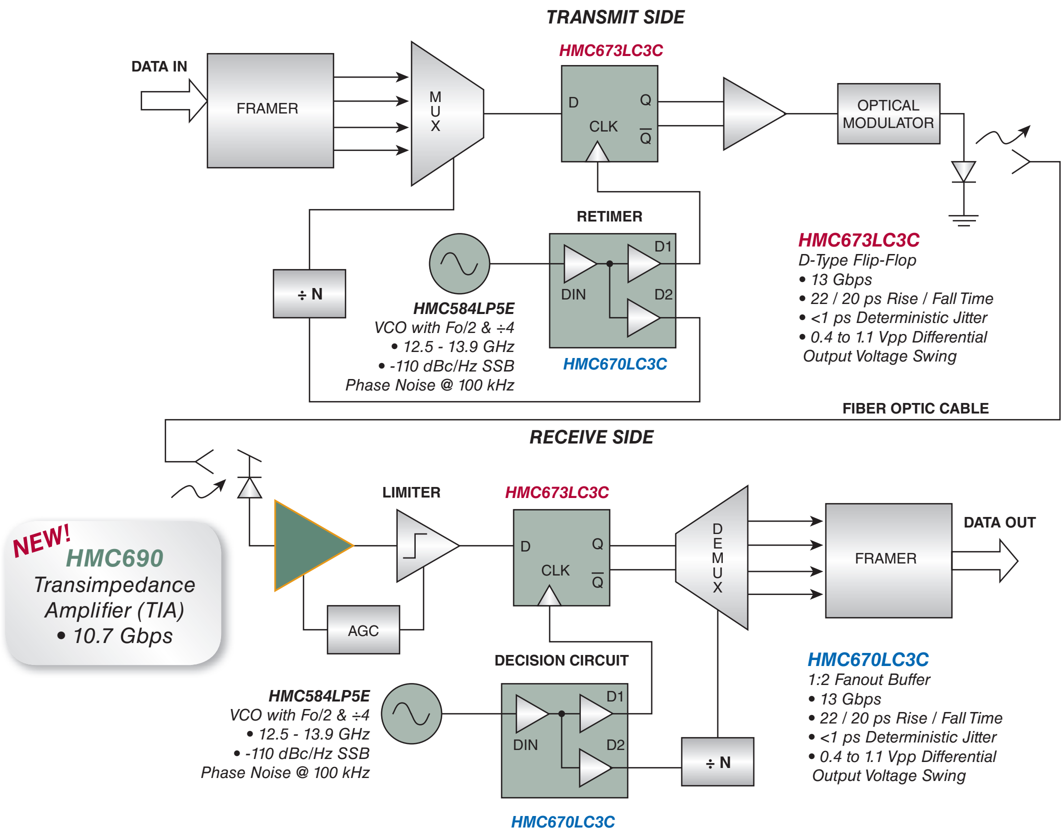

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AN INNOVATIVE AND INTEGRATED APPROACH TO III-V CIRCUIT DESIGN

In wireless handset design, specifically power amplifiers (PA), there is constant pressure to improve time-to-market while maintaining high yields. To meet these demands, designers need to evaluate current design practices and identify areas for improvement. Presently, most PA designers spend a great deal of time bench-tuning to optimize circuits. Since this is very time consuming, the main consideration is obtaining the best "nominal" performance, and process variation (or whether the wafer used for tuning is optimal) is generally an afterthought.

One common occurrence is that new circuit topologies are tried and minimal sample sizes are taken on a single wafer, often leading to "measured hero results." However, once the design is run over many wafers, normal process variations may result in large performance changes that may give unacceptable yield levels. These variations are often blamed on the starting material or the fabrication process but, in reality, are usually due to expected process variations.

Including process statistics in the simulation phase would greatly reduce the occurrence of these frustrating events. However, implementation of statistical simulations in microwave designs (and III-V designs, specifically) is very limited, even though it is well established in the silicon (Si) digital or analog-mixed signal worlds. What are the barriers? The methodology used in the Si design community is usually built around Monte Carlo (MC) simulations.[1-4] MC-based simulation is inherently time consuming, but necessary for most Si designs, where neighboring device mismatches are critical due to much smaller device sizes. The complicity and huge amount of time makes it "unfit" to III-V designs, where wafer turn-around time is much shorter (weeks rather than months, typical for Si designs). Si foundries may also provide "corner"

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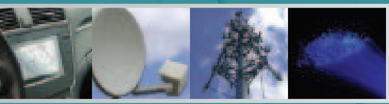

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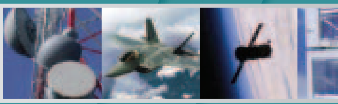
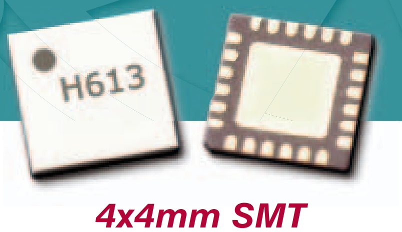
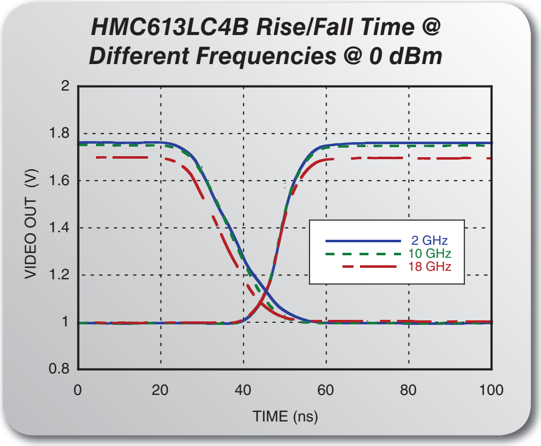




4x4mm SMT



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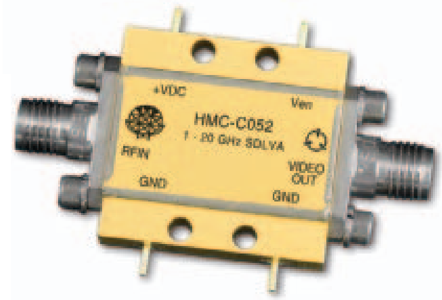

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	Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV / dB)	RF Threshold Level (dBm)	Bias Supply	Package	Part Number
NEW!	50 Hz - 3.0	Log Detector	74 ± 3	+19	-66	+3.3V @ 29mA	LP4	**HMC612LP4E**
	0.001 - 8.0	Log Detector	70 ± 3	-25	-61	+5V @ 113mA	LP4	**HMC602LP4E**
	0.001 - 10.0	Log Detector	70 ± 3	-25	-65	+5V @ 106mA	LP4	**HMC611LP4E**
NEW!	0.001 - 10.0	Log Detector	73 ±3	-25	-65	+5V @ 103mA	Chip	**HMC611**
	0.01 - 4.0	Log Detector	70 ± 3	19	-68	+3.3V @30mA	LP4	**HMC601LP4E**
	0.05 - 4.0	Log Detector	70 ± 3	19	-69	+3.3V @ 29mA	LP4	**HMC600LP4E**
NEW!	0.1 - 3.9	RMS / PAR Power Detector	71 ±1	37	-58	+5V @ 75mA	LP4	**HMC614LP4E**
	DC - 3.9	True RMS Detector	69 ± 1	37	-60	+5V @ 65mA	LP4	**HMC610LP4E**
NEW!	0.1 - 20	SDLVA	62	14	-57	+3.3V @ 83mA	LC4B	**HMC613LC4B**
	Connectorized Power Detector Modules							
NEW!	0.01 - 2.0	True RMS Detector	70 ±1	37	-58	+12V @ 95mA	C-6 / SMA	**HMC-C054**
NEW!	1 - 20	SDLVA	59	14	-67	+12V @ 86mA	C-10 / 2.92mm	**HMC-C052**

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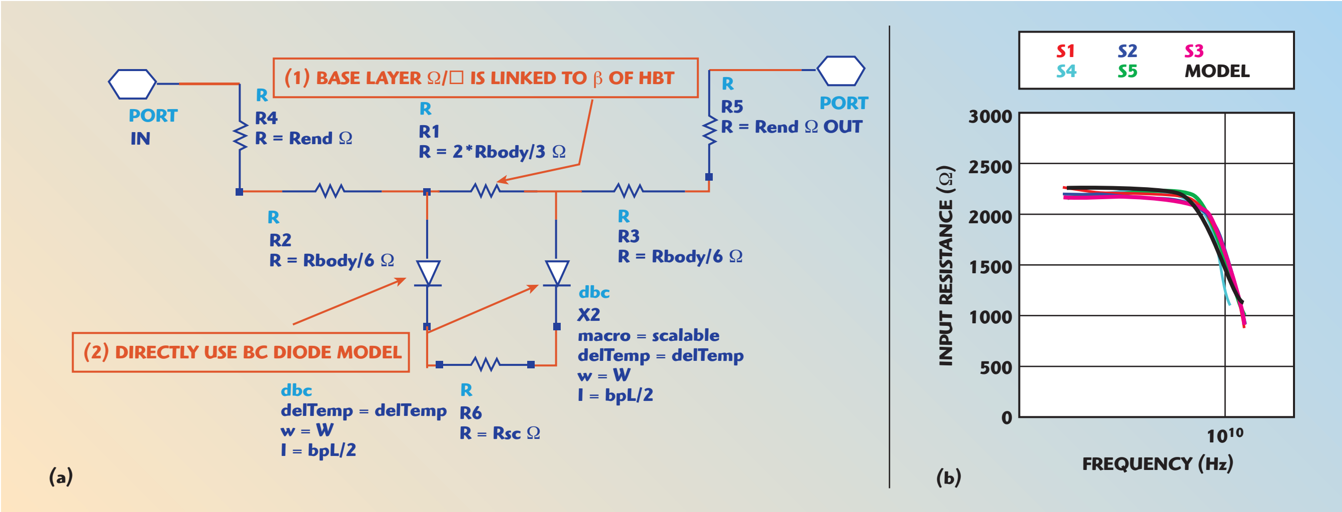

Fig. 1 Example of the unified modeling approach; (a) base layer resistor model and (b) predicted impedance drop.

models, but these are largely derived by driving figures of merit (like f_T) that are not appropriate for most RF designs, where multiple criteria are to be met in one design. Some also provide customers with the option of wafer lots that capture the expected process variation (due to changing process variables),[5] but do not provide a convenient way for customers to simulate exactly that set of wafers. Another major obstacle is the modeling approach of traditional GaAs devices, which is curve-fit-based rather than physics-based. The curve fitting makes it cumbersome, if not impossible, to provide a set of models that accurately tracks real-life process variations. Finally, most statistical analysis training focuses on using a particular software package, separate from the tool used for circuit simulation.[6] This creates a barrier, since designers often do not have the time to learn another piece of software (or do not want to further fragment the design flow).

To overcome these barriers, several key considerations are offered in the development of a statistical-simulation-included designer-friendly design flow.

The approach should:

- Be predictive and approximate—real life examples (no non-physical variations are allowed).
- Be simple, convenient and faster than "trial-and-error." Otherwise, it is viewed as an extra burden or nice "window dressing" for design reviews.
- Provide insight into what can be changed to make a better design, not just indicate how "poor" the design is. The simulation approach should be intuitive enough that designers can easily assess layout or design changes to reduce variation.
- Allow closure of the simulation loop by comparison with measurement of similar process spread wafers.

A design flow has been implemented, which takes advantage of the attributes of III-V HBT technology, by adopting a "unified" modeling approach and design-of-experiment (DOE) statistical simulation, selecting orthogonal only epi/process/operational variables, and using Advanced Design Systems (ADS) allowing high level integration of design, simulation and statistical analysis of a PA in a single tool.

Two examples are presented that significantly reduced circuit perfor-

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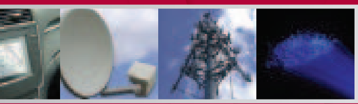

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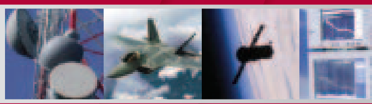

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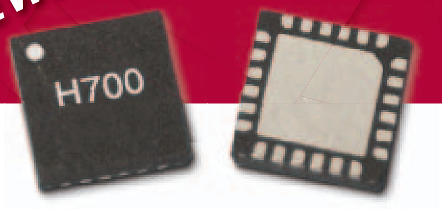
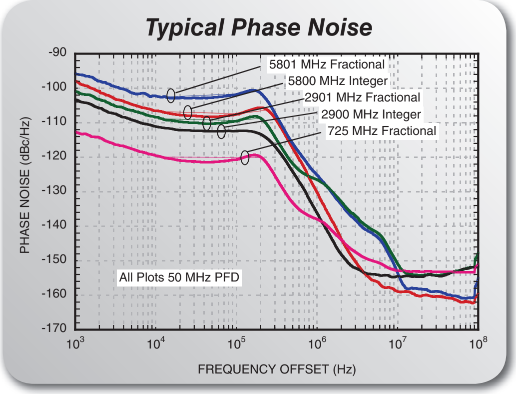
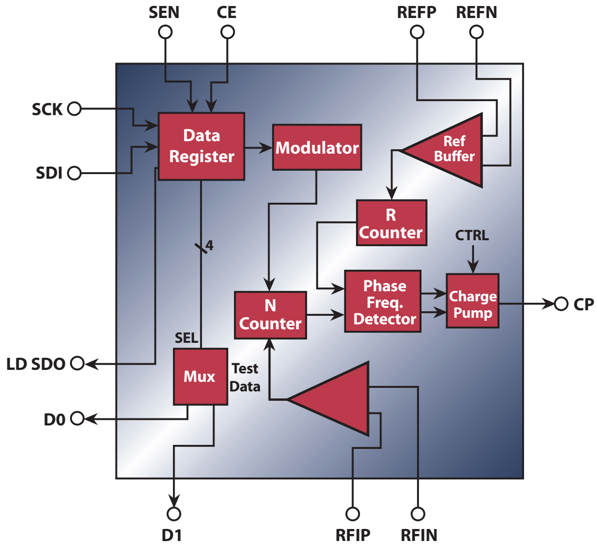


4x4mm SMT

HMC700LP4E Fractional-N Synthesizer





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- Low Phase Noise (Frac / Integer, 50 MHz PFD): -103 / -108 dBc/Hz @ 6 GHz
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	Frequency (GHz)	Function	Maximum PFD Frequency (MHz)	Maximum Reference Frequency (MHz)	Figure of Merit (Frac / Int) (dBc/Hz)	Frequency Resolution @ 50 MHz Ref. (Hz)	Bias Supply	Package	Part Number
NEW!	0.1 - 8.0	Fractional-N Synthesizer	100	200	-221 / -226	3	+5V @ 95mA	LP4	**HMC700LP4E**
NEW!	0.08 - 7.0	÷4 /5 w LD, INV	1300*	1300	- / -233	10	+5V @ 310mA	LP5	**HMC698LP5E**
NEW!	0.08 - 7.0	÷8 /9 w/ LD, INV	1300*	1300	- / -233	10	+5V @ 310mA	LP5	**HMC699LP5E**

* Maximum frequencies may be limited by available counter division ratio.

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mance variation while maintaining the same nominal performance. These improved results demonstrate that with the same epi/process/operational specifications, the design topology and layout choices can obviously impact performance variation.

Since the DOE-based flow makes designers aware of process variation and allows the exploration before committing the design to GaAs, more process tolerant designs are achieved. This approach has resulted in the following benefits:

- The resulting designs are more robust and show less variation. This improved consistency allows customers to "set it and forget it" once these parts are used.
- These simulations are part of the design review to ensure that the design topology is solid. This provides some foundation for failure-modes effects and analysis.
- In the early stages of development, it has eliminated numerous circuit topologies that were terrible in terms of process variation.
- It provides guidance on future directions for process development and has allowed it to refine the Process Control Monitor (PCM) development (DOE simulation has been used on the PCM measurements to understand if the measurement is really measuring what is thought).
- It provides a tool to determine if a designer requests for tighter control on a parameter, such as beta, is reasonable or if there is another root cause for their variation.
- It is a valuable de-bugging tool (it can simulate how much variation is expected from one of the theorized causes). This is faster and easier than running the wafers or, at the very least, can guide what wafers get run. Simulation also helps eliminate other factors that may be the cause of the variation (so the need for a die level change or board level change is known).

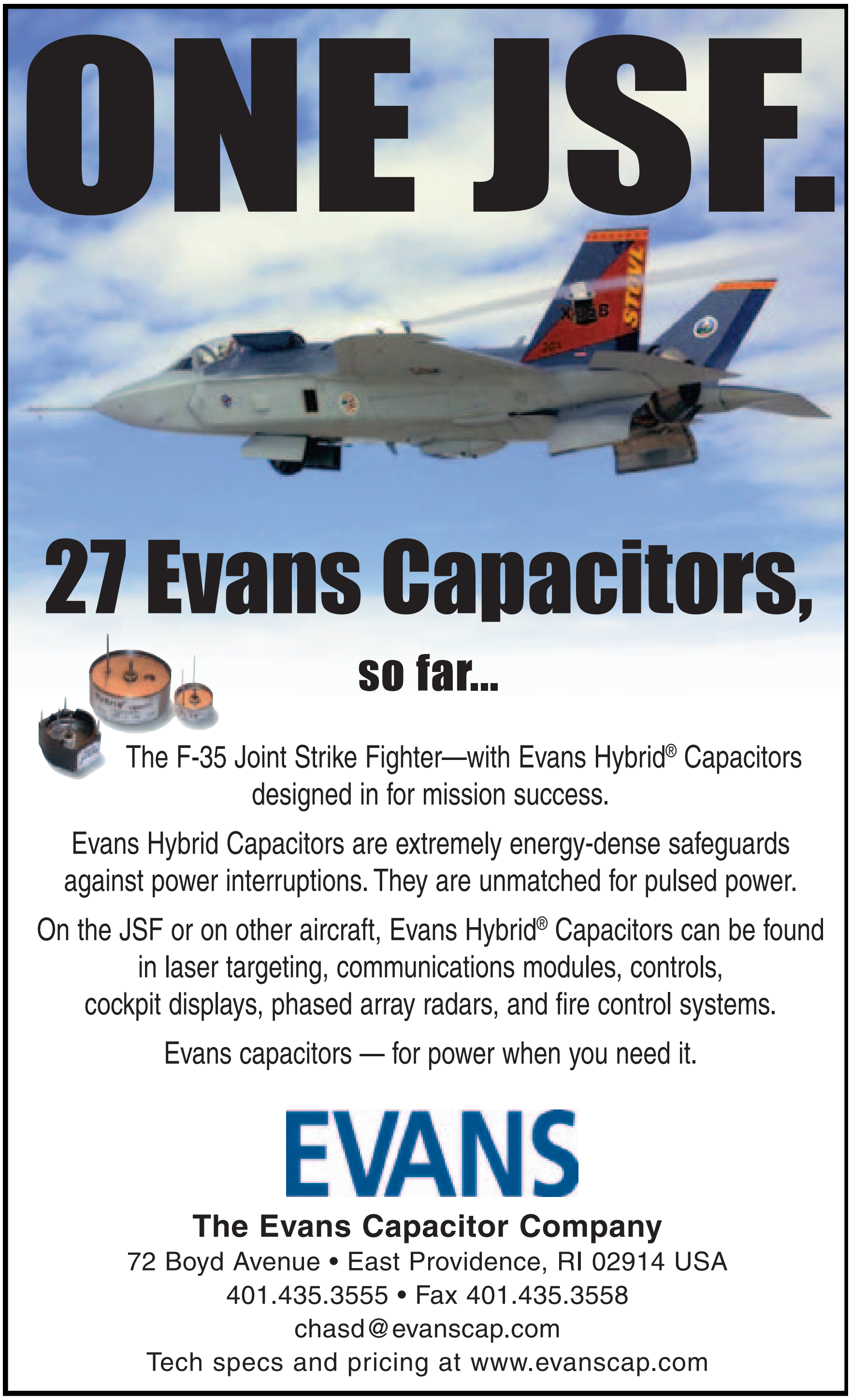
KEY ELEMENTS OF THE APPROACH

The "unified" modeling and DOE simulation elements are based on the assumption that PA designs use large devices, so that device mismatch is negligible. The orthogonal-only-variables element focuses on further reduction of necessary simulation runs. The Pareto-drive really provides clear directions for designers on what to improve. Finally, the high level integration, everything into ADS, makes this design flow a powerful and practical tool for the III-V design community.

"Unified" Modeling

The unified modeling approach is the foundation of this design flow. It is a geometrical and physical modeling approach, which is described in more detail in the references.[7,8] The term "unified" refers to the concept that devices fabricated from the same junctions or layers are forced to share, not only the same variation, but often the same model parameters.

For III-V HBTs technologies, front-end devices are formed by re-using junctions (base-emitter or base-collector junctions, etc.) or layers (emitter, base, sub-collector), and back-end devices (such as thin-film resistors, MIM capacitors and inductors)



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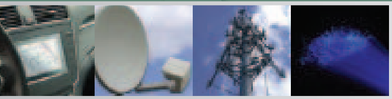

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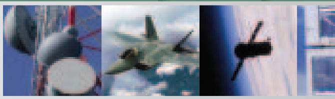

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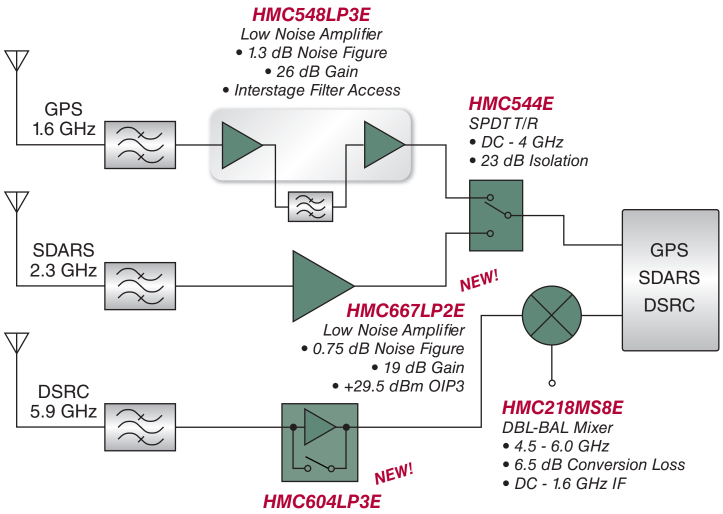

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NEW!	0.175 - 0.66	Low Noise	24	37	0.5	19	+5V @ 90mA	LP3	HMC616LP3E
NEW!	0.2 - 4.0	Low Noise, High IP3	13	38	2.3	22	+5V @ 110mA	ST89	HMC639ST89E
NEW!	0.2 - 4.0	Low Noise, High IP3	13	40	2.2	22	+5V @ 155mA	ST89	HMC636ST89E
	0.35 - 0.55	Low Noise	17	38	1	21	+5V @ 104mA	LP3	HMC356LP3E
NEW!	0.55 - 1.2	Low Noise	16	37	0.5	21	+5V @ 88mA	LP3	HMC617LP3E
NEW!	0.7 - 1.2	Low Noise, Failsafe Bypass	16	33	0.9	13	+5V @ 57mA	LP3	HMC668LP3E
NEW!	1.7 - 2.2	Low Noise, Failsafe Bypass	17	29	1.4	12	+5V @ 86mA	LP3	HMC669LP3E
NEW!	1.7 - 2.2	Low Noise	19	36	0.75	20	+5V @ 117mA	LP3	HMC618LP3E
NEW!	2.3 - 2.7	Low Noise	19	29.5	0.75	16.5	+5V @ 59mA	LP2	HMC667LP2E
	2.3 - 2.7	Low Noise w/ Bypass	20	31	1.1	17	+5V @ 74mA	LP3	HMC605LP3E
	3.3 - 3.8	Low Noise w/ Bypass	19	29	1.2	16	+5V @ 40mA	LP3	HMC593LP3E
NEW!	4.8 - 6.0	Low Noise w/ Bypass	15	26	1.5	14	+5V @ 42mA	LP3	HMC604LP3E

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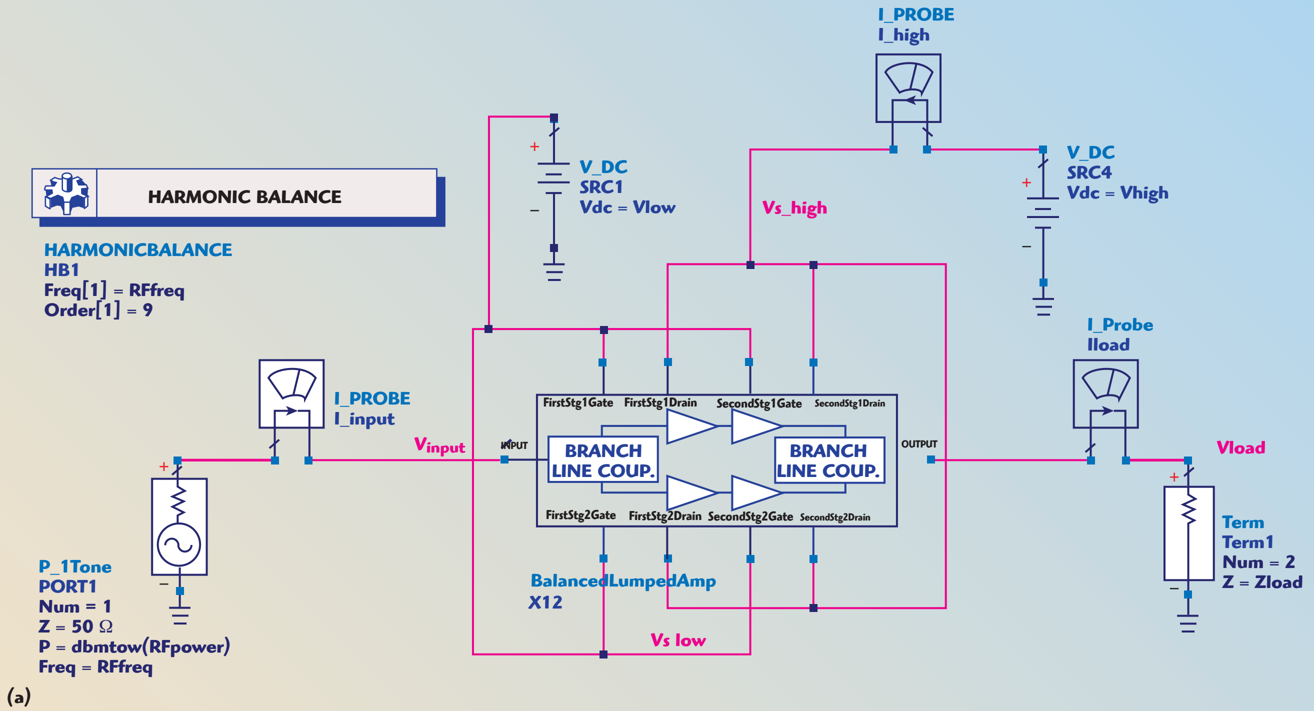
are independently formed but also share things like metal layers. The model parameters are separated into two sets: layout (geometry) dependent and material (epi) dependent. The geometry dependent parameters describing same type but different size devices, when varied, affect all devices of that type or sharing those layers equally. The geometrical dependence/variation is particularly important for resistor simulations. The material-dependent parameters allow to model the same geometry set of devices on a different epi by only changing a few parameters based on the specifics of the material design and drive variations across devices that share the same material layers, resulting in a greatly reduced total model/variation parameters for covering all devices in any given epi material.

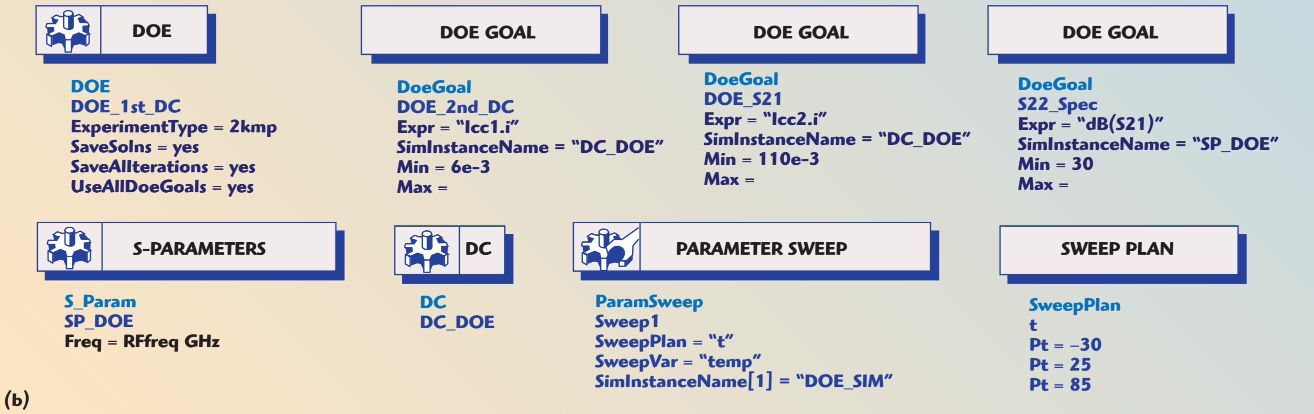
A good example of this approach is shown in ***Figure 1***, which illustrates how a semiconductor resistor (fabricated from the base layer of the HBT) model is constructed, and how it predicts the device behavior. In the model, the base sheet resistance is directly linked with a HBT parameter, β, and the base-collector junction diode model is directly "borrowed" to the model topology to describe the underneath layer. This direct "borrow" and "link" approach, since it is physical based, characterizes the resistor electrical behavior very well.

How "Unified" Modeling is Different from Traditional Modeling Approach

In a traditional curve-fitting approach, different devices were modeled independently and little thought was given to consistency of the devices, such as HBTs, which did not share the model parameters with junction diodes or semiconductor layer resistors. In the extreme, the model parameters for the devices of the same type, say HBTs of different size or geometries, were not linked. As a result, it would take many parameters to vary each of these devices statistically on an individual basis, and some

SIDEBAR I: *(A) CIRCUIT SCHEMATIC AND (B) DOE SIMULATION BENCH.*





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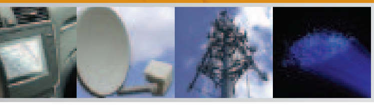

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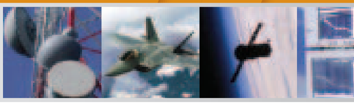

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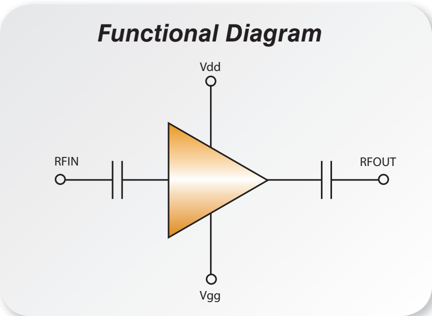
37 - 40 GHz



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NEW!	17 - 30	Medium Power Amp	20	31	22	+4.5V @ 400mA	APH196	HMC-APH196
NEW!	37 - 40	Medium Power Amp	20	35	26	+5V @ 640mA	APH510	HMC-APH510
NEW!	37 - 45	Medium Power Amp	21	32	23	+5V @ 475mA	APH403	HMC-APH403
NEW!	50 - 66	Medium Power Amp	24	25	17	+5V @ 220mA	ABH241	HMC-ABH241
NEW!	55 - 65	Medium Power Amp	13	25	16	+5V @ 80mA	ABH209	HMC-ABH209
NEW!	71 - 76	Medium Power Amp	24	-	17.5	+4V @ 160mA	AUH318	HMC-AUH318
NEW!	71 - 76	Medium Power Amp	13	-	20	+4V @ 240mA	APH633	HMC-APH633
NEW!	71 - 86	Medium Power Amp	16	-	15	+4V @ 130mA	AUH320	HMC-AUH320
NEW!	81 - 86	Medium Power Amp	22	-	17.5	+4V @ 160mA	AUH317	HMC-AUH317
NEW!	15 - 27	Power Amplifier, 1 Watt	17	37	29	+5V @ 1.44A	APH462	HMC-APH462
NEW!	18 - 20	Power Amplifier, 1 Watt	17.5	38.5	30	+5V @ 900mA	APH478	HMC-APH478
NEW!	21 - 24	Power Amplifier, 1 Watt	17	39	30.5	+5V @ 950mA	APH518	HMC-APH518
NEW!	24 - 26.5	Power Amplifier, 1 Watt	17	38	30	+5V @ 950mA	APH608	HMC-APH608
NEW!	27 - 31.5	Power Amplifier, 1 Watt	14	37	28	+5V @ 900mA	APH460	HMC-APH460
NEW!	37 - 40	Power Amplifier, 1 Watt	15	37	28	+5V @ 1.08A	APH473	HMC-APH473

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non-physical statistical states may be simulated.

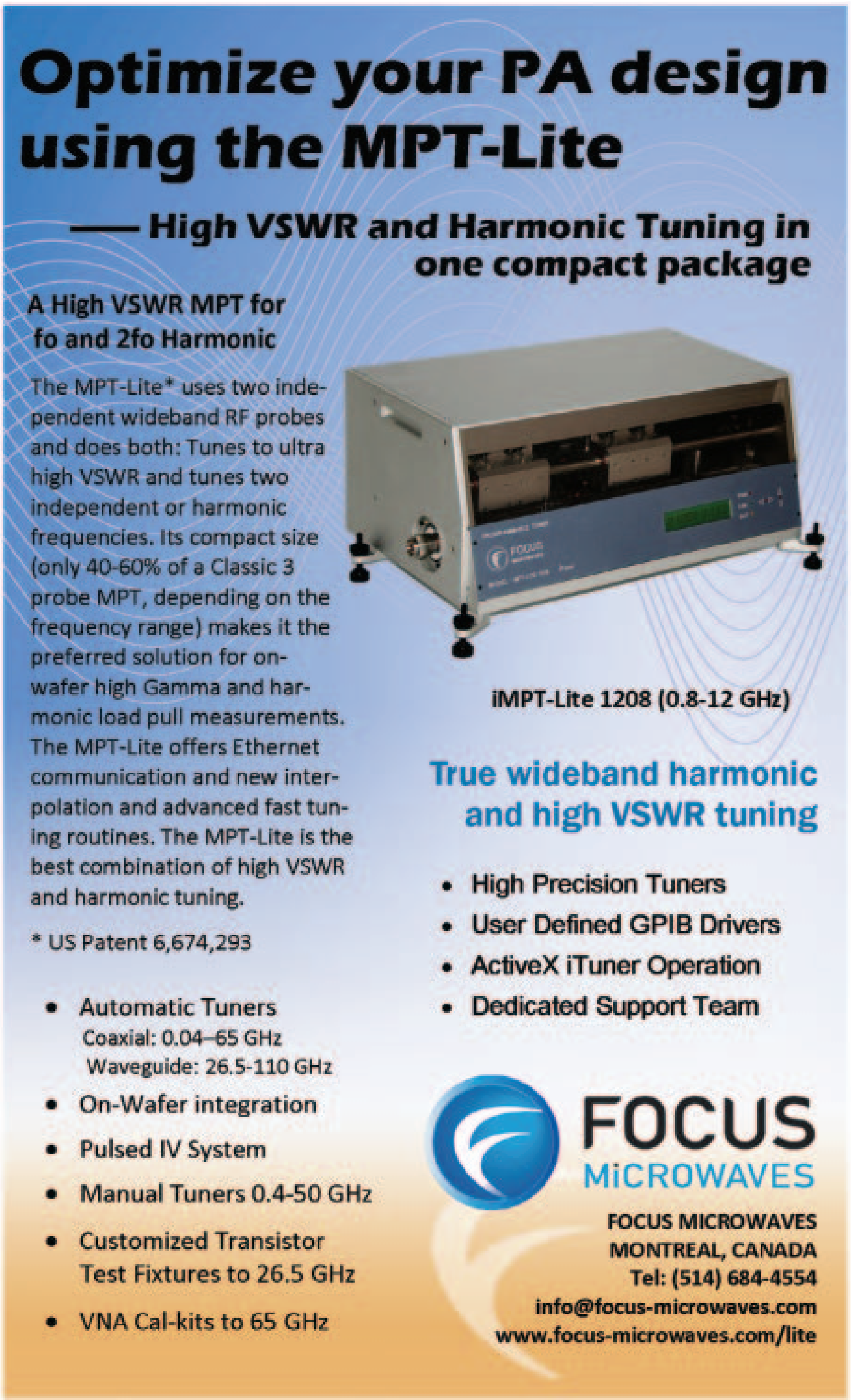
Discussion on "Unified" Modeling and "Corner" Modeling

A simulation approach based on individual device corner modeling has been reported for some devices.[9] That approach was only useful if there was only one design performance criteria, or for characterizing a system in which a single component really dominated the system behavior while other components' variations were negligible, or when all the components varied independently (as if the parts were all independent discrete components). The possible statistical system responses, in these cases, could be obtained by simulating through the combinations of all the corners of all different devices being corner-modeled. However, for an MMIC, the assumption that circuit components vary independently, or that one device changes while other devices are constant are clearly incorrect. Adopting that approach would result in non-physical states and a lot of wasted effort worrying about variations that could never occur in reality.

This unified modeling approach is a physical corner modeling approach. It instantly generates corner models, by inputting statistical DOE parameters, which control all the on-chip devices together rather than individually and naturally guarantees physically possible circuit corner responses. It also requires less simulation iterations than running through different individual device corner models.

Statistical Variable Selection

For a GaAs HBT chip, there are many variables that can potentially be changed based on starting material or fabrication variation. For epi-variation, the models were implemented to allow individual material parameters (like doping and thickness) to be varied. However, for this work, model parameters are used (such as beta) that are actually responses to the doping and thickness.[7] This link is necessary to help understand the circuit response (that is, it is important to know which parameter caused beta to change). As a result, only independent (orthogonal) epi and process variables, represented by model parameters, are made accessible for circuit statistical simulations, even though the orthogonality is not a requirement for general statistical simulation. The benefits are it minimizes the simulation time for the same circuit response one would get with more correlated variables and it eliminates any non-physical circuit responses of correlated parameters going in uncorrelated directions. The accessible parameters are listed in ***Table 1***. The variations of the independent parameters are obtained from PCM data, which also provides the correlation parameters (based on material DOE runs)[10] and validation of the orthogonality of the parameters.[11] Reviewing the semiconductor resistor example again, instead of using both Ω/◻ and β variables to describe the resistor's and HBT's variations, only β is made accessible (but Ω/◻ changes according to β inside the model code) to simulation. The strategy is to catch as much variation as possible with as few



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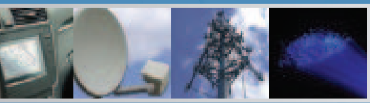

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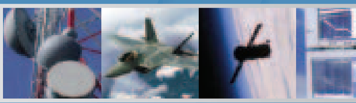

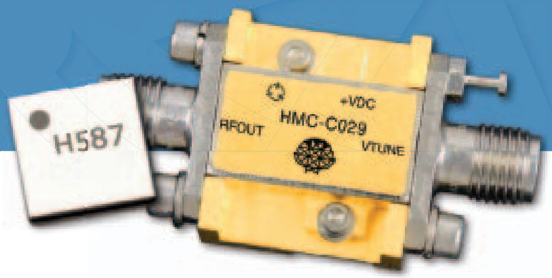

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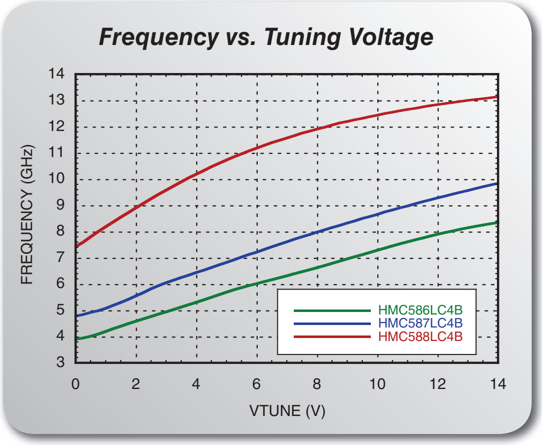

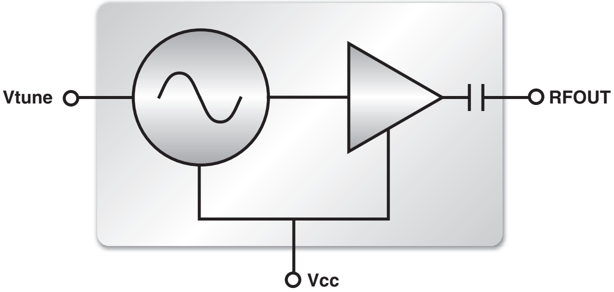

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4 - 8	Wideband VCO	20	-75	-95	+12V @ 185mA	C-1 Module	**HMC-C028**
5 - 10	Wideband VCO	5	-65	-95	+5V @ 55mA	LC4B	**HMC587LC4B**
5 - 10	Wideband VCO	20	-64	-93	+12V @ 195mA	C-1 Module	**HMC-C029**
8 - 12.5	Wideband VCO	5	-65	-93	+5V @ 55mA	LC4B	**HMC588LC4B**
8 - 12.5	Wideband VCO	21	-59	-83	+12V @ 195mA	C-1 Module	**HMC-C030**

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TABLE I

INDEPENDENT OPERATIONAL VARIABLES AND THEIR CORRESPONDING CIRCUIT OPERATIONAL CHANGES

INDEPENDENT PROCESS/EPI STATISTICAL VARIABLES
VT (V) (FET threshed)
Beta (DC gain)
Ref (Ohm) (Re for PCM device)
Vbe (V) (HBT turn on voltage)
TaNRho (Ohm/sq) (for Rt, TaN resistor)
dw (µm) (for Rt, TaN resistor)
dl (µm) (for Rt, TaN resistor)
dwb (for Rb, TaN base resistor)
dlb (µm) (for Rb, base resistor)
RhRho (Ohm/sq) (for Rh, Implant resistor)
dwh (µm) (for Rh, Implant resistor)
dlh (µm) (for Rh, Implant resistor)
MIM capacitance area density (fF/µm2)
SCdv (V) (Schottky diode turn on voltage deviate from nominal)
BCdv (BC diode turn on voltage deviate from nominal)
CIRCUIT OPERATION "STATISTICAL" VARIABLE
Vcc (V)

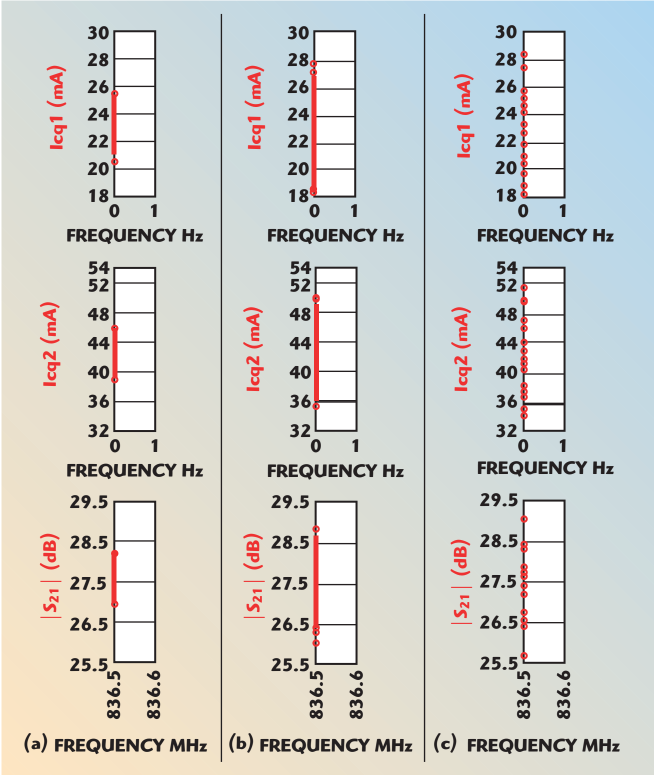

Fig. 2 Circuit response comparison between DOE and MC simulations; (a) 240 MC simulations, (b) 64000 MC simulations and (c) full-factorial DOE.

parameters as possible. The circuit operational variables are set to be simulation parameters as well.

Another feature of this implementation is that all the statistical parameters can be easily fixed to their nominal values. This allows designers to skip simulations of parameters that are not important for their particular design (for example, why simulate Schottky diode variation if it is not used in your circuit?), which greatly reduces the total simulation time. The number of statistical parameters in a typical circuit simulation, after such a selection approach, is less than 10.

DOE versus MC

The predicted mean and distribution ranges from MC depend on the number of variables and the number of simulations. The higher the ratio of simulation runs to the number of variables, the more accurate the predictions are. In reality, one normally does not really know which of the selected variables will have the most impact on a particular circuit design. Running hours of simulation to find this out is not very appealing. Worse, it could result in the most important parameters not getting selected because not

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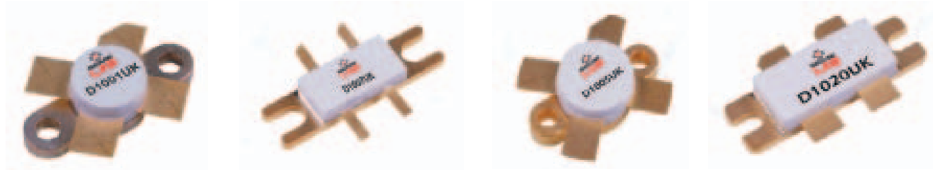

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D1007UK	40	50	13	400	DK
D1008UK	80	50	13	400	DK
D1011UK	10	50	13	500	SO8
D1013UK	20	50	13	500	DP
D1017UK	150	50	13	175	DM
D1020UK	150	50	10	400	DR
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D1029UK	350	60	13	175	DR

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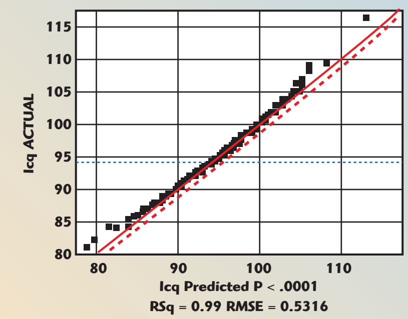
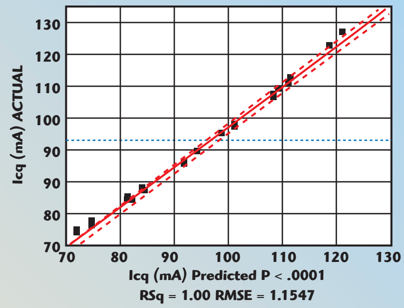


PARAMETER ESTIMATES

TERM	ESTIMATE	STD ERROR	t RATIO	PROB>|t|
Intercept	235.12907	2.205585	106.61	<.0001*
beta	–0.768165	0.005714	–134.4	<.0001*
VT	–34.46339	0.685096	–50.30	<.0001*
Rho	–1.686377	0.037747	–44.68	<.0001*
Re	0.3360732	0.023789	14.13	<.0001*

(a)

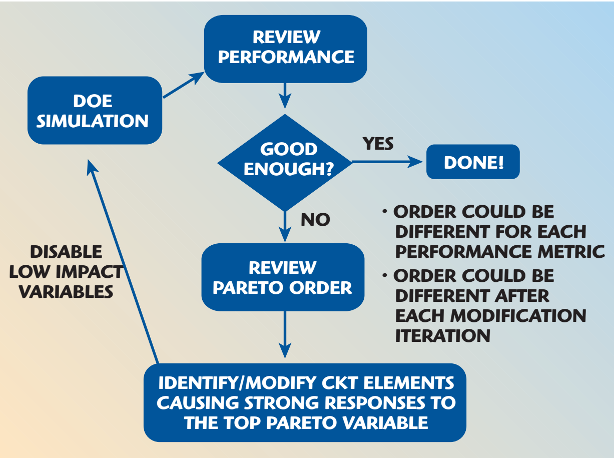


PARAMETER ESTIMATES

TERM	ESTIMATE	STD ERROR	t RATIO	PROB>|t|
Intercept	240.24561	4.165511	57.67	<.0001*
stat_beta	–0.781703	0.011833	–66.06	<.0001*
VT	–34.64583	1.360798	–25.46	<.0001*
stat_TaNRho	–1.694079	0.071621	–23.65	<.0001*
stat_Ref	0.3102022	0.050029	6.20	<.0001*

(b)

▲ *Fig. 3 Comparison of statistical parameters' effects of an auto bias circuit; (a) MC simulations (250 runs) and (b) full-factorial DOE (32 runs).*



▲ *Fig. 4 The DOE Pareto driven design flow chart.*

enough simulation iterations were run. Both cases could lead to non-realistic distribution range predictions and less accurate mean predictions. DOE is widely used in the semiconductor industry. A short tutorial article to help readers understand DOE methodology is provided through the following link: http://www.agilent.com/find/eesof-doe. In the case that neighboring device mismatches are negligible, the study indicates that DOE is really an optimal simulation choice. ***Figure 2*** shows in the situation of 4 variables, 64000 MC simulations led to much wider Icq ranges than that of 240 MC simulations. Since typical products ship in the millions, the ranges from 64000 MC simulations would be closer to accurately represent what really happens. However, 64000 MC simulations take 18.5 hours to finish while 240 simulations took only 470 seconds. The figure also shows that the results of a large number of MC simulations are required to approach the results of running a full factorial DOE simulation. The difference is that the DOE approach only took 28 seconds. To further investigate, the effect of each of the five variables involved in 250 runs MC and full factorial DOE simulation ($2^5 = 32$ runs) of another design was analyzed using JMP statistical software. The results are shown in ***Figure 3***. The analyzed effects can be expressed by Equations 1 (MC) and 2 (DOE). Comparing these equations, it is obvious that the weight and direction of each variable from both results are identical. The main difference is the predicted means. As indicated earlier, this can be caused by using too few MC runs for the number of variables.

$$Icq(mA) = 235 - 0.768beta - 34.5VT - 1.69TaNRho + 0.336\ Ref \quad (1)$$

$$Icq(mA) = 240 - 0.768beta - 34.6VT - 1.69TaNRho + 0.310\ Ref \quad (2)$$

Full Factorial DOE is Necessary

To refine the DOE approach, different DOE designs were studied. As seen in ***Appendix A***, the full factorial DOE method (2kmp) gives consistent results with the much denser sampled

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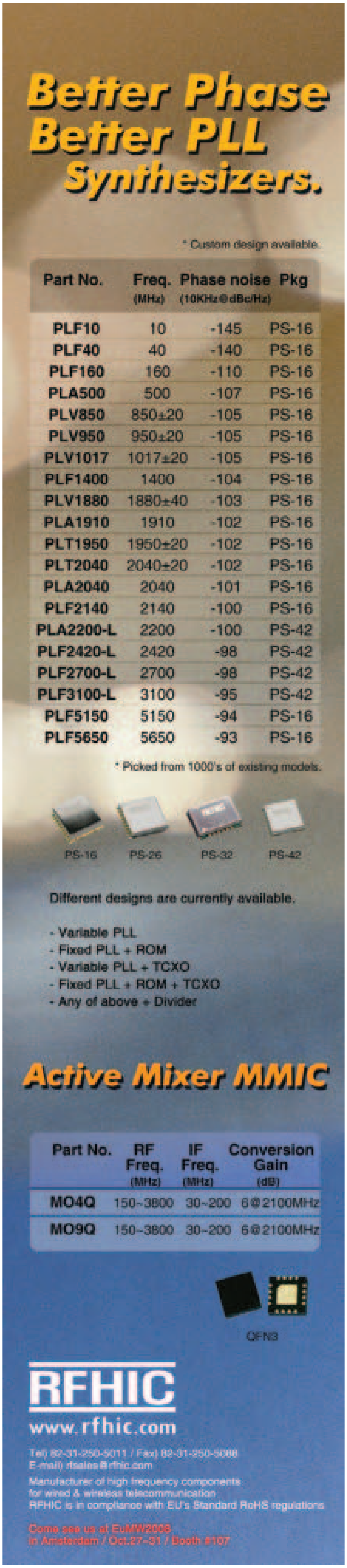

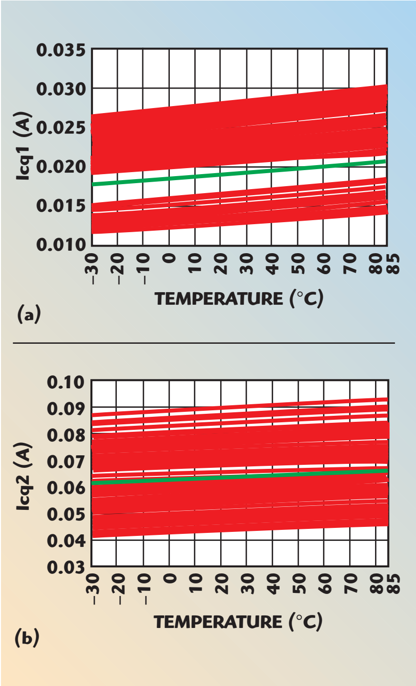

Fig. 5 *Dual-band PA design using DOE simulation of Icq1 and Icq2.*

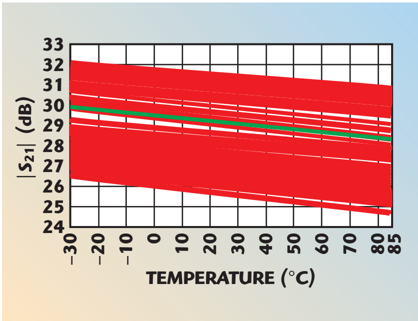

Fig. 6 *Dual-band PA design using DOE simulation for gain.*

3k method, but takes much less time to run. The results of other DOE methods are not consistent with each other, even though they need a little less time than the full factorial method. The reason for the inconsistency of some other DOE methods is partly due to the orthogonal only (at device level) variable selection. The full factorial method is optimal, considering accuracy and simulation time, and was selected to be the method implemented in the design flow.

DOE versus "Sensitivity Analysis"

"Sensitivity Analysis" simulation is also evaluated. It predicts totally different results than the full factorial DOE and the dense sampled DOE (3k). The reason is that the "sensitivity" method only considers small perturbations around a nominal condition, with one parameter changed at a time. It is not a recommended method to improve design robustness.

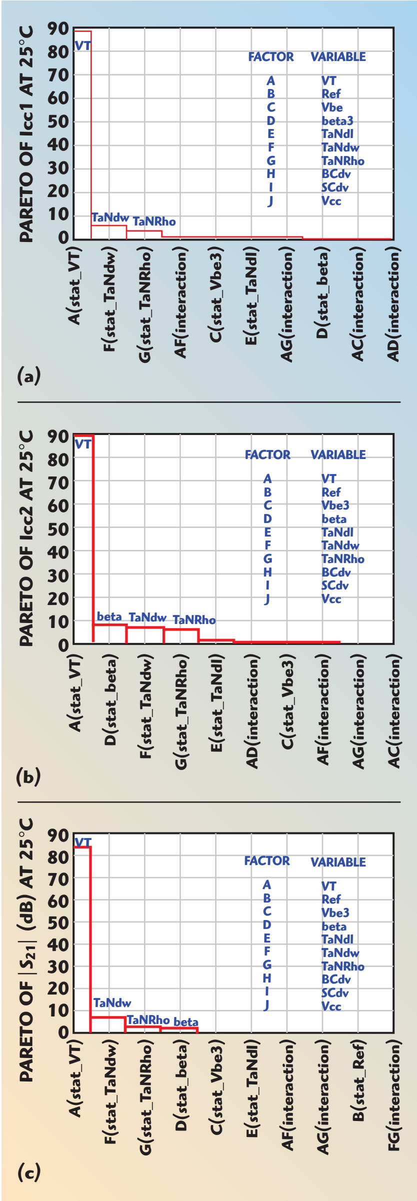

Fig. 7 *Pareto charts for initial design; (a) Icq1 variations, (b) Icq2 variations and (c) gain variations.*

Integrated Design Flow in ADS

The fact that models, design circuits, DOE simulations and the instant simulation analysis are all integrated into ADS (see ***Sidebars 1*** (pg. 142) and **2** (pg. 154)) really makes the DOE design flow practical, even for those not so statistically savvy designers. In Sidebar 2a a few different circuit performances (the green lines) are displayed. The statistical state, for the performances where the markers are landed, is displayed as well. The mark-

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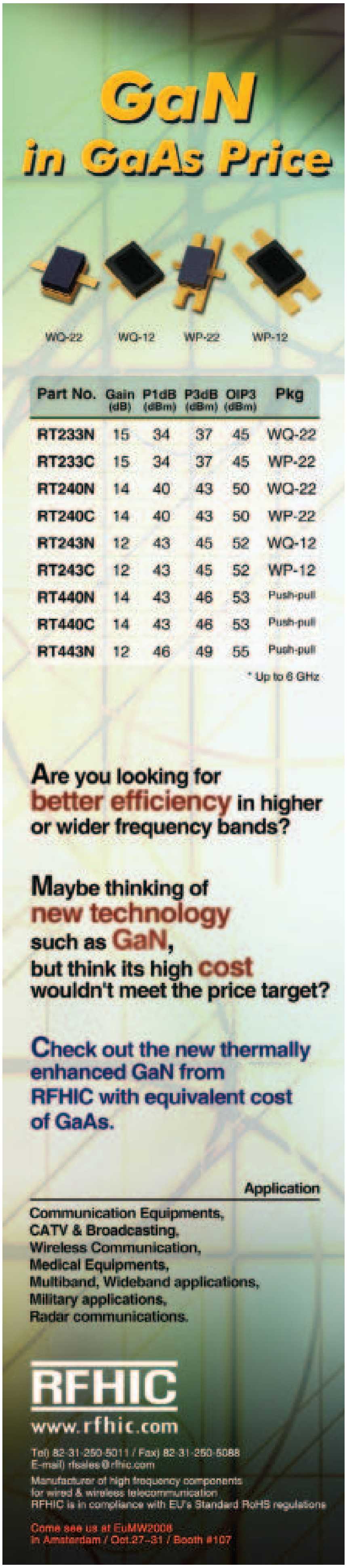
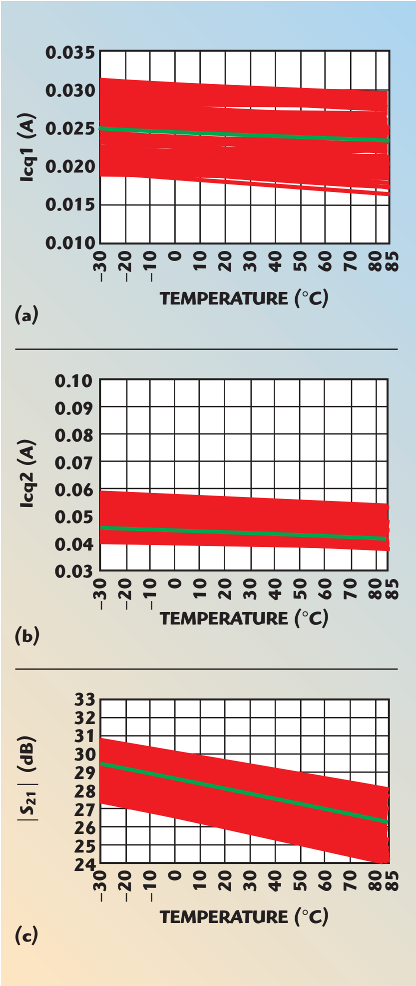


ers on different performances plots are synchronized, that is when one marker on a particular measure is moved, the markers on other performance measures are automatically moved to indicate the performances of the same statistical state. Traditionally, statistical analysis, requiring special software and training, has been intimidating to many designers and has been one of the major barriers to its use in PA design.

The DOE Pareto Driven Design Flow

As shown in ***Figure 4***, the integrated design flow consists of iterations of DOE simulations, reviewing circuit performances, reviewing Pareto charts, identifying circuit element corresponding to top Pareto factors for performance variation, and modifying the circuit. Once modified, the loop is followed until satisfactory results are obtained. The Pareto charts provide useful information about which variables dominate performance variation for the circuit. Such information is powerful for identifying which part of a design or specific component needs to be modified.



▲ *Fig. 8 Performance after modifications to reduce the impacts of top-order variables.*

RESULTS

Dual-band PA

The first-cut design had wide Icq (see ***Figure 5***) and RF gain (see ***Figure 6***) variations. Pareto analysis showed that threshold voltage variations of the FET devices, width variations of some critical thin-film resistors, and DC gain variation of HBT devices were the dominant factors for the circuit performance variations (see ***Figure 7***). To address these top-order effects, the internal reference voltage and values of three resistors were identified as the components to be changed. The performance variations were drastically reduced while the nominal performances are kept the same (see ***Figure 8***).

WCDMA FEM

Battery voltage (Vcc) variations caused large circuit performance changes in the initial design (see ***Figure 9***). Through the DOE Pareto driven design flow, insufficient ballasting and rising voltage on a particular node were identified as the root cause. As a result, clamping diodes and increased ballasting were implemented in the circuit. Some measured data verified that as Vcc changes from 3.2 to 4.5 V, Icq, after the design improvements, is relatively constant and the standard deviations are largely reduced at high Vcc. This example further illustrates the effectiveness of the DOE Pareto driven flow.

CONCLUSION

This work is the first one to integrate a unified modeling approach, DOE statistical circuit simulations of both epi/process and circuit operational variables, Pareto analysis, as well as design schematics into one design flow for a PA design. Each iteration of design modification is clearly driven by the Pareto-determined top-order variable, and the interactive process of design modification, simulation and obtaining feedback can be accomplished in a matter of minutes. It is shown how each key element in this system is determined to make this work distinct from all other statistical or design works. The examples of utilizing this approach demonstrate that much tighter performances can be achieved

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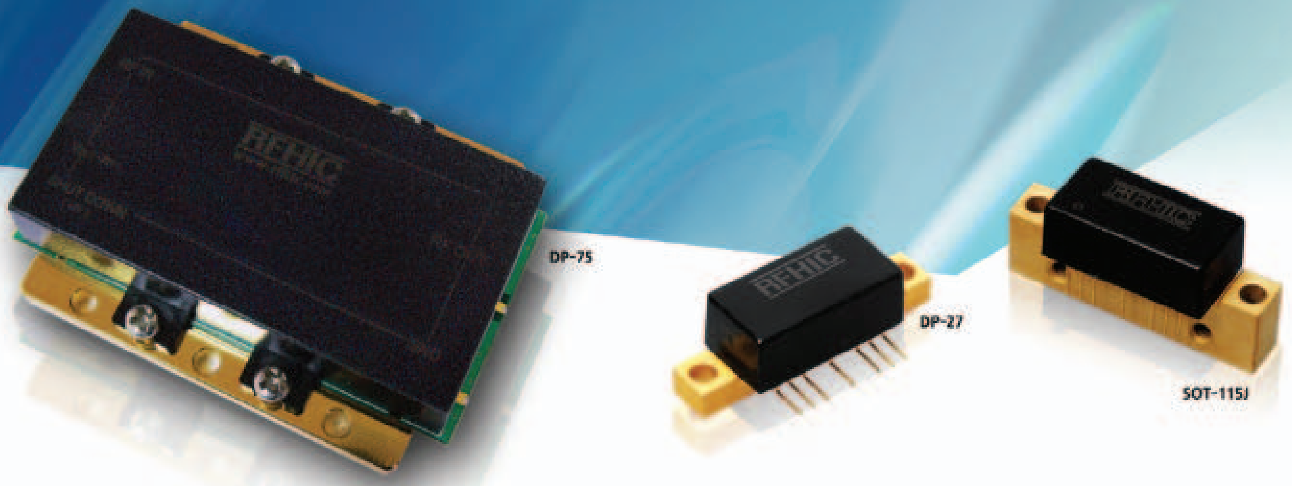

Part Number	RFW2500H10-28	RFW1G35H20-28	RFW7735H20-28	RFW5035H40-28	RFW8835H40-28	RFW1G33H40-28
Frequency (MHz)	20 ~ 2500	20~1000	450~ 770	20 ~ 500	450 ~ 880	20 ~ 1000
Power Gain (dB)	13	35	35	35	35	34
P3dB (dBm)	36	41	43	46	46	44
OIP3 (dBm)	41	46	50	53	53	50
Supply Voltage (V)	28	28	28	28	28	28
Current (A)	0.9	1.8	1.8	2.5	2.5	3.1

* Custom design available.

Other Wideband Amplifiers

Part Number	Freq. (MHz)	Pout (dBm)	OIP3 (dBm)	Pkg
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RFC041	400~800	30	47	DP-27
RFC092	800~1000	30	50	DP-27
RFC1G22-24	20~1000	30	50	DP-27
RFC1G18H4-24	20~1000	36	46	DP-27
RFC1G18H4-24S	20~1000	36	46	SOT-115J
Under Development	500~2600	40~50		
Under Development	2500~6000	40~47		

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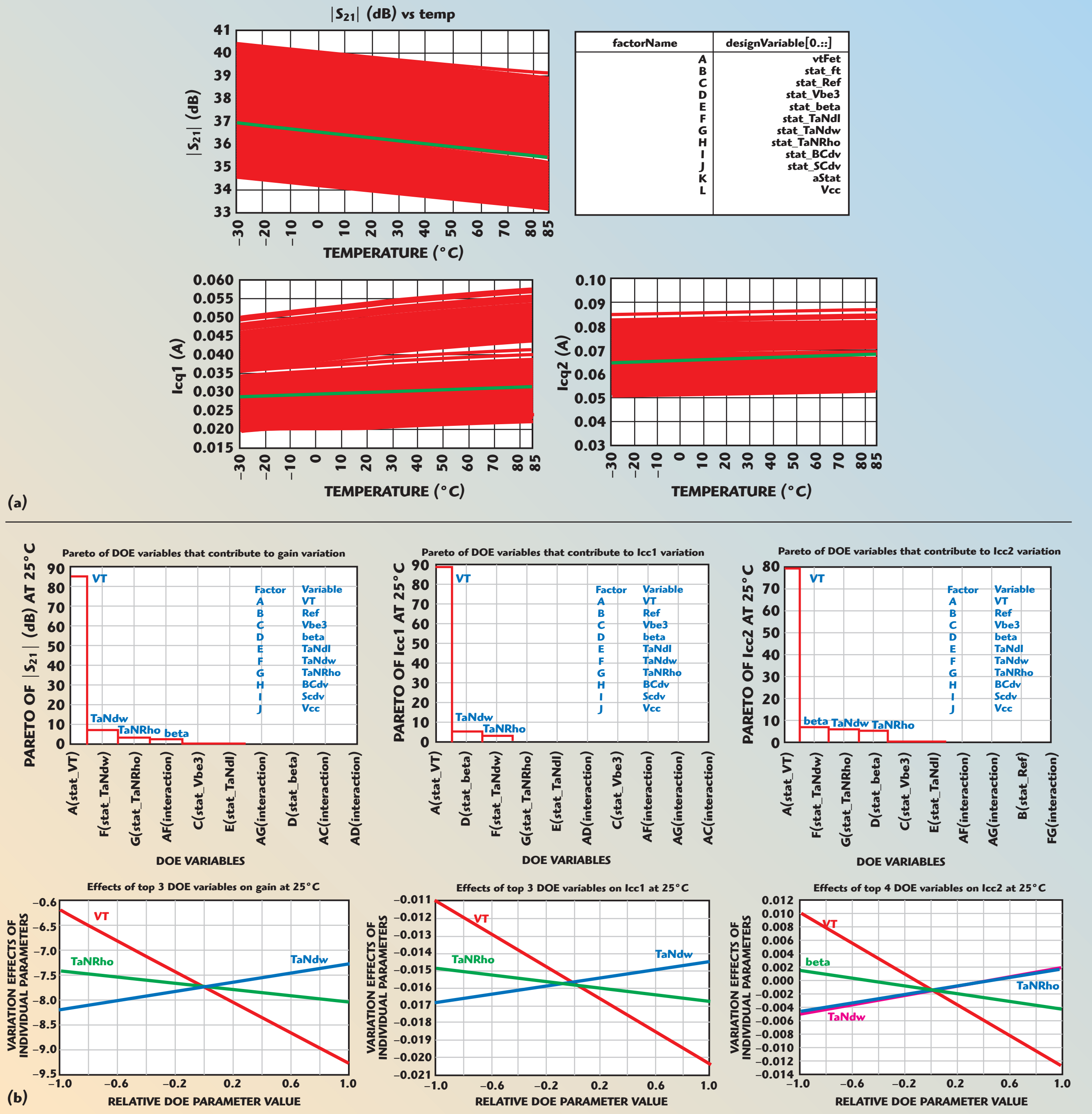
SIDEBAR II: *(A) STATISTICAL RESULTS OF CIRCUIT PERFORMANCE AND (B) STATISTICAL PARETO CHART.*



through modifying designs even if epi/process specifications are kept the same. Designers should have an active role in determining product robustness. As one can see, there are too many benefits to this approach to not adopt it. ■

ACKNOWLEDGMENT

The authors acknowledge model related discussions with Kai Kwok and Bin Li, and circuit discussions with Shiaw Chang and Andre Metzger. They also thank the several designers that acted as guinea pigs and helped refine this flow.

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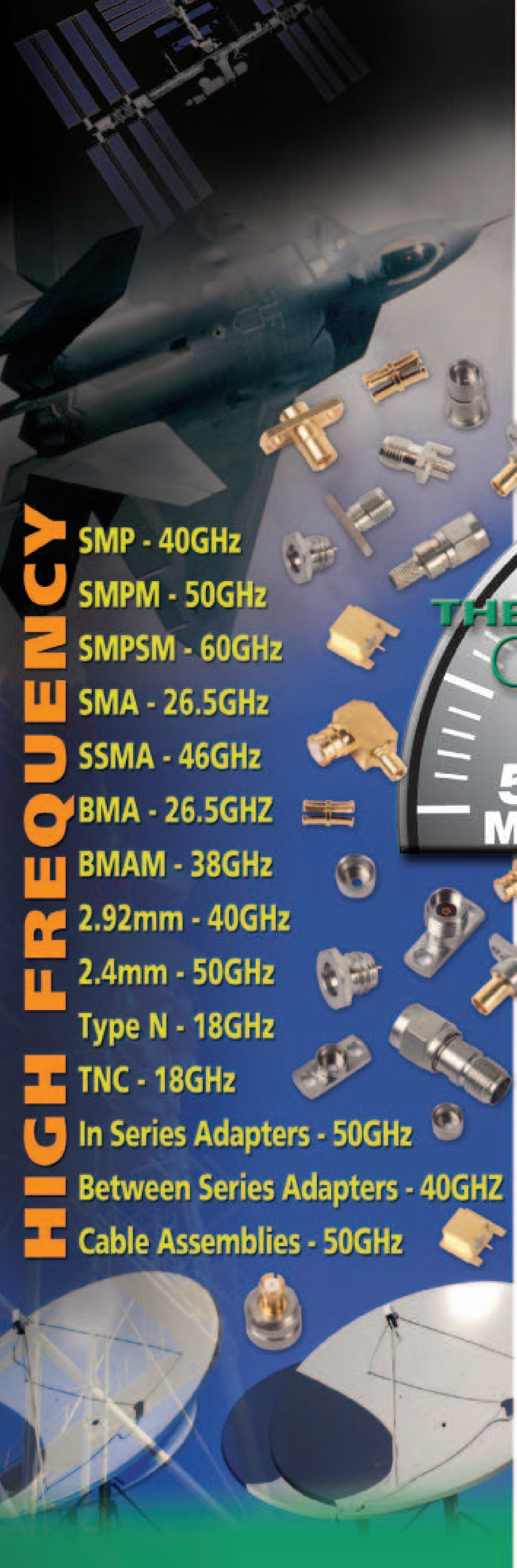

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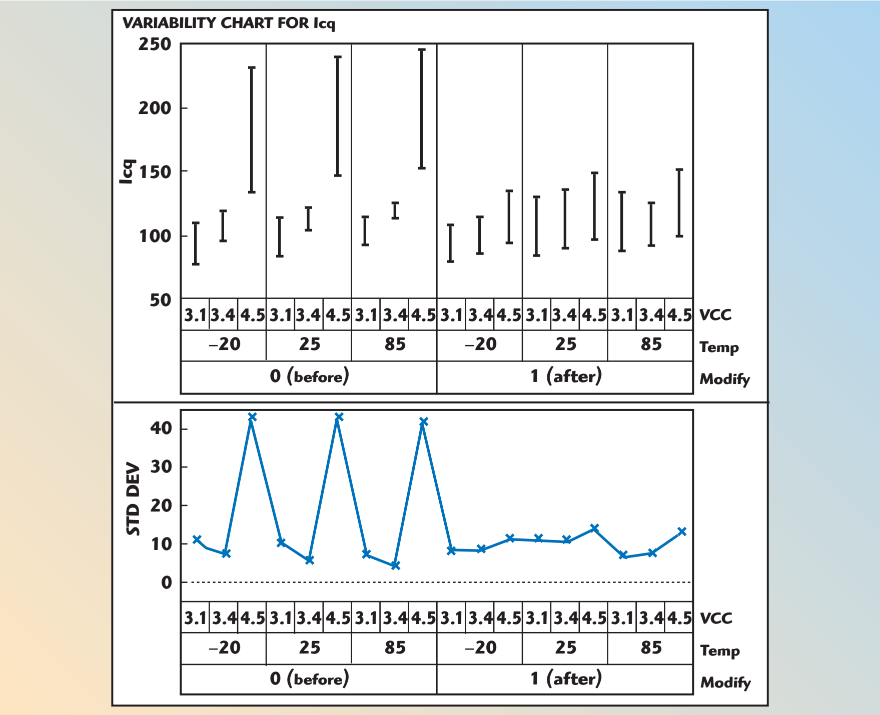

Fig. 9 Measured data for a WCDMA FEM design.

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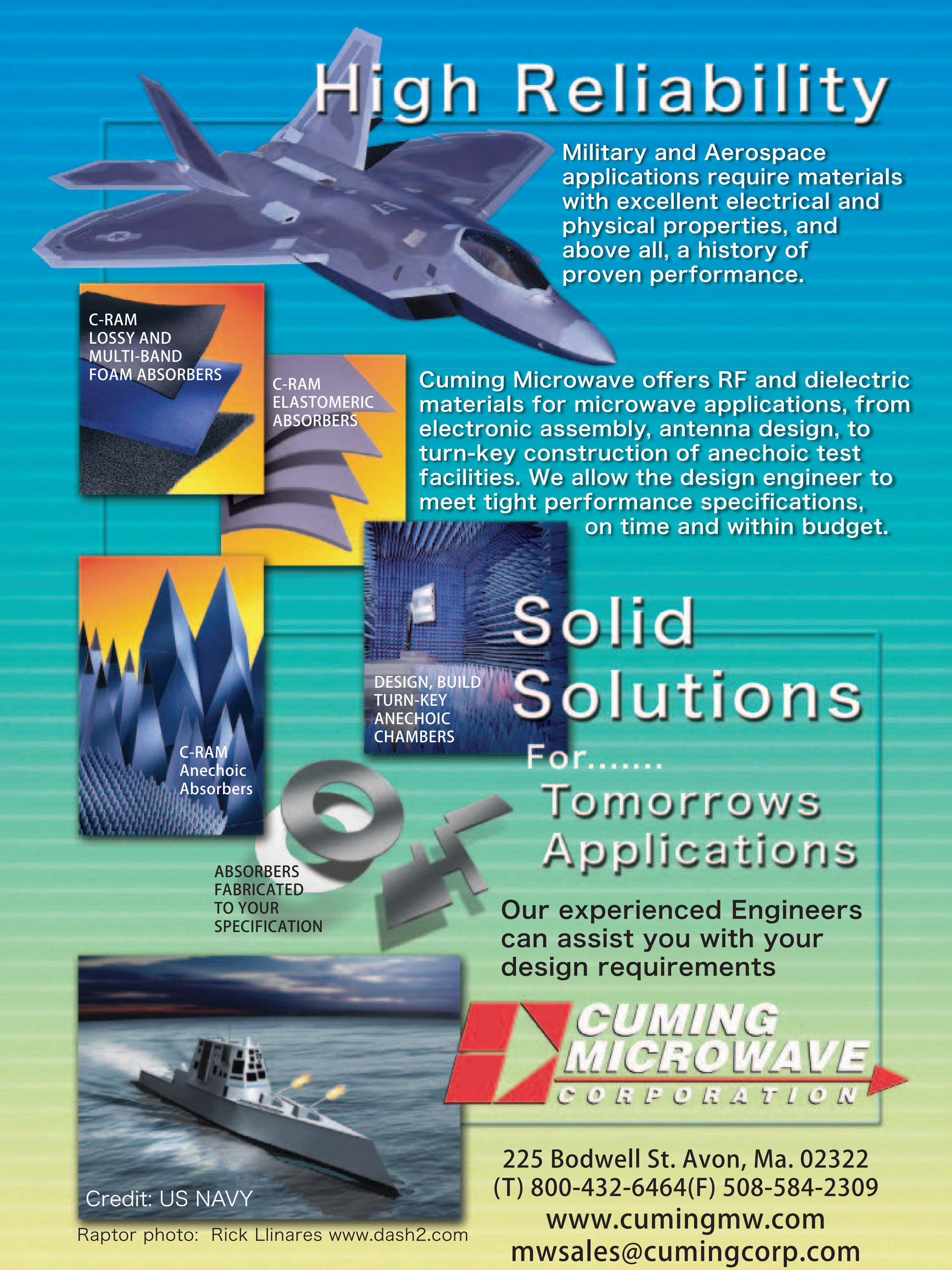
APPENDIX A

DOE METHOD COMPARISONS

			Icq1(mA) at 25°C			Variable Order in 25°C Pareto Chart									
Method	**Sim Time (sec)**	**# Samples**	**Icq1_Min**	**Icq1_Max**	**Icq1 Range**	**VT**	**Beta**	**Vbe3**	**Ref**	**Rho**	**dw**	**dl**	**SCdv**	**BCdv**	**Vcc**
2kmp	488	1024	19	31	12	1	4	5		2	3	6			
Placket-Burman	8	12	19	27	8	1	5	4		2	3		6		
Box-Behnken	33	181	21	27	6	1	4	5		2	3	6	7		
CCD	493	1045	17	32	15	1	4	5		2	3	6			
3K	16070	59049	19	31	12	1	4	5		2	3	6			
Sensitivity							4	1		3		2			
			Icq2(mA) at 25°C			**Variable Order in 25°C Pareto Chart**									
Method	**Sim Time (sec)**	**# Samples**	**Icq2_Min**	**Icq2_Max**	**Icq1 Range**	**VT**	**Beta**	**Vbe3**	**Ref**	**Rho**	**dw**	**dl**	**SCdv**	**BCdv**	**Vcc**
2kmp	488	1024	34	54	20	1	3	5		2	4	6			
Placket-Burman	8	12	35	48	13	1	3	5		2	4	6	7		8
Box-Behnken	33	181	39	48	9	1	3	5		2	4	6	7		
CCD	493	1045	33	64	31	1	3	5		2	4	6	7		
3K	16070	59049	34	54	20	1	3	5		2	4	6	7		
Sensitivity							3	4		2		1			
			dB(S21) at 25°C			**Variable Order in 25°C Pareto Chart**									
Method	**Sim Time (sec)**	**# Samples**	**dB(S21)_Min**	**dB(S21)_Max**	**dB(S21)_Range**	**VT**	**Beta**	**Vbe3**	**Ref**	**Rho**	**dw**	**dl**	**SCdv**	**BCdv**	**Vcc**
2kmp	488	1024	25.7	29.5	3.8	1	4	5		3	2	6	7		
Placket-Burman	8	12	26.1	28.7	2.6	1	4	5		3	2	6	7		
Box-Behnken	33	181	26.8	28.7	1.9	1	4	5		3	2	6	7		
CCD	493	1045	24.2	29.7	5.5	1	4	5		3	2	6	7		
3K	16070	59049	25.7	29.5	3.8	1	4	5		3	2	6	7		
Sensitivity								3		2		1			



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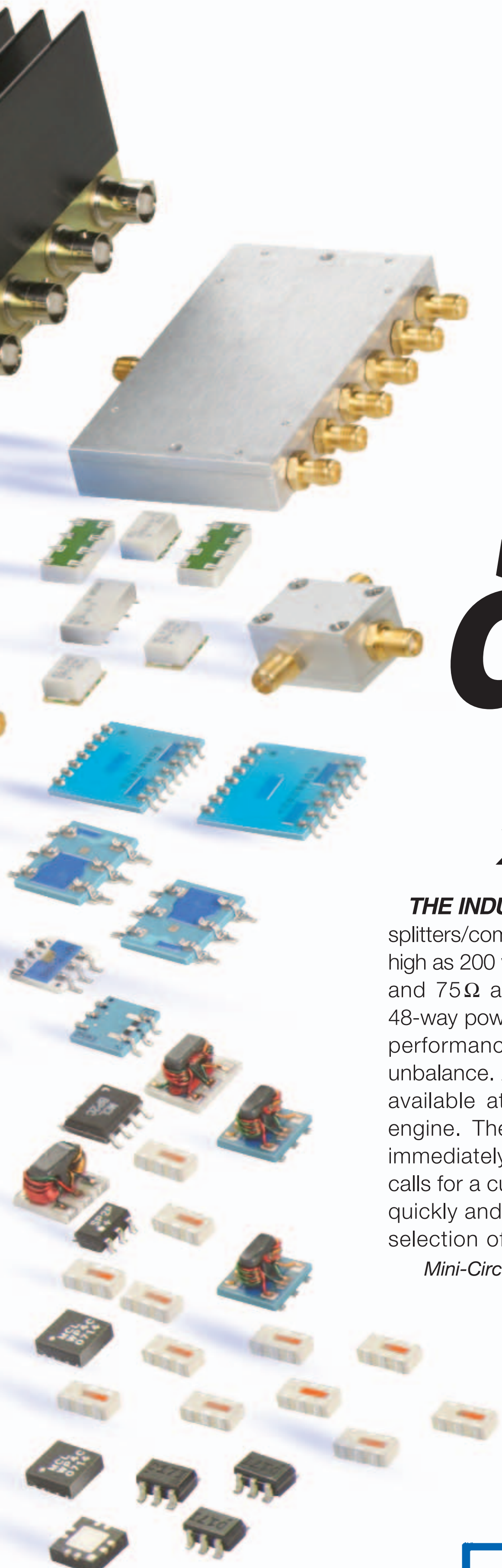

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ANTENNA PASSIVE REPEATERS FOR INDOOR RECOVERY OF MICROWAVE CELLULAR SIGNALS

The use of passive repeaters for mobile communications is often discarded because of the inherent losses that these systems introduce. However, the radio signal coverage of indoor areas poses a particularly complex problem in buildings with heavily reinforced concrete walls and shielded or underground infrastructure, which introduce great attenuation. In these particular conditions, active or passive repeater systems can be implemented for recovering the indoor signal to the level of normal reception. In this article, the important potential upgrading of indoor signal coverage is theoretically demonstrated and experimentally proved by use of low-cost passive repeaters for the 900 MHz cellular band.

Assuring adequate signal coverage of indoor areas is an important problem for cellular systems in regions where buildings have high attenuation walls. Active repeaters are often used to solve the problem,[1,2] but, in addition to their added cost, they need a power supply and maintenance. Also, the amplified signal has the potential of creating significant interference in those areas that are already covered by a direct signal of the same frequency channel.

In this article, the potential for field coverage improvement by means of antenna passive repeaters is explored, similar to those employed in the microwave radio relay links years ago for redirection of wave propagation over hilly terrain.[3,4] In addition, a signal phase shifter is introduced to the traditional antenna passive repeater scheme, aimed at optimizing indoor signal distribution.[5]

A simplified theoretical study by the authors[5] has shown that for wall attenuation less than 10 to 12 dB (a brick wall, single-mesh reinforced concrete wall, wooden wall, etc.), the signal enhancement due to a passive repeater with a medium gain antenna is moderate. Significant benefits can only be expected at limited ranges or by using high gain antennas at the expense of angular coverage. For the case of a high loss wall, however, with an attenuation larger than 20 to 25 dB, a considerable improvement in indoor signal coverage can be easily achieved.

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Three exemplary schemes of building passive repeaters have been described initially. The classic one is a single-path, double-antenna repeater, for which the power-transfer equation was worked out. This scheme was implemented for cellular signal recovering in the underground parking sector of a corporate building. It consisted of two different antennas, donor and coverage, connected by a long coaxial cable. By means of this passive repeater the signal coming from a nearby cellular base station was raised by approximately 20 to 25 dB, and normal, low-cost cellular signal coverage was provided in a 70 m^2 isolated parking area.

The second scheme is an on-wall twin-antenna passive repeater, which was studied theoretically and experimented in a laboratory indoor environment. It is comprised of two equal antennas, mounted outside and inside on a building exterior wall, and connected through a hole by a short piece of cable and a phase shifter in series. The average signal improvement obtained experimentally with the repeater in a multipath environment (a small furnished room, 4.6 by 2.6 m), ranges from 15 to 17 dB near the repeater to approximately 3 dB at a distance 4 m away.

The third scheme is a variation of the first scheme, with the coverage antenna replaced by a distributed antenna array. For all of these schemes, the costs of active repeaters would be far higher. Passive repeaters cannot, of course, be expected to substitute in all cases for the need for active radio devices that cover larger areas and will radiate through windows and other low loss sections of the same area. However, passive repeaters can provide significant signal improvement, particularly when limited areas (hot spots) must be covered.

RAY-TRACING ANALYSIS OF OUTDOOR-TO-INDOOR PASSIVE REPEATERS

The passive repeater has two antennas, an outdoor antenna aimed at a donor base station and an indoor or coverage antenna, linked back to back by a cable through an exterior building wall or roof. It is a two-way transmitting device, but for the purpose of analysis it is assumed that the outdoor antenna is receiving and the indoor antenna is transmitting.

As shown in ***Figure 1***, there are three possible passive repeater schemes. Scheme 1 has an elevated outdoor high- or medium-gain omnidirectional antenna A_1 (roof-top mounted, for instance), an indoor wall-mounted coverage antenna B_1 and a cable C_1. S is a transmitting base station antenna and M is the point where the fixed or mobile wireless unit is located. The power received by the outdoor antenna A1 is transferred to the coverage antenna B1, which in turn radiates into the building's inner space. This repeater scheme would be appropriate for mobile cellular links.

In Scheme 2, both antennas, the outdoor antenna A_2 and the coverage antenna B_2, are set on a building wall and are connected by a short piece of coaxial cable C_2.[5] For instance, the antennas can be printed patches over ground plates, which, in combination with the lossy wall, will ensure very high electromagnetic isolation between them. This scheme is intended for repeating signals from only one or several base stations located in the small-angle of visibility of the outer antenna A_2. The advantage of this scheme is its compactness and high transfer efficiency, owing to minimal cable losses. An illustration of Scheme 2[6] is shown in ***Figure 2***. It was prepared in accordance with a two-ray tracing model.[7]

Scheme 3 (A_3 – C_3 – $B_3^{(1)}$ $B_3^{(2)}$…, $B_3^{(n)}$) differs from the first one in the

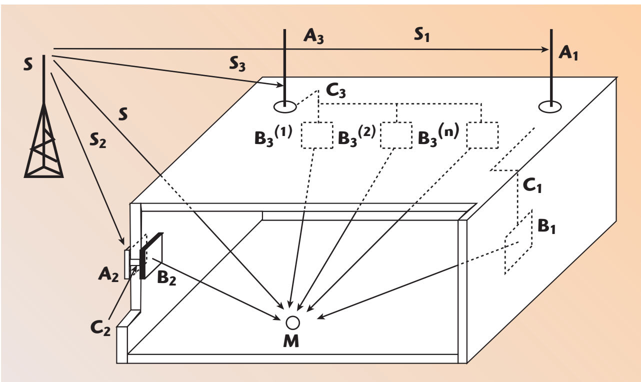

Fig. 1 Passive repeaters schemes.

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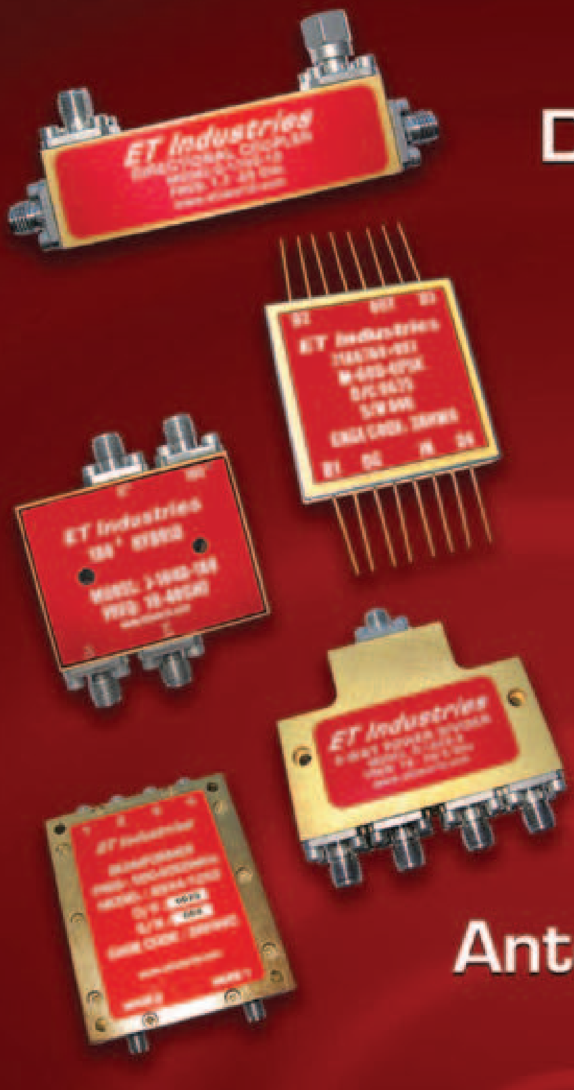

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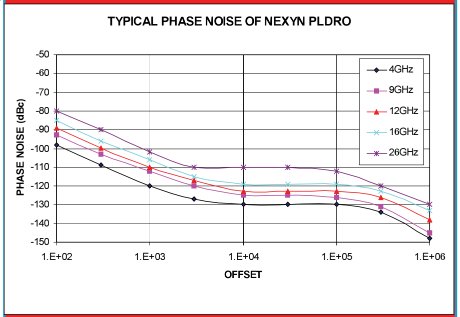

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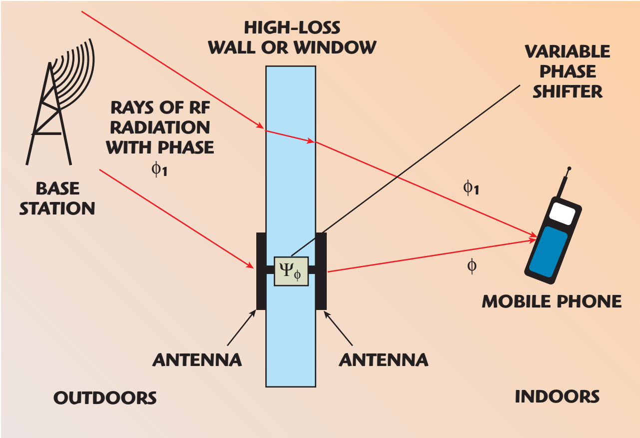


▲ *Fig. 2 Passive repeater scheme 2.*[6]

coverage antenna design only. It is not a single antenna, but an array of n on-wall antennas, connected in parallel (or in series) to an indoor coaxial feed cable circuit C_3. The distributed coverage antenna array can produce better signal delivery in large indoor areas.

POWER TRANSFER THROUGH PASSIVE REPEATER

In this section, the analysis is limited to the simplest, single-path repeater scheme (Scheme 1). Here, the indoor rays, transmitted through or reflected by building walls, are neglected. The power P_M received by the mobile unit antenna at point M as a function of the coordinate angles ϕ and θ is given by the modified Friis line-on-sight equation applied to the paths s and r via the passive repeater.[5]

$$P_M(\phi,\theta) = P_S(\lambda/4\pi)^4 (1/sr)^2 \bullet \eta_c G_s(\phi_A,\theta_A) G_A \bullet G_B(\phi,\theta) G_M(\phi,\theta) \quad (1)$$

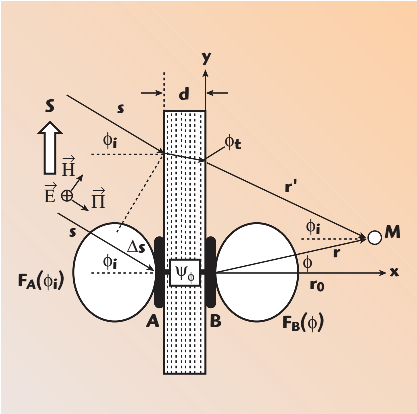
where

P	= power radiated by the base station antenna S
λ	= free-space wavelength
$G_s(\Phi_A,\phi_A)$	= base station antenna gain in the direction of the outdoor antenna A_1
G_A	= gain of the antenna A_1, with the main lobe looking at the base station antenna
$G_B(\Phi,\theta)$	= gain radiation patterns of the coverage antenna
$G_M(\Phi,\theta)$	= gain radiation patterns of the mobile unit antenna
η_c	= total cable efficiency

DOUBLE-RAY ANALYSIS OF ON-WALL PASSIVE REPEATER

Figure 3 shows the double-ray geometry of a cellular link between the base station S and indoor mobile telephone M (Scheme 2). A plane wave radiated by the base station antenna illuminates the building wall under the azimuth angle Φ_i. The elevation incidence angle θ_i is set to zero. The direct ray crosses the wall through the path S-W-M and the repeater ray goes along the path S-A-B-M. The wall is considered a lossy homogenous plate with a thickness d, relative permittivity ε_r and conductivity σ. For simplicity, the indoor site is assumed to produce negligible multipath effects. The electric and magnetic field vectors, and the power propagation vector of the incident wave are labeled by $\vec{E}$, $\vec{H}$, $\vec{\Pi}$, respectively. If $\vec{E}$ is parallel to the wall and perpendicular to the plane of propagation (the horizontal plane in the figure), the wave polarization is specified as vertical (v), or $\vec{E} = \vec{E}^{(v)}$. In the case of horizontal (h) polarization, $\vec{H}$ is parallel to the wall and $\vec{E}$ is parallel to horizontal plane.

The electric field $E_1^{(v,h)}$ at point M, resulting from the wave passing directly through the building wall, can be expressed as a product of the free-space wave E_M and transmission (refraction) coefficient $T_w^{(v,h)}(\phi_i)$, or



▲ *Fig. 3 Two-ray geometry of an on-wall passive repeater in the horizontal plane.*

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$$E_1^{(v,h)} = E_M T_w^{(v,h)}(\phi_i) \tag{2}$$

where $T_w^{(v,h)}(\phi_i) = |T_w^{(v,h)}(\phi_i)| \exp(j\Psi_w^{(v,h)}(\phi_i))$ is a complex function with a magnitude $|T_w^{(v,h)}(\phi_i)|$ and phase angle $\Psi_w^{(v,h)}(\phi_i)$. The upper indexes (v, h) refer to the vertical or horizontal polarizations, respectively. The through-wall attenuation is also defined as $A_w^{(v,h)}(\phi_i) = 1/|T_w^{(v,h)}(\phi_i)|$.[2]

For a given frequency, wall thickness d, permittivity ε_r and conductivity σ, the complex transmission coefficient $T_w^{(v,h)}(\phi_i)$ and the attenuation (loss) $A_w^{(v,h)}(\phi_i)$ are easily calculated by use of the equations for a lossy dielectric plate.[4]

The field at each indoor point M is found as a vector sum of the field $\vec{E}_1^{(v,h)}$ and the field $\vec{E}_2$ radiated by the inside antenna B, that is, in this simplified analysis it is assumed that the space behind the wall is not bounded, or that in the case of a bounded space the secondary waves reflected and transmitted by the other building walls and indoor objects are negligible.

Depending on the wave polarization the total field is written as

$$E^{(v)} = E_1^{(v)} + E_2^{(v)} \tag{3}$$

for vertical polarization, and

$$E^{(h)} = E_1^{(h)} \cos\phi_i + E_2^{(h)} \cos\phi \tag{4}$$

for horizontal polarization.

The analysis that follows is for vertical polarization only; the case of horizontal polarization can be treated in a similar manner. By use of Equation 3, the total field $E \equiv E^{(v)}$ can then be easily expressed as

$$E = E_s\Big[\exp(-j\Psi_1)/(s+r')\sqrt{A_w(\phi_i)} + \exp(-j\Psi_2)\bullet \left(\lambda\sqrt{G_A(\phi_i)G_B(\phi)}/4\pi s r\sqrt{A_{rep}}\right)\Big] \tag{5}$$

where $E_s = \sqrt{60P_S G_S(\phi_i)}e^{-j\beta_0 s}$, with $G_S(\phi_i)$ being the gain pattern of the base station antenna in the direction of the passive repeater; $\Psi_1 = \beta_0 r' - \Psi_w(\phi_i)$ and $\Psi_2 = \beta_0(\Delta_s + \sqrt{\varepsilon_{rc}}d + r) - \Psi_\Phi$ are the phase-shift angles, corresponding to the direct field E_1 and repeater field E_2; Ψ_Φ is the phase angle, introduced by the repeater phase shifter; $t = d/(\sqrt{1-(\sin^2\phi_i)/\varepsilon_{rc}})$, ($\varepsilon_{rc}$ is the relative permittivity of the cable dielectric) and $r' = r_0/\cos\phi_i$; and A_{rep} is the total attenuation (loss) factor, which includes the antenna, cable and mismatch loss.

The repeater recovering efficiency or gain as a power ratio g is defined at the receiver point M, which gives the local power density increase (or decrease) due to the passive repeater

$$g = \left(\frac{|E|}{|E_1|}\right)^2 \tag{6}$$

If the transmitter and receiver points S and M are at positions normal to the repeater, that is if $\Phi_i = \Phi = 0$, then bearing in mind that $s >> r_0$ and $r = r_0$, Equation 6 becomes the following simple equation:

$$g = 1 + 2(Q/r_0)\cos\psi + (Q/r_0)^2 \tag{7}$$

where

$$\Psi = -\Psi_{rep} - \Psi_w + \Psi_\Phi \tag{8}$$

and

$$Q = (\lambda/4\pi)\sqrt{A_w/A_{rep}}\sqrt{G_A(\phi_i)G_B(\phi)} \tag{9}$$

can be considered as a repeater quality factor.

For the case of real antenna impedances and low mismatch, the phase-delay angle is equal to $\Psi_{rep} = \Psi_c + \beta_0\sqrt{\varepsilon_{rc}}d$. As Q is always a positive quantity, it is evident from Equation 8 that the maximum value of the recovering efficiency g is obtained from $\Psi = 0$, or for

$$\Psi_\Phi = \Psi_w + \Psi_{rep} \tag{10}$$

and is given by the following simple expression:

$$g_{max} = (1 + Q/r_0)^2 \tag{11}$$

For a specific building wall, the passive repeater can be tuned for maximum power at the receiver. The repeater delay angle Ψ_{rep} is easily calculated. For a known wall structure and electrical parameters, the transmission phase angle Ψ_w is also computable. Thus, according to Equation 10, the phase-shifter angle can be set to the optimum value of Ψ_Φ. If, however, the wall is not specified, the optimum value of Ψ_Φ can be found only

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MSH-6411703	9.1-10.5	30.0	32.0	1.8
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MSH-5452304	4.0-8.0	29.0	15.0	3.0
MSH-7486403	6.0-18.0	29.0	20.0	6.0
MSH-7464401	8.0-18.0	25.0	18.0	5.0
MSH-9344202	18.0-26.5	20.0	7.0	5.0

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MSD-2654601	1.0-2.0	40.0	30.0	.80
MSH-4426602	3.7-4.2	25.0	30.0	1.0
MSH-5556603	4.0-8.0	35.0	30.0	1.0
MSH-6543603	8.0-12.0	34.0	30.0	1.1
MSH-7406601	12.7-13.2	30.0	30.0	1.2
MSH-4525701	3.7-4.2	35.0	33.0	2.0
MSH-5555701	4.0-8.0	32.0	33.0	2.0
MSH-5515701	5.9-6.4	35.0	33.0	2.0
MSH-6545701	8.0-12.0	33.0	33.0	2.0
MSH-4327702	3.7-4.2	24.0	34.7	2.0
MSH-4527702	5.3-5.9	34.0	34.7	2.0
MSH-6317701	7.7-8.5	24.0	34.7	1.8
MSH-6517702	9.0-10.0	34.0	34.7	2.0
MSH-4528704	5.3-5.9	33.0	37.0	3.2
MSH-5617801	5.9-6.4	38.0	37.0	3.6
MSH-6617801	7.7-8.5	39.0	37.0	3.6
MSH-6417802	9.0-10.0	29.0	37.0	4.4
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by indoor field trials. Also, in typical practical cases, the multipath propagation will result in a much more complex interference environment making optimum angle prediction very difficult, as will be illustrated by an empirical study.

NUMERICAL ANALYSIS AND LABORATORY EXPERIMENTS WITH AN ON-WALL PASSIVE REPEATER

To provide numerical examples for the improvement in signal coverage that can be expected in real situations, the recovering efficiency for three specific walls of thickness d = 0.28 m and an infinite extent were calculated and compared. It was assumed that each wall can be modeled with an acceptable accuracy as a homogeneous structure with an effective relative permittivity ε_r and conductivity σ. The following types of walls were assumed: a brick wall, a doubly-reinforced concrete wall with two steel meshes,[8] and an extremely-lossy or shielded wall. The incident wave is assumed to be vertically polarized.

Tables 1 and ***2*** show the measured wall parameters ε_r and σ,[8,9] and the computed values of A_w and Ψ_w for a normal wave incidence (Φ_i) are given for the three types of walls. The shielded wall electrical parameters and transmission loss values are assumed equal for both frequencies.

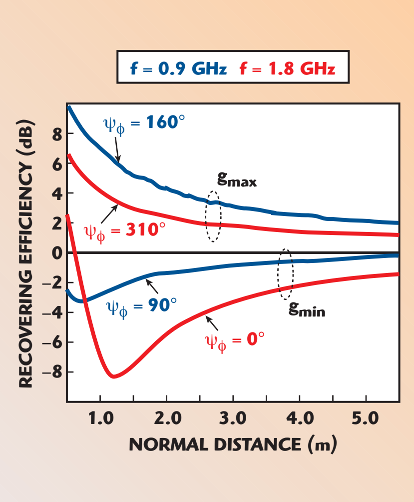
Figure 4 illustrates the calculated recovering efficiency g in the area behind a large brick wall versus the normal distance r_0 for $\phi_I = \phi = 0$ (normal wave incidence) and different values of the extra phase shift Ψ_Φ. ***Figure 5*** illustrates the same relations for a concrete wall. In both figures, the recovering efficiency graphs $g(r_0)$ are calculated for two cellular frequen-

TABLE I
ELECTRICAL PARAMETERS, LOSS AND PHASE SHIFT OF THREE TYPES OF WALLS AT 0.9 GHz

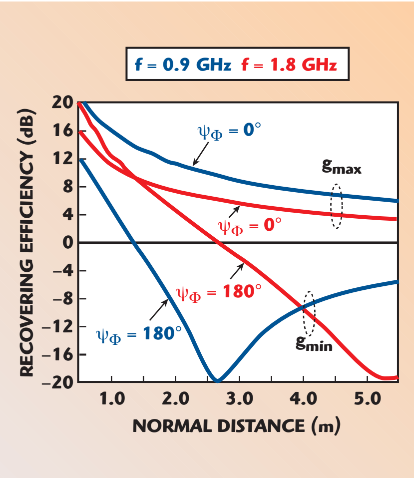
	Wall Loss (dB)	Phase Shift (°)
Brick ($\varepsilon_r = 4.6$, σ = 0.02 σ/m)	6	22
Reinforced concrete ($\varepsilon_r = 7.3$, σ = 0.05 σ/m)	19	217
Shielded ($\varepsilon_r = 7.0$, σ = 0.3 σ/m)	55	170

TABLE II
ELECTRICAL PARAMETERS, LOSS AND PHASE SHIFT OF THREE TYPES OF WALLS AT 1.8 GHz

	Wall Loss (dB)	Phase Shift (°)
Brick ($\varepsilon_r = 7.3$, σ = 0.05 σ/m)	8	40
Reinforced concrete ($\varepsilon_r = 8$, σ = 0.07 σ/m)	23	82
Shielded ($\varepsilon_r = 7.0$, σ = 0.3 σ/m)	55	170



▲ *Fig. 4 Recovering efficiency vs. normal distance from coverage antenna for a brick wall.*



▲ *Fig. 5 Recovering efficiency vs. normal distance from inside antenna B for a reinforced concrete wall.*

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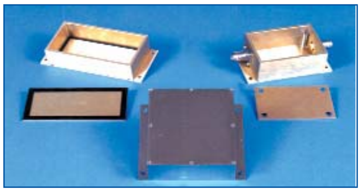

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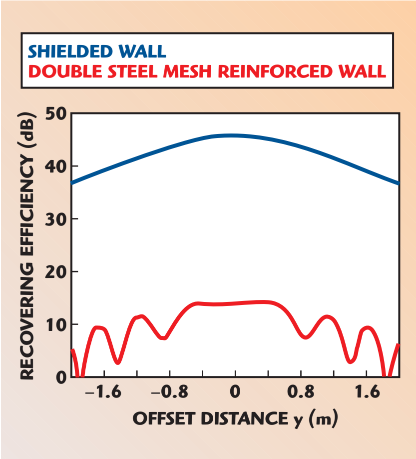
cies: 0.9 and 1.8 GHz. The efficiency graphs correspond to the phase shifters tuned for maximum (g_{max}) and minimum (g_{min}) recovering efficiency.

It is concluded that, for the brick wall, the passive repeater is effectively tuned by the phase shifter, but its potential for signal improvement is moderate and reduces with the distance from the wall. The recovering efficiency can be further increased only by use of more directive antennas (A and/or B). In contrast, in the case of a double steel-mesh concrete wall, the potential recovering efficiency is much higher for a significant range of distances.

The worst-case curves suggest that a proper choice of Ψ_Φ is again very important. It must be stressed, however, that these figures refer only to the situation at a specific angular position and that usually the goal is improvement of area coverage. As will be discussed later, the empirical results show that in a practical case,

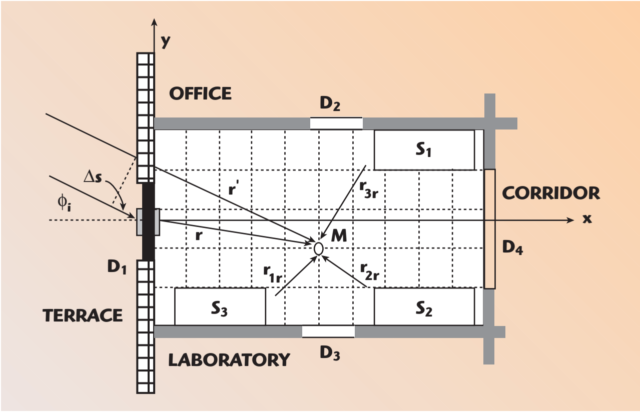


▲ *Fig. 6 Power gain vs. offset distance.*

with significant multipath propagation, the average improvement over an area is little affected by the choice of phase shift. This is due to the fact that the phase shift basically changes the position of the regions of constructive and destructive interference, not their size.

The recovering efficiency as a function of the offset distance y of point M is illustrated in ***Figure 6*** for the double steel-mesh reinforced concrete and for the shielded wall. The distance r_0, measured from the receiver point M to the passive repeater antenna B, is kept constant ($r_0 = 2$ m). The recovering efficiency is approximately 10 dB for the reinforced wall, while the shielded wall has much higher values: 45 dB for y = 0 m and larger than 25 dB in the range of y = ±10 m. For the latter case, the direct (through-wall) signal is practically zero, and naturally the phase shifter becomes superfluous.

Complex conditions, such as the effect of multiple arriving wave fronts and reflecting objects, which are difficult to analyze theoretically and which will vary with position inside a room, are best treated through an empirical study to collect statistically relevant data. The procedures described as follows concentrate on this aspect, providing the results of a real implementation and its comparison with the simplified theoretical model. A passive repeater illuminating a small room is sketched in ***Figure 7***. Shown are the horizontal room layout and the repeater ray-interference scheme at the receiver point M (direct or transmission ray r', repeater ray r and three reflected rays: r_1, r_2 and r_3). The room is 2.6 m wide, 4.6 m long and 3.5 m high and comprises an exterior brick and mortar wall with a metal door D_1 and partition walls with doors D_2, D_3 and D_4. The ceiling and the floor are made of reinforced concrete. S_1, S_2 and S_3 are metal stands, 1.8 m (height) × 1.20 m × 0.50 m each. The passive repeater device un-



▲ *Fig. 7 Passive repeater illuminating a small room; horizontal plane layout.*

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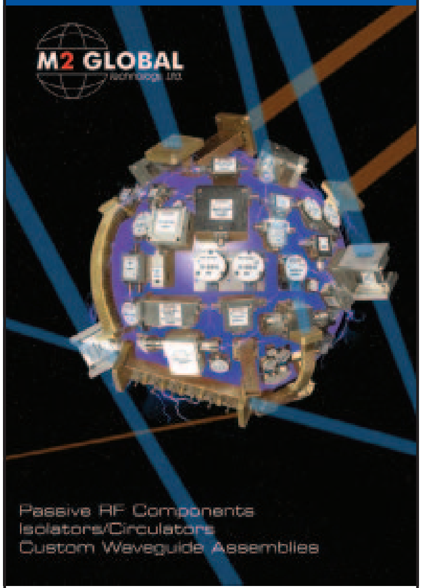

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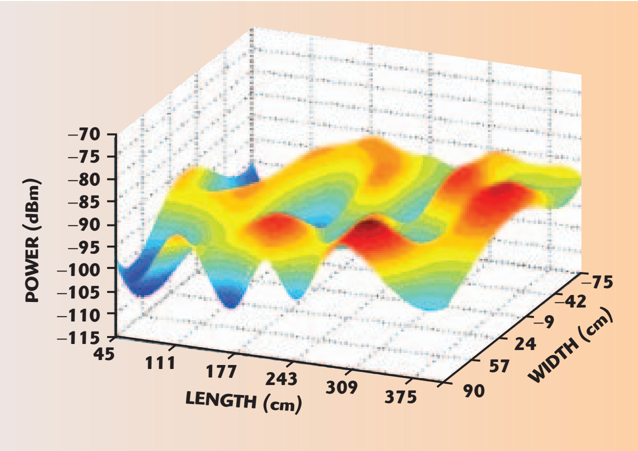
der examination consisted of two equal or "twin" plane-reflector antennas A and B with vertical polarization, each 21 × 21 × 5 cm, a nominal gain of 8 dB at 0.9 GHz, VSWR = 1.5 and a horizontal-plane beam width of 80°. The repeater twin antennas were mounted on the metal door, at a height of 1.6 m above the floor. In order to increase the through-wall attenuation, simulating a very high loss wall, the outer side of the wall was loosely covered (shielded) by an anti-mosquito metal mesh.

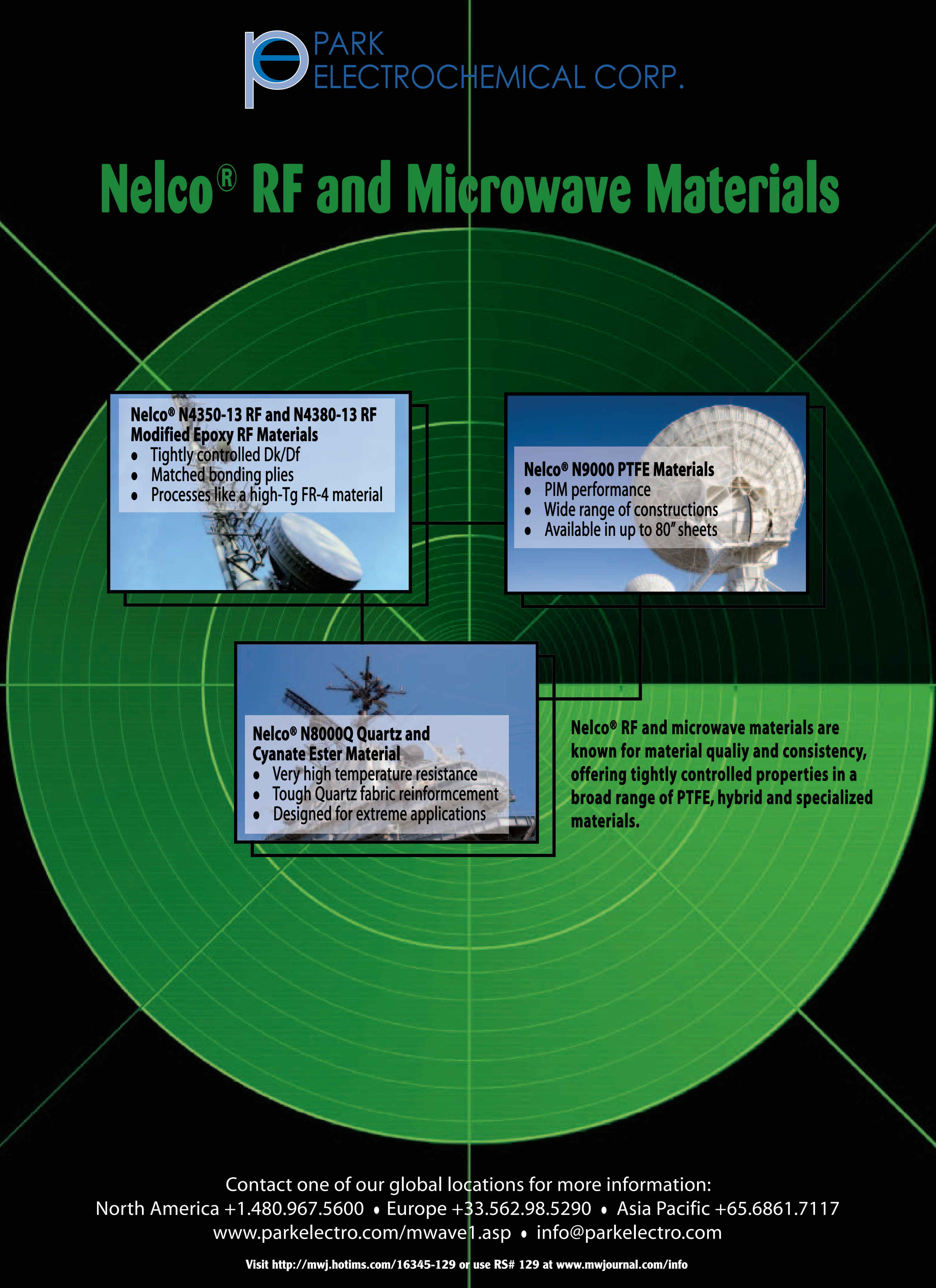
The power gain associated with the use of the passive repeater was determined for the case of a continuous wave signal. The procedure involved first measuring the received power in the chosen indoor area, under normal conditions, that is when the passive repeater was switched-off. This was done over a wide range of positions in the room according to a square measurement grid of a size equal to one wavelength. Both the transmitter antenna and receiver antenna were held at the repeater's height. The transmitter antenna was placed outdoors at a distance much larger than the far-field extent from the shielded wall.

An element of uncertainty in any real situation is the angle of arrival of the outside signal with respect to the bore sight of the receiving antenna. Any practical repeater for cellular telephony would be expected to cover a wide azimuth range, as the base station position serving a call is not usually known. That is why the measurements included positioning the transmitter antenna to "see" the passive repeater from several different angles Φ_i ranging between 0° and 60°, in increments of 10°. Because the antennas have relatively low directivity, there exists a potential for significant multipath signal propagation, a condition representative of an urban environment. The measured values without the repeater were contrasted with the theoretical free space received power. This provides information on the combined effect of the wall obstructing the direct path, and the multipath interference due to the surrounding building elements and furniture. For each position inside the room, the corresponding value of received power with the repeater switched-on was subsequently measured. An extra phase shift, Ψ_Φ = 0°, 90°, 180° or 270°, was introduced by means of the phase shifter in order to test the influence of this parameter. For a quasi-plane wave incident on a large wall, in an environment devoid of multipath effects, the optimum phase shift can be evaluated numerically.

Figure 8 shows the distribution of the power received from the outdoor test transmitter as measured inside the room, when the passive repeater is switched-off. The indoor coverage antenna is placed at x = 0 and its bore sight direction is +x. On the average, the measured power level values vary from –90 to –110 dBm. ***Figure 9*** shows the measured power in the same room, when the passive repeater is switched-on, with a phase-shifter tuned at Ψ_Φ = 270° and for a normal incidence of the outside wave. On average, 10 to 15 dB higher power levels are observed, with multipath fluctuations that are similar to those when the repeater is switched-off. Measurements performed for other values of the phase shift show similar results. As expected, it was observed that in the region where the repeater power dominates, the phase shift is of little consequence. In contrast, in the region where the repeater output is comparable to the signals entering through the walls, the diagram changes significantly.



▲ *Fig. 8 Measured received power with repeater switched off and angle of incidence $\phi_i = 0°$.*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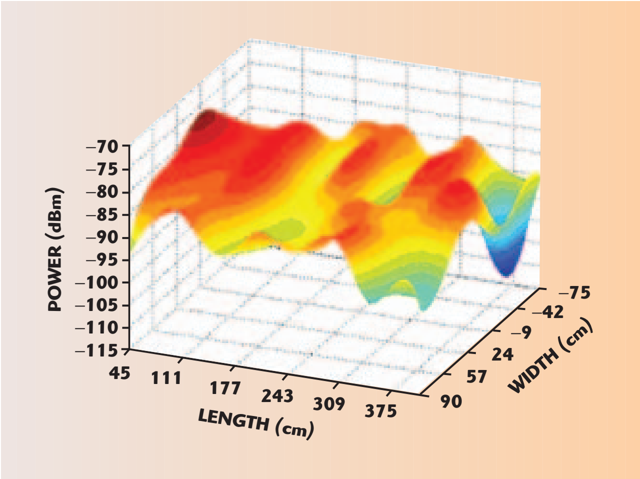
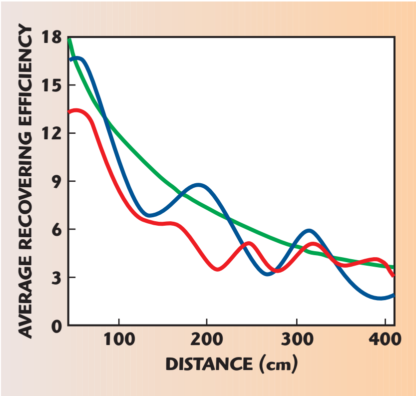


▲ *Fig. 9 Measured received power with repeater switched on with $\phi_i = 0$ and $\psi_\phi = 270°$.*



▲ *Fig. 10 Average recovering efficiency vs. normal distance for an on-wall passive repeater.*

The large amount of collected data, and the variations that are to be expected for these types of measurements, require the use of statistical processing of the data in order to be able to draw general conclusions. From the measured power data, the average recovering efficiency gave at a given distance from the repeater wall was calculated: $g_{av}(dB) = P_{av}\,(dBm) - P_{1,\,av}\,(dBm)$.

The average empirical recovering efficiency curves as a function of distance from the repeater to the door D_4 are drawn in ***Figure 10*** for two values of the phase shift Ψ_Φ 90° (blue line, best case) and 180° (red line, worst case). As a reference, the green line in the same figure illustrates the theoretical function g_{r0} for the ideal case of a transmitter and receiver located on the axis of the repeater antenna beams. It was calculated, using Equation 6, for $A_w = 28$ dB, $A_{rep} = 1.3$ dB, $\Psi_\Phi = 90°$ and $G_{Amax} = G_{Bmax} = 8$ dBi. As can be seen, on average, the difference between best and worst case is not large, far less than the extreme conditions depicted previously. It is evident that the average signal recovering efficiency oscillates and decreases quickly with the distance, ranging from approximately 15 dB near the repeater, to approximately 3 dB at the far end of the room.

PASSIVE REPEATER FOR UNDERGROUND PARKING LOT

Encouraged by the laboratory results presented in the previous section, it was decided to use a passive repeater in a real setting. The corporate building of a cellular service provider had an interesting signal coverage problem that needed to be solved. The building had two levels of underground parking and a storage space. Due to space limitations in the building, the storage area of the lowest floor was considered for emergency use as a meeting room. An assessment of the received power levels was performed on the selected underground area (70 m²) using the TEMS CellPlanner Universal® instrument developed by Ericsson.[10] The signal levels recorded in the selected area were approximately –105 to –115 dBm, as can be seen in ***Figure 11***. Cellular coverage was desirable, but not available in that space without the use of some kind of repeater.

To make the repeater installation, an external 12 dBi gain Yagi antenna was positioned on a 7 m high terrace of the building and aimed at a line-of-sight, close-by base station. The level of received power, measured with the TEMS on the terrace near the Yagi antenna, was found to be approximately –61 dBm. The passive repeater 8 dBi gain coverage patch antenna was placed on one of the walls of the underground storage at a height of 1.65 m and was connected to the Yagi antenna by means of a 100 m long, 7.5 dB loss coaxial cable. As a result of the repeater installation, with a total antenna gain of

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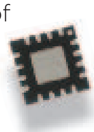

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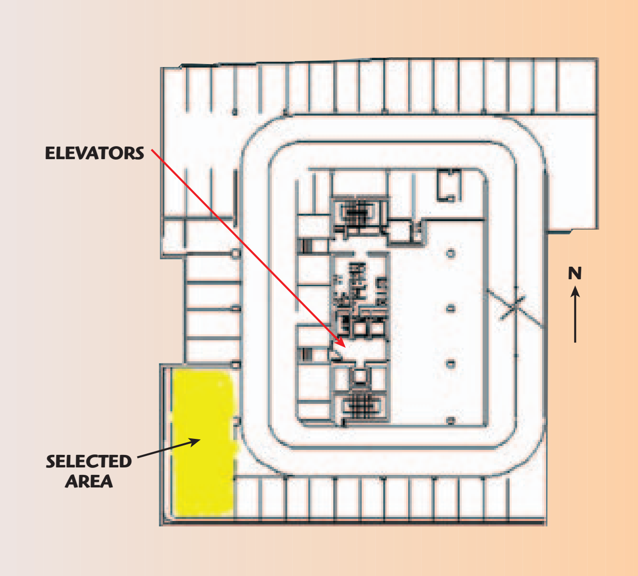
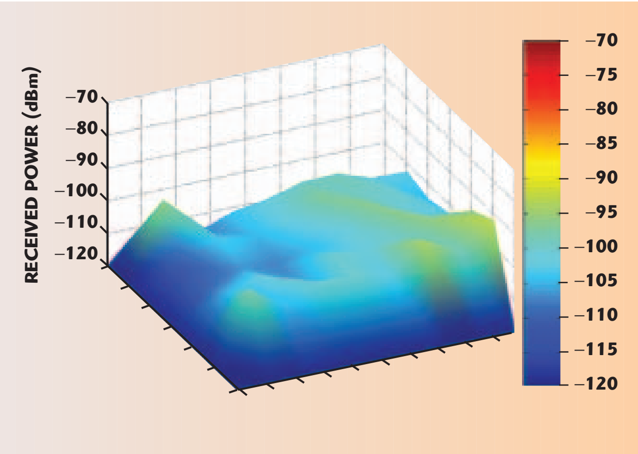
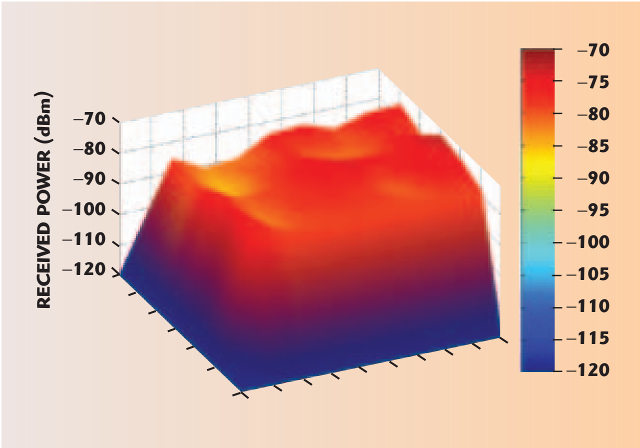
20 dB, and the inevitable effect of cable and mismatch losses, power levels of approximately –73 dBm were now observed near the interior patch antenna by means of the same measurement setup used on the terrace. At a distance of 10 m, the power level dropped to approximately –88 dBm, but was still adequate for a normal cellular call.



▲ *Fig. 11 Underground storage area where cellular coverage is provided by means of a passive repeater.*



▲ *Fig. 12 Cellular coverage prior to installation of a passive repeater.*



▲ *Fig. 13 Cellular coverage after passive repeater installation.*

Comparing ***Figure 12*** with ***Figure 13***, it is seen that the use of passive repeaters in certain practical settings such as underground spaces, where propagation losses through walls are considerable, may be an attractive, cost-effective alternative for achieving a large signal improvement in reduced spaces.

CONCLUSION

The potential for improvement of indoor signal coverage by use of an on-wall passive repeater for the 900 MHz cellular band has been studied theoretically and demonstrated experimentally. A phase shifter, a novel element in passive repeating, was added and its impact on the indoor signal level and a distribution was studied. The numerical repeater link analysis and measurements confirmed that for the specific case of an 8 dB antenna repeater, illuminating a small building room with a high loss exterior wall and a realistic indoor environment, moderate signal recovering is achieved, ranging from 15 to 17 to approximately 3 dB depending on the distance from the repeater. Multipath propagation tends in practice to

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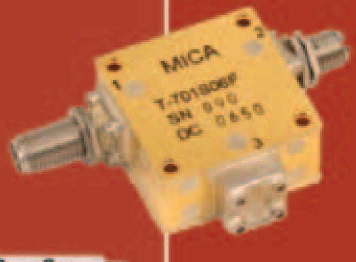

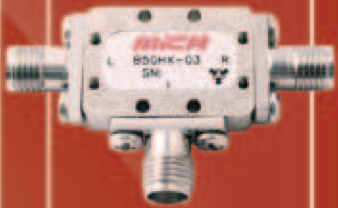

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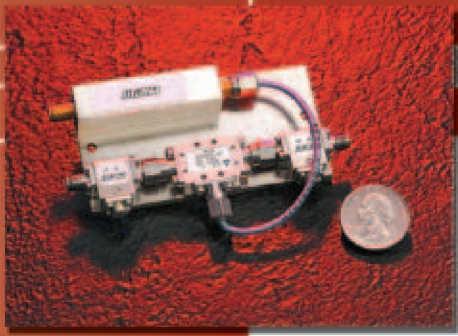

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make the phase-shift choice uncritical when larger areas need to be covered, as improvements in certain small regions due to the choice of the proper phase shift are made at the expense of deterioration in other areas. It was observed that in the region where the repeater power dominates, the phase shift is of little consequence. In contrast, in the indoor areas where the repeater output was comparable to the signals entering through the walls, the field distribution changes considerably.

The passive repeating principle was then applied in an office building environment, where cellular coverage was practically non-existent in a specific region of interest, an underground storage and parking area. After checking that sufficient signal could be received with a directional antenna from a given base station to compensate for coaxial cable losses, the passive repeater system provided the necessary cellular coverage with low installation and maintenance costs. Although situations like the one described may not be frequent, the use of passive repeaters in underground subway and pedestrian walkways may be an interesting commercial application to exploit passive repeaters for mobile service providers.

While the analysis in this article stressed the improvement in signal coverage in an extended area (mobile situation), for the case of fixed-terminal communication systems the signal level can be further increased using more directive repeater antennas or antenna arrays that cover only certain angular positions. ■

ACKNOWLEDGMENTS

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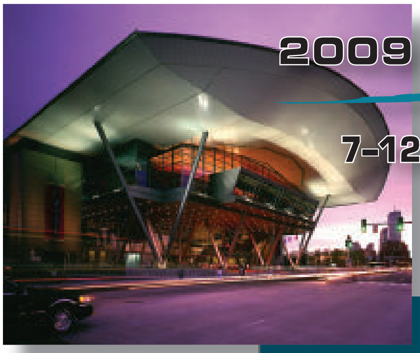

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CONSTANT EFFICIENCY ACHIEVEMENT WITH SWITCHED GAIN STAGE AND DRAIN SUPPLY ADJUSTMENT FOR A UHF POWER AMPLIFIER

In two-way radio applications, achieving constant efficiency across a wide power level is an important design criterion to be considered. Constant efficiency in this context refers to efficiency improvement at low power level while maintaining high efficiency at high power level. Switched gain stage and drain supply adjustment methods are discussed. With both methods, an efficiency of 45 percent is achieved at low power (1 W) for a frequency range from 420 to 440 MHz, while maintaining the same efficiency at high power with a LDMOS device amplifier.

A power amplifier (PA) achieves maximum efficiency when operating close to saturation. When the input drive signal is backed off, the output power decreases and eventually the efficiency degrades. In two-way radio applications, two modes of operations are allowed, which are high (5 W) and low power (1 W) levels in the UHF frequency band. Thus, it is important to achieve constant efficiency for the two modes of operation levels. In a PA design, constant efficiency can be achieved at both power levels, with supply or load adjustment or both.

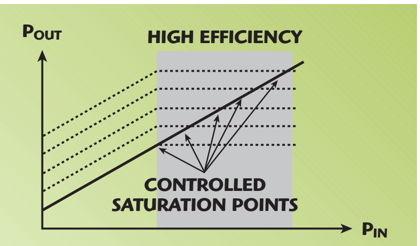

Fig. 1 Constant efficiency vs. input power level with saturation point control.

Using SiGe HBTs, Leuzzi, et al.[1] have shown an efficiency of 20 to 60 percent for a power range of –10 to 5 dBm with load adjustment. Fowler[2] used variable bias and supply voltages for efficiency improvements at low power levels and variable load impedance at higher levels. Buoli, et al.[3] have demonstrated efficiency improvements by envelope controlled drain supply adjustment applied to GaAs FETs, which led to a reduced DC consumption of 45 percent. Geller, et al.[4] showed, for a 1 W amplifier, an efficiency of 65 percent at saturated power and 55 percent when backed off by 10 dB with drain voltage adjust-

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MODEL	FREQ. (GHz)	GAIN (dB)	POUT (dBm) @ 1 dB Comp.	NOISE FIG. (dB)	PRICE (1-9)
ZVA-183+	0.7-18	26	+24	3.0	895.00
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ment. Switched gain stage or stage bypass is accomplished by switching the amplifier between the final stage and driver stage according to peak signal level. Staudinger has demonstrated an improvement of the average efficiency from 2.1 to 9.5 percent over a large dynamic range.[5] Patent ideas by Sevic[6] and Brozovich[7] have described an efficiency improvement by selecting the amplifier stage with a switch bypassing scheme.

This article explains the switched gain stage and drain supply adjustment methods to improve efficiency at low power level (1 W) while maintaining the same efficiency at high power (5 W) with an LDMOS PA device. With both methods, an efficiency of 45 percent at low power is demonstrated, while preserving similar efficiency at high power. Issues for both methods, such as nonlinear behavior of the transconductance of the MOSFET, insertion loss of the RF switch and PA gain stage, are discussed.

PRINCIPLE OPERATION OF CONSTANT EFFICIENCY

To achieve low power consumption and maximum battery lifetime, it is desirable that the power stage of a power amplifier chain (assuming multiple stage design) keeps a constant efficiency across a wide range of power levels.[1] The efficiency reaches its maximum in the extended saturation region. Hence, controlling the saturation point can produce constant efficiency across varying power levels. ***Figure 1*** shows the constant efficiency area with different saturated power levels. The load line, together with the device characteristics, determines the operation at a certain power level and the allowed excursions of drain current and voltage and thus output power.[3] For maximum efficiency, the RF voltage and drain current must swing towards twice the supply voltage and I_{max} (defined by the maximum FET current) respectively at the desired output power level. Two approaches have been demonstrated so far, which are the adjustment of the drain supply voltage and the adjustment of the load impedance.[1]

Looking at the I-V characteristics of the transistor (see ***Figure 2***), both arrangements shift the power level to where the saturation of the amplifier occurs. In the first case, the load line is shifted to the left in the I-V plane. In the second case, the slope of the load line becomes less negative. In both cases, saturation occurs at a lower power level and the efficiency is peaked. A reduction of the RF drive level under fixed bias conditions does not allow the DC component of the drain current to drop proportionally to the RF signal.

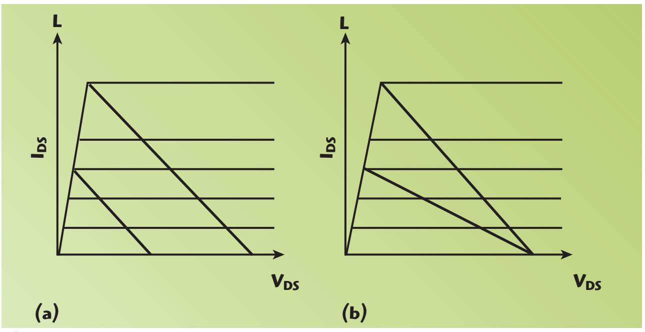

Fig. 2 Load line variation by drain supply (a) and load impedance (b) adjustment.

SWITCH GAIN STAGE DESIGN CONSIDERATIONS

The switch gain stage method uses a switch to bypass the final stage amplifier for low power operation. The final amplifier is shut down, which decreases the overall DC power consumption and the amplifier efficiency is increased. The topology in ***Figure 3*** shows the bypassing method of the final stage amplifier. At low power, the Q_1 amplifier amplifies the signal with switches SW_1 and SW_2 switched to point 1. At high power operation, both amplifiers (Q_1 and Q_2) operate with switch SW_1 and SW_2 switched to point 2. The slope of the load line decreases due to the lower power levels of Q_1 during the bypass mode. Consequently, the drain current is reduced. At low power level, the entire signal is amplified with Q_1 and the RF signal is routed from the first stage to the output (via the bypass path). V_{g2} is set to pinch off; hence, I_{d2} is zero.

At higher power level, both stages of the amplifier operate with constant high efficiency. Basically, two RF switches are needed to bypass Q_2 and an additional matching circuitry is required to provide the desired Q_1 load line in the bypass mode. Mitsubishi RD01MUS1 and RD07MVS1 power MOSFET devices have been used for the first and second stage, respectively. Both amplifiers are built using LDMOS FET technology. CAD models of the RD01MUS1 and RD07MVS1 were developed and used in the simulations.

In the RF switch application, resonance tank and PIN diode circuits are introduced for high power (up to 5 W), as shown in ***Figure 4***. For lower power operation, RF switching networks (SW_1) and (SW_3) are added to bypass the final stage power amplifier. Good correlation of the RF switching (three-port networks) between simulation and measurement results was obtained. In order to deliver 5 W from the final stage, an optimum inter-stage match between the first and final stages must be carried out in the no-bypass mode. In the bypass mode, an additional matching is necessary to achieve the optimum load impedance for low power. A routing path, using a matched transmission line, is necessary in the bypass mode.

DRAIN SUPPLY ADJUSTMENT DESIGN CONSIDERATIONS

In this method, the drain supply voltage is adjusted according to the required power level. A reduction of the RF drive level under fixed bias

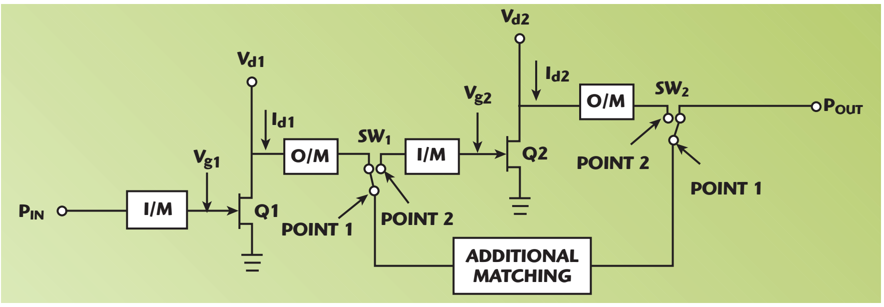

Fig. 3 Stage bypassing architecture of a two-stage power amplifier.

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

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T82-250	2-8	250	54
T188-250	7.5-18	250	54
T-500 Series • 500 Watts CW 1-18 GHz			
T251-500	1-2.5	500	57
T7575-500	2.5-7.5	500	57
T188-500	7.5-18	500	57
MMT Series • 5-150 Watts, 18-40 GHz			
T2618-40	18-26.5	40	46
T4026-40	26.5-40	40	46
S/T-50 Series • 40-60 Watts CW 1-18 GHz			
S21-50	1-2	50	47
T82-50	2-8	50	47
T188-50	8-18	50	47

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CMC1000	80-1000	1000	60
SMX Series • .01-1000 MHz			
SMX100	.01-1000	100	50
SMX200	.01-1000	200	53
SMX500	.01-1000	500	57
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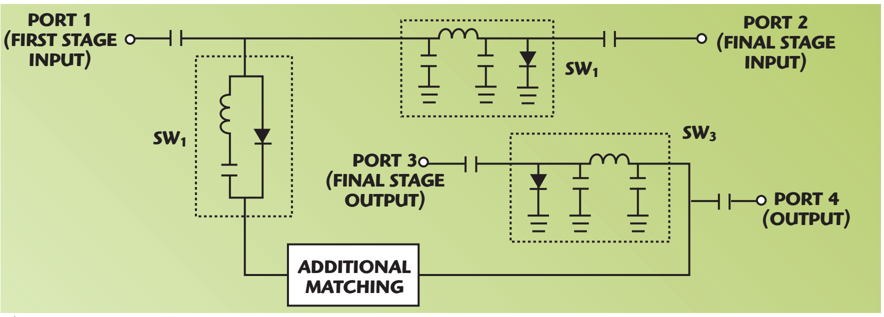


▲ *Fig. 4 RF switches in switched gain stage method.*

conditions does not allow the DC component of the drain current to drop proportionally to the RF signal. If the drain bias is decreased when the RF drive is reduced, the DC component can be reduced substantially. The optimum drain supply voltage V_{DSopt} for any power operation can be expressed as

$$V_{DSopt} = \sqrt{2P_{OUT}R_{OL}} + V_K \quad (1)$$

V_k can be obtained from the I_{DS}–V_{DS} characteristics, either from simulation or from measurement. In addition to the reduction of V_{DS}, a small increase (more positive) of the gate voltage is helpful to increase the average g_m.[4] Thus, this will increase the gain and PAE. The MOSFET transconductance g_m is defined as the change of drain current I_{DS} with respect to the corresponding change of gate voltage V_{GS}[8] with V_{DS} constant.

$$g_m = \partial I_D / \partial V_{GS} \quad (2)$$

Knowing the I_D of an N-channel MOSFET, one can derive the g_m in the saturation region as

$$g_m = \frac{W\mu_n C_{OX}}{L}\left(V_{GS} - V_T\right) \quad (3)$$

To increase g_m, the channel width W of the transistor can be increased, but this also increases the channel length L and reduces the oxide thickness.[8] Equation 3 shows that an increment of V_{GS} helps to boost up g_m. Biasing the amplifier in the class AB mode is effective, with respect to the control of the gate biasing, for optimum efficiency (PAE) adjustment. The simulation analysis showed the degradation of g_m below V_{DS} = 4.8 V for the RD07MVS1 (LDMOS) device. This is illustrated graphically in **Figure 5**.

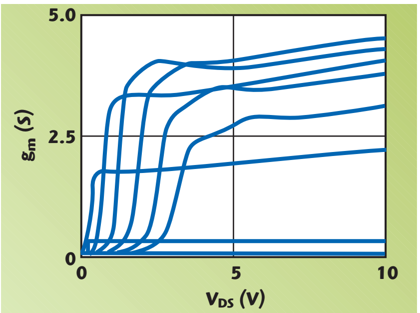
MEASUREMENT RESULTS

The concept of achieving constant efficiency with the proposed methods is validated through on-board measurements. A test board using an FR-4 substrate material was fabricated. The PCB has a dielectric constant of 4.5 and a thickness of 14 mils. For the switched gain stage, RD01MUS1 (first stage) and RD07MVS1 (second stage) are used in the experiment. And for the drain supply adjustment method, only the RD07MVS1 device is used to prove the concept. For each method, two different test boards were fabricated. Optimizations are done for each board at an early stage to meet the power performance. A heat sink is mounted at the bottom of the test board (for the RD07MVS1) for good heat transfer.

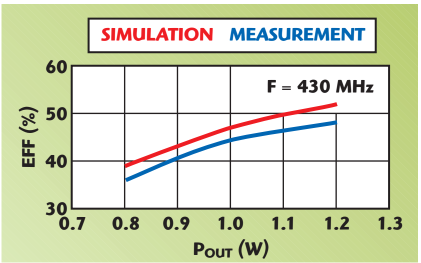
SWITCHED GAIN STAGE RESULTS

The efficiency measurement results across the power level range for bypass and non-bypass modes are shown in ***Figures 6*** and ***7***, respectively. The insertion loss of the RF switch is 0.29 and 0.58 dB during bypass and non-bypass mode, respectively. An isolation greater than 28 dB is obtained for bypass and non-bypass modes. The measured efficiency is improved by 25 percent at low power (1 W) in the bypass mode. A degradation in efficiency of 7 percent at 5 W is experienced in the non-bypass mode. This is due to the insertion loss (0.58 dB) of the RF switch between the inter-stage matching circuit and the output final stage amplifier in the non-bypass mode. Good correlation is observed between measurement and simulation results.

Nevertheless, constant efficiency could be achieved for the wide power range from 1 to 5 W. If the first stage power amplifier saturates at higher power, it can produce a constant high efficiency. Experimental results prove that the device gain is important. Possible wideband amplifier devices, with wider dynamic range, may increase the versatility of the proposed technique.



▲ *Fig. 5 Transconductance g_m vs. V_{DS} for the RD07MVS1 device.*



▲ *Fig. 6 Simulated and measured efficiency vs. output power for the two-stage amplifier in the bypass mode.*

DRAIN SUPPLY ADJUSTMENT RESULTS

Simulated and measured efficiency versus P_{OUT} are shown in ***Figure 8***. The results show a constant efficiency of 45 percent at low (1 W) and high power (5 W). The input RF drive to the power amplifier has to change according to the required output power. The input RF drive to the power amplifier requires a dynamic range of 10 dB. A slight decrease in gain was experienced below 4.8 V, which was already predicted through calculation and simulation due to the gm of the device dropping in this region. Below this point, the gate bias voltage is increased to maintain PAE and gain. The device is operating in class AB. The measurement results showed good correlation with simulation. A summary of the performance of switched gain stage and drain supply adjustment methods is illustrated in ***Table 1***.

CONCLUSION

Enhancement of efficiency at low power (1 W) operation, while maintaining the same efficiency at high power (5 W) with switched gain stage and drain supply adjustment methods, is demonstrated. Efficiency improvement

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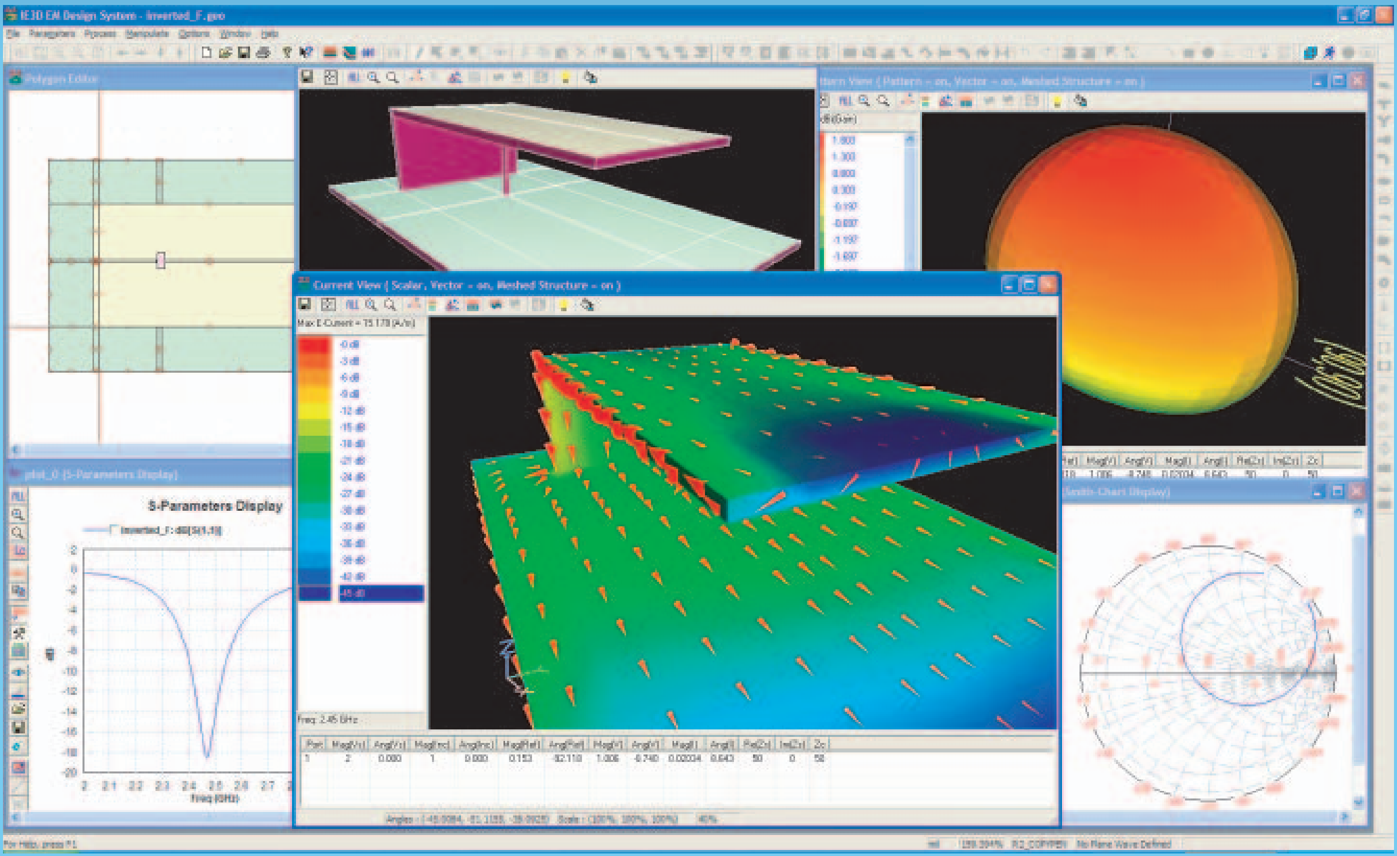

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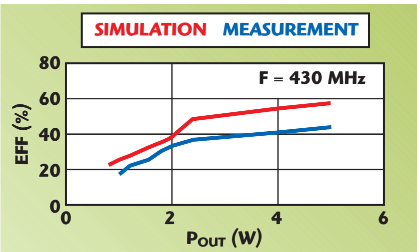
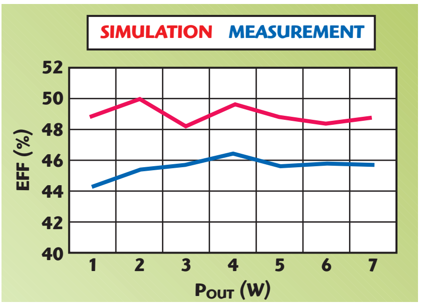
TABLE I

PERFORMANCE SUMMARY OF SWITCHED GAIN STAGE AND DRAIN SUPPLY ADJUSTMENT METHODS AT 430 MHz

Power Operation	Methods of Achieving Constant Efficiency (%) Switched Gain Stage	Drain Supply Adjustment
High (1 W)	45	44
Low (5 W)	41	46



▲ *Fig. 7 Simulated and measured efficiency vs. output power for the two-stage amplifier in the non-bypass mode.*



▲ *Fig. 8 Simulated and measured efficiency vs. output power with drain voltage adjustment.*

of 25 percent with bypass mode for low power (1 W) and with degradation of 7 percent at high power (5 W) are achieved. With a lower insertion loss of RF switch, the efficiency at high power will be maintained in the non-bypass mode. An efficiency of 45 percent, across a wide range of power level (1 to 5 W), is achieved with the drain supply adjustment method. The transconductance of the active device is analyzed and a class AB bias scheme is proposed. The gain drop at very low power levels can be compensated by a slight increase in gate source voltage. ■

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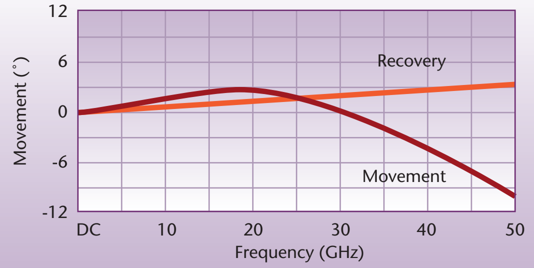
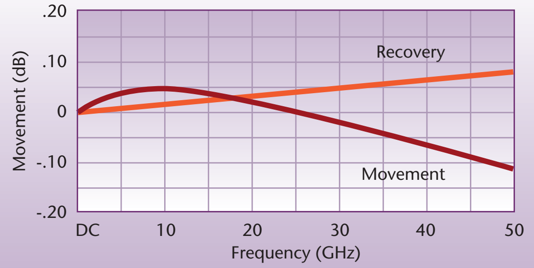


Typical Amplitude vs. Flexure



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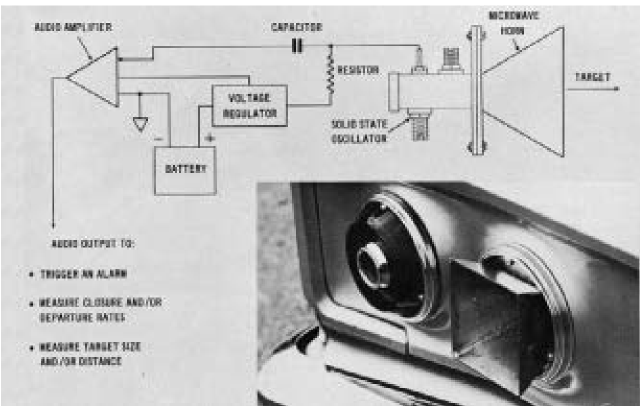
A MICROWAVE JOURNEY, PART III: THE 1970s

This series looks at the past five decades of our industry as described in this magazine. In this third installment of our six-part series, we focus on the 1970s, the decade of Watergate, a gas crisis, Americans held hostage in Iran... ah, yes, good times. At least we had disco to help us dance away our malaise.

Despite some low points between 1970 and 1979, the microwave industry was robust with innovations on multiple fronts and healthy government and private funding. Microwave solid-state devices and microwave integrated circuits (MIC) continued to develop and allow new systems such as the next-generation of airborne weather avoidance radar, phased arrays, radio-telescopes, more satellite communications and microwave links for telecommunications. Numerous contributors openly contemplated data communication at GHz rates and fiber optics became reality. In 1970, analysts Frost and Sullivan predicted that the data-communications market "could be worth $2 billion dollars by 1975 and that data traffic could capture 50% of the telephone network by 1979." Here's a sample of what appeared on the pages of *Microwave Journal*.



▲ *Fig. 1 From "Detection Range Measurements on a Simplified Doppler Radar," a December 1971 article depicting use in an early collision avoidance radar.*

JANUARY 1970

This issue was dedicated to ferrites and filters. Articles included "High Performance YIG Filters," "Recent Trends and Advances in Filters and Couplers" and "New and Unique Ferrite Devices." Associate editor Seymour B. Cohn wrote an opinion piece entitled "Computers Have Limitations, Too" that celebrated the computer's role in allowing laboratories to do "sophisticated design work," but also warned "that computers cannot think" and that the engineer "should decide beforehand whether his purpose is best served a direct approach or by digital optimization." While engineers today still get into trouble for optimizing every possi-

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ble parameter or accepting simulation results without fully understanding if the problem is properly defined, the author would no doubt be impressed by how close today's software comes to actual thinking, greatly simplifying many design tasks.

Publisher William Bazzy discussed "the recent vote in the US Senate on the anti-ballistic missile program Safeguard." With an approved budget, Bazzy pointed out that, "the new need is to develop and produce the microwave hardware and special test equipment that is part of the Perimeter Acquisition Radars (PAR) and Missile Site Radars (MSR) and the associated Spartan and Sprint Missiles." Bazzy went on to note that while phased-array radars had been investigated since the mid-1950s and reported in the *Journal* since 1959, the R&D programs in play during the 1970s would bring these systems to the point of technological feasibility. Bazzy concluded that, "In view of the importance of the entire anti-ballistic program, we will continue to report on those aspects affecting the microwave community, such as the impact phased-array radars will have on the components industry, the solid-state group, test equipment requirements, etc."

DECEMBER 1971

Staff changes are reflected in the masthead with William Bazzy now serving as president-publisher, Ted Saad as vice president and Charles E. White assuming the lead editor position. Assistant editor R.C. Hansen wrote an editorial on "Future Antenna Trends at Allerton," in which he discussed the outcome of the USAF annual conference on antenna R&D, held for DoD antenna contractors. Conference attendees agreed that due to a tight money situation, the needs of the system would be the driving force behind antenna R&D. They also agreed on the continuing importance of computers in antenna design and analysis, almost 20 years before the first commercial electromagnetic software is available. Hansen wrote, "In the design area, computers will be even more vigorously used. Most designs will still use results of appropriate analyses, but the scope of these analyses will increase, especially in methodology wherein the computer simulates the current carrying surface. More powerful moment-type methods are to be expected. Design utilizing optimization codes will be limited in use, mostly due to cost but also because complicated problems often have subsidiary maxima." (Incidentally, this conference, the 2008 Antenna Applications workshop, is still held today, taking place this month from September 16 to 18 at Allerton Park in Monticello, IL).

On computer optimization of antenna design, the author concluded that "optimization using moment methods without heavy use of engineering judgment to greatly reduce the number of cases is indeed a bold venture unless one's computer time is free." Today, *Microwave Journal* receives many antenna papers utilizing commercial software to generate and optimize antenna designs. We applaud today's electromagnetic simulation software and optimization capabilities, and marvel at how they have allowed our industry to design components with functionality unimaginable just a few years ago. However, it is our long held belief that a solid understanding of engineering principles is critical to successful design and contributors need to share this knowledge with our readers. For this reason, papers that fail to discuss the engineering principles governing the antenna behavior and dictate design considerations are typically rejected.

An application note from this issue, "Detection Range Measurements on a Simplified Doppler Radar" by General Electric, described the use of the transferred electron effect in Gallium Arsenide bulk material to produce a useful diode oscillator microwave (X- and K-band operations) power outputs at low power supply voltages and with a low noise spectrum around the carrier. Potential applications included intrusion alarms, radar speed detectors and the system shown in ***Figure 1*** depicting what appears to be an early collision avoidance system for cars.

JANUARY 1972

The cover of this issue features a collage depicting various aircraft making an approach for landing or take off, highlighting the theme of Microwave Landing Systems. Three technical features include a "Step-Scan to the Radio Technical Commission for Aeronautics Landing System," a "Microwave Doppler Scanning Landing Guidance System" and a "Microwave Landing System Using Continuously Scanning Beams." The editorial feature for the month by Robert Shank brought into sharp focus the safety issues plaguing air travel in the early 1970s.

Today, we take for granted a flight crew's ability to land planes despite poor weather conditions such as fog, rain or ragged cloud ceilings. But the crash of Flight 932 that killed 75 crew and passengers (including the Marshall University football players, coaches and fans travelling with the team) on November 1970 brought the hazards of flying in poor weather into the nation's psyche. The excerpt from Shank's article talks about our industry's efforts to improve landing system reliability.

Shank writes, "The year 1971 was not kind to the technical community. Its judgment and its intentions were questioned by such events as the scrapping of the SST or cutting back the NASA Space Program; and its capabilities were blamed for the pollution mess and abusing the ecology. After all, shouldn't the scientists and engineers have foreseen this when they were putting America on wheels or building our super-productive industrial machine and super consuming economy!... To prove that some engineers and scientists do look ahead, 1971 was also the year in which over 30 years of effort by a diligent and, sometimes, stubborn group was rewarded by seeing a major project get underway to develop their concepts. We refer to those who have been trying to introduce World War II technology into the Aviation Approach and Landing problem, which remains aviation's leading cause of accidents and fatalities." Thirty-seven years after this was written, we all appreciate safer airline travel thanks to these engineers. In 1971, multiple advertisements from Raytheon featured their pulse modulator packages being utilized in "most major weather programs" touting this success of the microwave industry. ■

Please visit www.mwjournal.com/journey_70s to read this article in its entirety.

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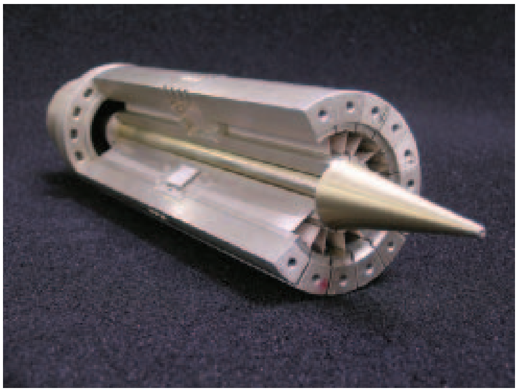

SPATIAL COMBINING TECHNOLOGY: REVOLUTIONIZING THE MICROWAVE POWER AMPLIFIER

As the second decade of the twenty first century approaches, the digital frontier continues to encroach on what was once considered to be the bastion of the analog domain. There is still, however, a critical need for microwave and RF high-power and low-noise amplifiers for the transition between the system and the ether. Components with more bandwidth and efficiency, higher power, better noise figure or pulse response, lower spurious and more compact size continue to be required, especially by the defense industry, for various highly specialized applications.

Historically, RF and microwave amplifiers (along with many microwave circuits in general) were considered too complex and variable to be cost-effectively produced using "conventional" circuit assembly techniques. CAP Wireless has been at the forefront in addressing many of these needs, and has developed a unique technology that unites an innovative combining structure with state-of-the-art monolithic microwave integrated circuit (MMIC) power devices, providing the optimum method of achieving multiple element power combining.

The unique, patented Spatium™ technology, which incorporates a coaxial antipodal finline structure within a proprietary spatial combining architecture, provides a breakthrough product that offers the stability of solid-state amplifiers with exceptionally broad bandwidth and high power. Classical planar combining networks suffer increasing loss and size as the bandwidth and number of combined devices increase (see ***Figure 1***). The result is that the practical attainable bandwidth when combining a large number of devices is typically limited to 3:1, and, ultimately, a point of diminishing returns is reached as the combining loss approaches the gain of the combined devices.

The Spatium platform is largely frequency-independent. Parallel identical channels minimize combining loss, which is the same as for one channel (see ***Figure 2***). Bandwidth is limited only by individual device characteristics, mechanical tolerances and size constraints. Power is limited only by device characteristics, thermal dissipation and the physical quantity of devices that can fit in the architecture. The

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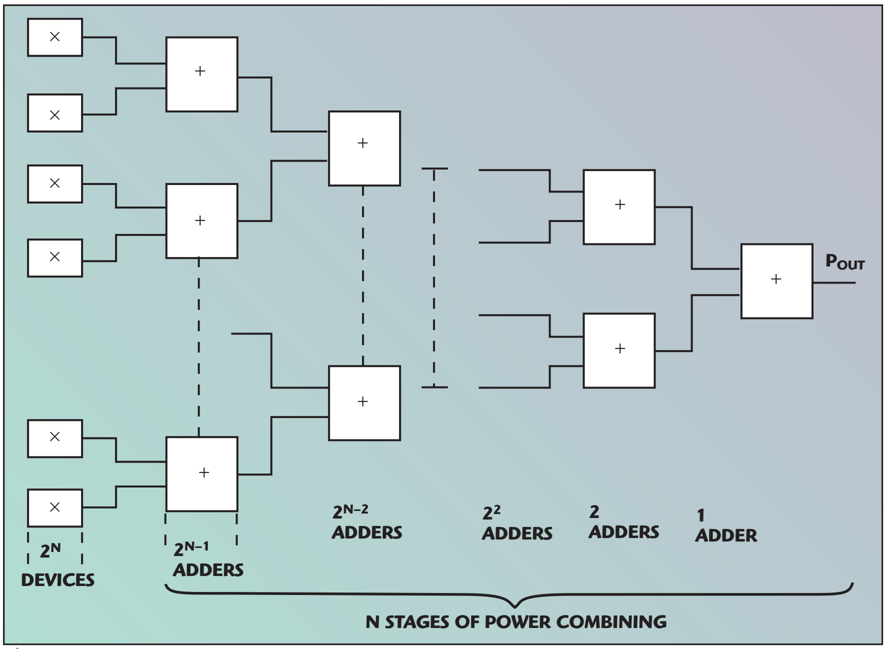
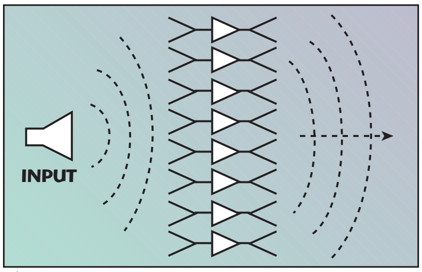


▲ *Fig. 1 In a conventional binary planar combiner, the loss becomes too high when combining a large number of amplifier cells.*

result is that numerous combinations of power and bandwidth are possible simply by changing the devices. The Spatium engine is compatible with a large number of available MMICs, enabling the circuit topology to provide a highly manufacturable platform that leverages component commonality between different models. This eliminates time-consuming redesigns for each variation and increases unit-to-unit repeatability, resulting in significant time-to-manufacture cost savings for customers.

WHAT IS SPATIAL COMBINING TECHNOLOGY?

Spatial power amplification is the method of coherently combining the power of many amplifying devices using free space or air as the power dividing/combining medium within a guided wave structure. This method is often referred to as quasi-optical combining.

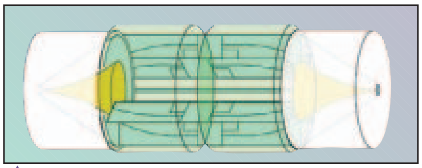


▲ *Fig. 2 The innovative Spatium spatial power combining technology provides parallel identical channels so the loss is the same as for one channel.*

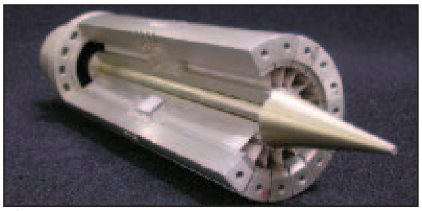
The earliest known use of the technology is pre-World War II, when, in its most basic form, it was used for tubes and dipole antennas. Substantial research and development efforts were undertaken in the mid-1990s at several universities, including the University of California at Santa Barbara (UCSB). CAP's Spatium technology springs from work done by chief technology officer Pengcheng Jia for his PhD degree as part of UCSB's spatial combining development program. CAP's R&D efforts were begun in response to customer demand for an amplifier architecture that could provide, in a compact package, the reliability and ruggedness associated with solid-state power amplifiers (SSPA) and the signature low thermal-noise characteristic of solid-state performance, and could also support moderate to high power levels and operate linearly with minimal harmonic and intermodulation distortion over very broad frequency ranges, all at a competitive price.

HOW DOES IT WORK?

The Spatium technology achieves its remarkable performance through an amalgamation of innovation, sophisticated modeling and implementation. The arrangement can be visualized as an oversized coaxial guided wave structure. A tapered center conductor transitions from the traditional subminiature version A (SMA) coax



▲ *Fig. 3 Spatium structure.*



▲ *Fig. 4 Spatium physical implementation.*

connector to a larger center conductor. Once the enlarged radius coaxial line is reached, multiple antipodal finline antenna elements arranged radially around the center gather all the microwave energy across a wide frequency spectrum, and transition the gathered signals to several microstrip transmission lines. Each microstrip line feeds a MMIC power amplifier housed in a 20 GHz resonance-free ceramic package, where the signals are simultaneously amplified by equal amounts. The amplified signals out of the MMICs are launched back onto microstrip lines, which then couple to output antipodal finlines back into a coaxial waveguide, where the fields coherently combine. The output signal transitions through a tapered coaxial line back to an SMA connector, providing the high output power levels. ***Figure 3*** shows a simplified pictorial representation of the structure. ***Figure 4*** shows the completed mechanical structure that makes up the "engine."

The uniformity of the MMICs and the intrinsic structure enables the maintenance of nearly identical phase and amplitude variation through all amplification channels, resulting in high power combining efficiencies. Typical combining efficiency across the 2 to 20 GHz band is < 0.5 dB loss with 16-way combining. As mentioned previously, the loss is independent of the number of combined elements, unlike a corporate structure where the losses increase as the number of combined elements increases. Because the combining losses are low and power is not wasted in the combining scheme, the operational efficiencies are maximized, resulting in lower heat dissipation and less prime

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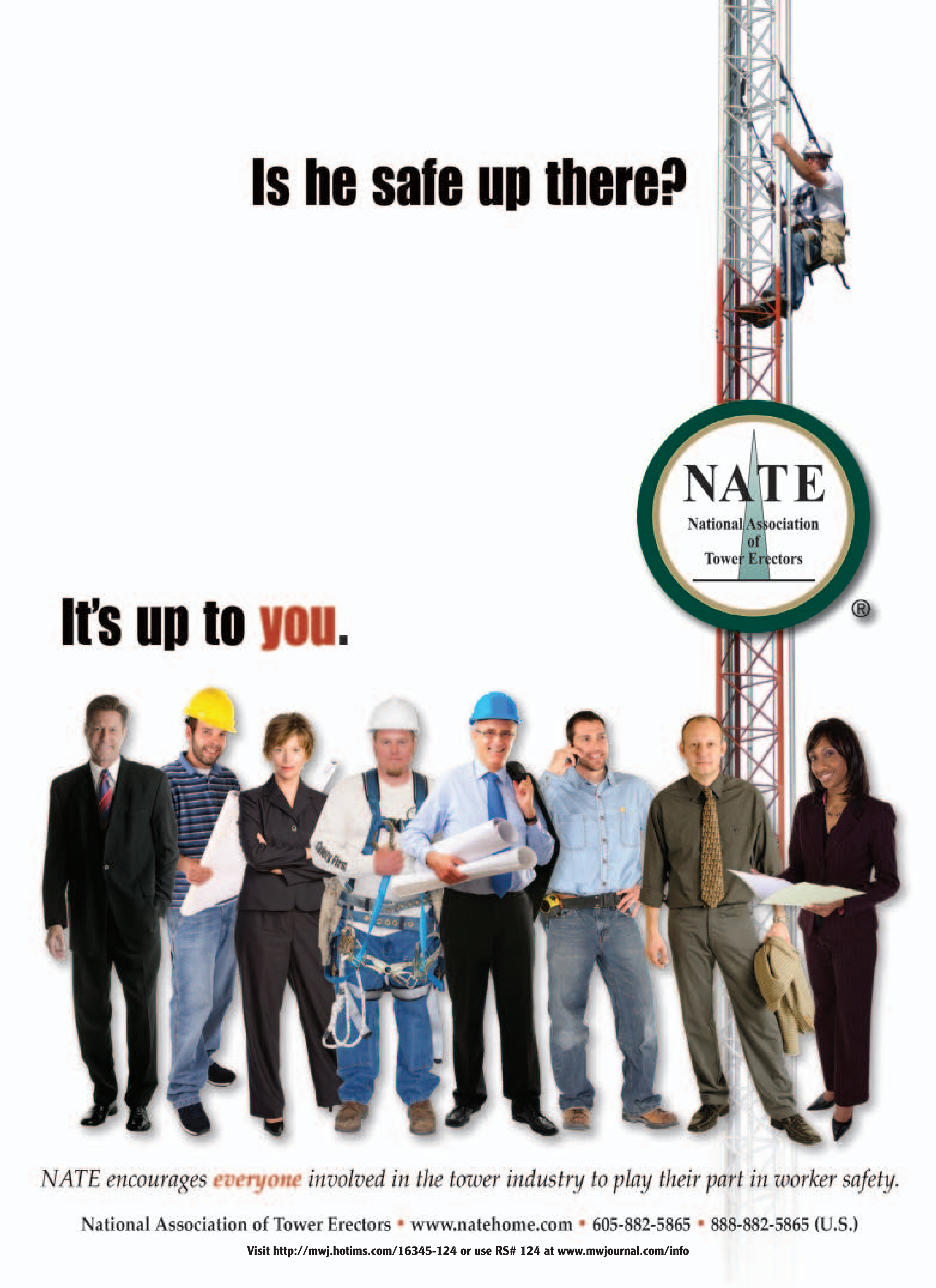
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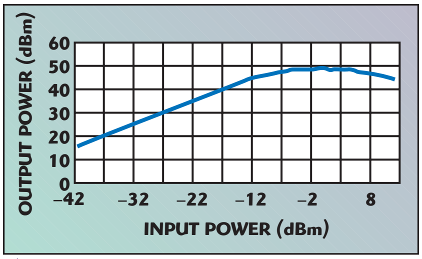


▲ *Fig. 5 Typical power saturation curve for 100 W, nonlinearized TWTA.*

power for a given power level. Also, because of the high number of combined elements, the root mean square (RMS) phase noise of the amplifier is less than that of a single comparable device and significantly lower than what might be expected from a traveling wave tube amplifier.

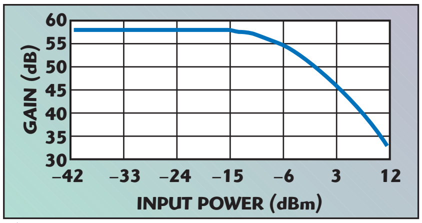
SPATIUM FEATURES AND BENEFITS

The novel Spatium power combining structure shows great promise for revolutionizing the microwave power amplifier. Applications traditionally dominated by traveling wave tube (TWT) or vacuum electronic device (VED) solutions, such as test and measurement, electronic warfare, electronic counter measures and simulators, can now take advantage of all the associated preferable performance attributes of solid-state implementation, including higher reliability, low-voltage operation for safety, longer life, low thermal noise characteristics for improved signal-to-noise ratios and improved linearity. ***Table 1*** quantitatively compares the Spatium amplifier capability with alternative amplifier technologies.

LINEARITY

TWT amplifiers have a power rating defined by their peak power output capacity and must be operated substantially (typically six or more dB) below their rated saturated output power for linear performance. Solid-state amplifiers, on the other hand, have power ratings defined by their one or two dB gain compression point and can be operated at or near their rated one dB compression level to achieve linear performance. This means, for example, that at a given power level below 50 W, a solid-state amplifier rated at 50 W P1dB will offer equal or better linear performance compared to a TWTA rated at 200 or more watts of saturated power.

Figure 5 illustrates a typical power saturation curve for a 100 W, nonlinearized TWTA. It can be seen that a peak power level is obtained at around 0 dBm of input drive level, and that further increasing the input level actually causes the output power level to decrease. In the corresponding gain curve, illustrated in ***Figure 6***, the TWTA gain at the maximum output power level is already significantly compressed compared with its small-signal gain.



▲ *Fig. 6 In a corresponding gain curve, the TWTA gain at the maximum output power level is significantly compressed compared with its small-signal gain.*

TABLE I

SPATIUM AMPLIFIER CAPABILITIES vs. ALTERNATIVE AMPLIFIER TECHNOLOGIES

	Spatium	SSPA	TWTA
Combining efficiency	> 90%, independent of number of combined elements	75 to 90%, suffers diminishing returns as combining increases	100%
Bandwidth capability	decade+	two octave	two octave
Single point failure	no	no	yes
Noise figure	8 dB	8 dB	35 dB
Harmonics at P_{sat}	–20 dBc	–20 dBc	0 to –6 dBc
Platform commonality across frequency	replace MMICs	new devices, new package, new combiner structure	new design
Phase noise	low	low	high
Supply voltage	low (< 32 V)	low (< 32 V)	high (> 1 kV) personnel hazard
Reliability	> 100 kHrs	> 100 kHrs	< 10 kHrs
Thermal	3D cooling—minimal mutual heating	single plane cooling—center devices suffer mutual heating	3D cooling
Output noise power	low	low	high
Load mismatch tolerance	good	good	poor
Required warm-up	none	none	3 to 5 minutes

SUPPLY VOLTAGE

The Spatium amplifier technology takes advantage of available microwave semiconductor power device technology by combining high multiples (> 16) of devices to achieve moderate output powers. Because this device technology operates from low (< 28 VDC) supply voltages, rather than the high (> 1 kV) supply voltages typically associated with TWTAs, it can operate from readily available, lower cost power supplies without risking the safety of personnel. Power supply design complexity is substantially reduced, associated mean time between failures (MTBF) is considerably higher and safety concerns are minimized.

To further increase the reliability of a solid-state amplifier system, one can take advantage of the availability and sophistication of low voltage supplies to implement a degree of redundancy, which ensures continued operation in the event of partial failure.

WARM UP

Spatium amplifiers require no warm-up time to reach their optimum performance. TWTAs may require several minutes to stabilize and reach peak operation capability.

RELIABILITY

Spatium amplifiers use solid-state devices, which inherently provide high reliability. Published TWTA reliability appears to be substantial as well, but noted exceptions are failures

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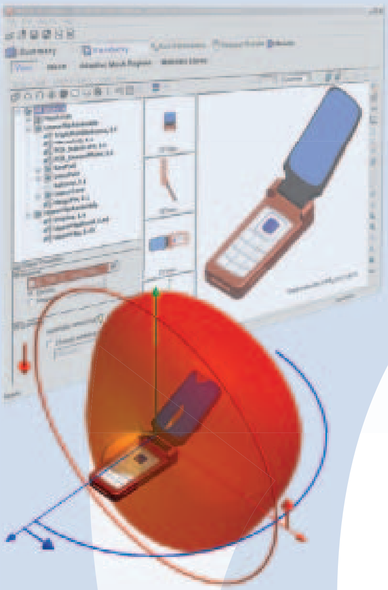

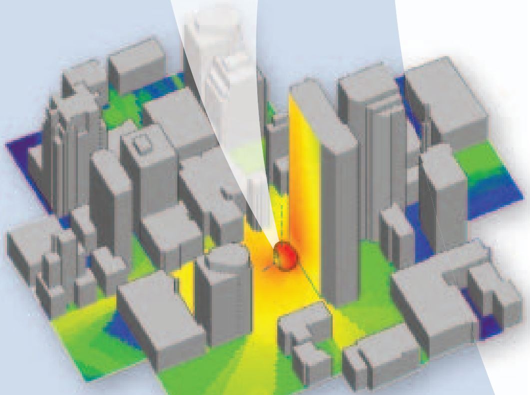

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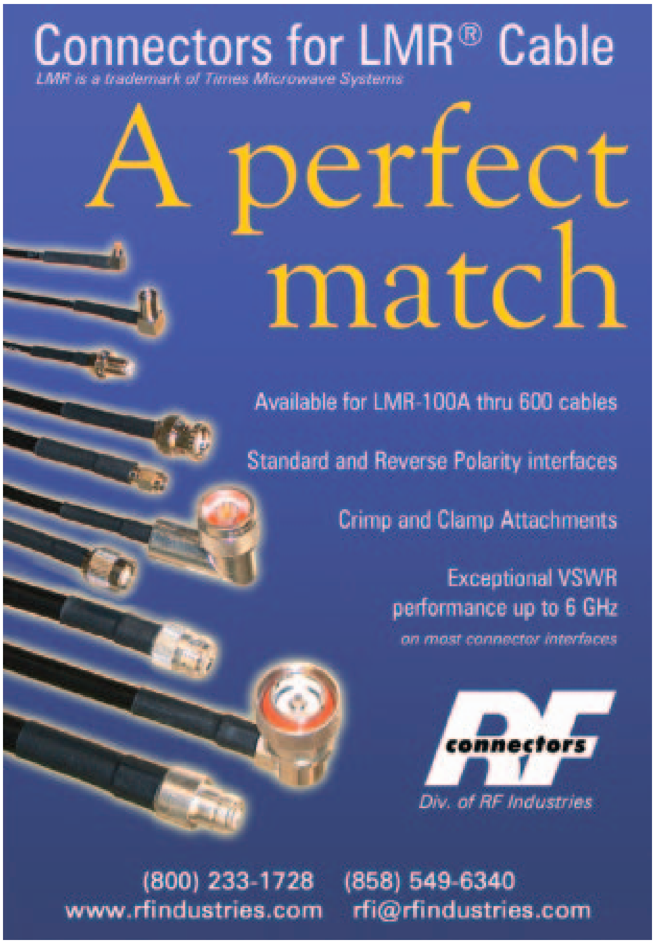

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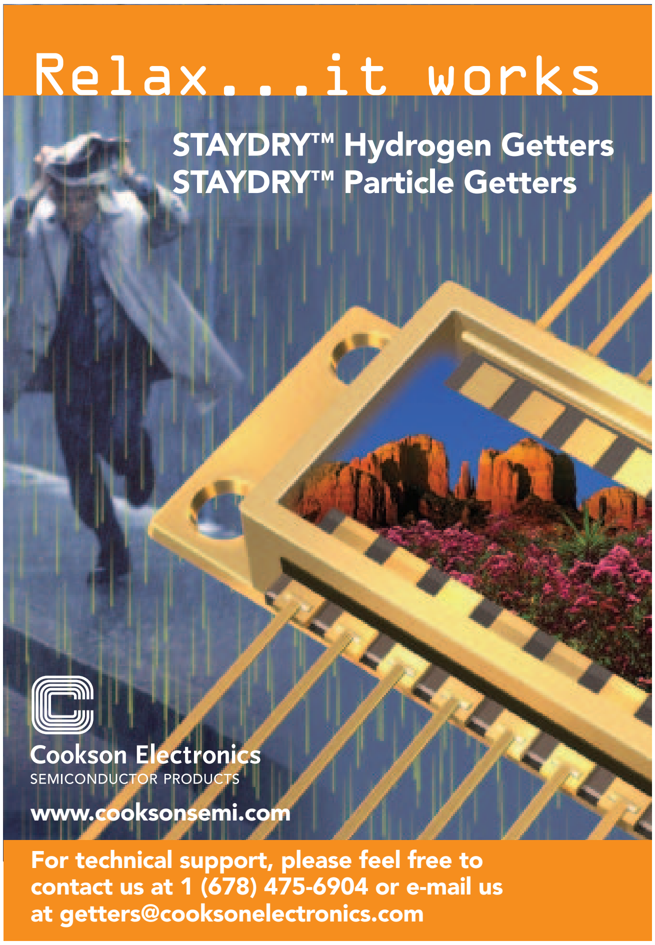

due to the high voltage supplies used for powering the tube. In addition, the parallel nature of the Spatium amplifier adds a multiplicative factor to the inherent reliability as it eliminates a single point failure mode.

BANDWIDTH

The Spatium offers up to decade bandwidth, surpassing current tube technology by a factor of two.

SOFT FAIL

The Spatium amplifier uses multiple combined devices, providing functionality at a reduced power level in the event of a single device failure.

ROBUST CONSTRUCTION

Spatium amplifiers, because they are solid-state devices, are inherently mechanically rugged. TWTAs, on the other hand, are subject to damage by abuse or shock because they are highly mechanically tuned, vacuum-encapsulated-by-glass devices.

AM-PM CONVERSION

Spatium amplifiers exhibit little AM-PM conversion to their rated 1 dB compression point. TWTAs must typically be backed off 16 dB or more from their rated saturated power level before achieving minimal AM-PM.

NOISE FIGURE

Spatium amplifiers have an inherently low noise figure, typically no more than 8 dB. TWTAs often have noise figures ranging from 30 to 35 dB, potentially limiting the dynamic range of measurements.

ENVIRONMENTAL CONCERNS

TWTAs often use beryllium oxide (BeO) material as a thermal management material. BeO dust is a known carcinogen and health hazard.

CONCLUSION

CAP Wireless Spatium broadband spatially combined products obsolete some of today's power amplifiers and make the unachievable a reality. By efficiently combining large numbers of amplifiers, Spatium PAs deliver an inherently low loss structure, graceful degradation on failure, low-voltage operation, solid-state reliability and good phase noise characteristics. The Spatium technology is uniquely positioned to provide the optimum solution for applications such as electronic counter measures (ECM), laboratory instrumentation and electromagnetic compatibility/electromagnetic interference (EMC/EMI) test, as well as narrower band applications like radar, microwave imaging and satellite communications. Spatium amplifiers excel when extremes of bandwidth and power are needed and, at the same time, provide all the characteristics required for today's demanding defense and commercial communications application challenges, at a realistic cost.

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4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70
SP2T								
0.2 – 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60
SP3T								
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85
1 – 18	SW3-010180RN1NF	3.1	70	2:1	20/20	150	180	85/85

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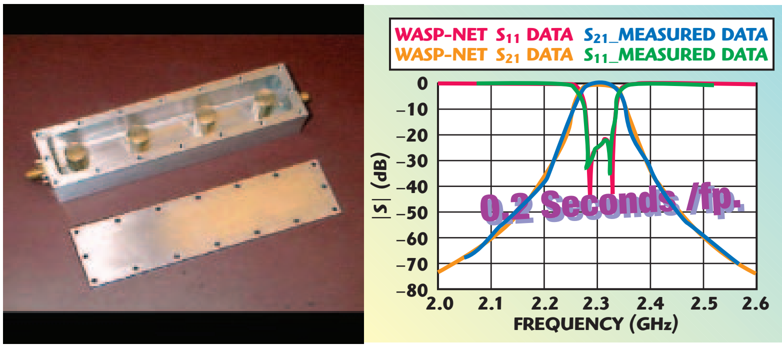
HYBRID EM CAD TOOL: FULL-WAVE PRECISION IN A MATTER OF SECONDS

The demand from the microwave and space industry for a drastic reduction in the time-to-market for new components and systems requires fast CAD tools, yielding reliably accurate, optimized designs within extremely short response cycles. Common electromagnetic (EM) simulation using single global three-dimensional (3D) solvers—mostly based on finite element (FE) or finite difference (FD) techniques—yields the desired flexibility, but can require long design and optimization times. On the other hand, mode-matching (MM) solvers and their extensions can provide efficiency, but may not be so flexible. For radiating structures, method-of-moment (MoM) solutions can be advantageous, but simulation times can also be comparatively long.

MIG's well established WASP-NET® EM CAD and optimization tool uses fast hybrid MM/FE/MoM/FE techniques, which typically go beyond the capabilities of single/dual methods. The latest version, version 7.0, expands the tool's capability and functions even further. Particular advances include a significant breakthrough in EM design and optimization speed, extended synthesis wizards and a new user-friendly graphical user interface (GUI).

The fact that when using version 7.0, EM simulation times can typically be reduced on standard low-cost dual core PCs (without additional hardware acceleration tools) to only a few seconds for the likes of common coaxial microwave components, dielectric loaded horns and large antennas will be of great interest to design engineers as will be illustrated

Fig. 1 A tapped resonator combline filter with circular posts without tuning screws, and theory/measurement results (picture and measurements courtesy of University of Bremen, Germany).



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				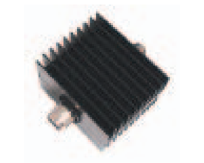	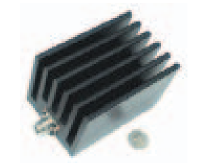
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			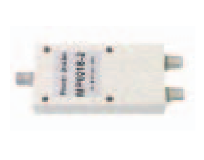	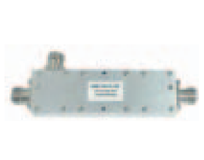	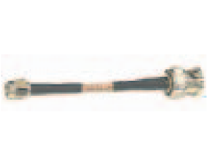
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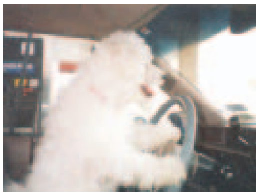

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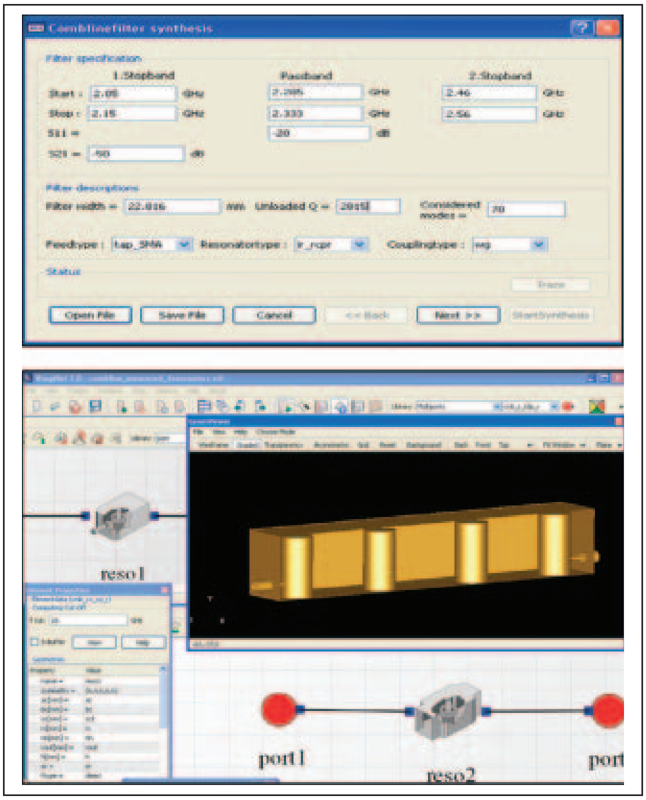
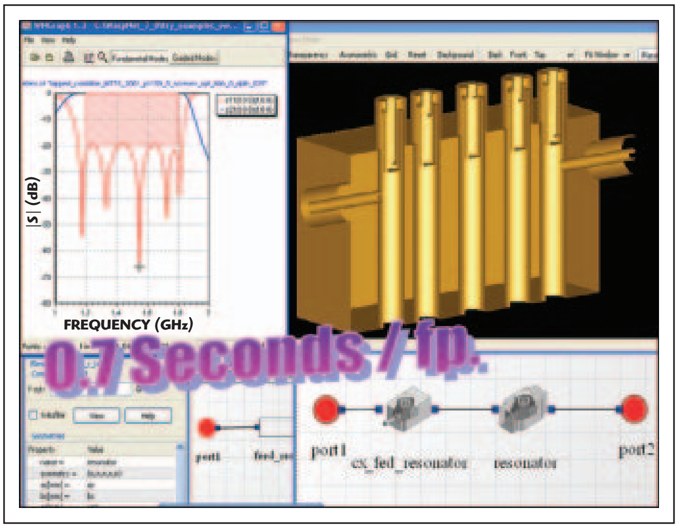


▲ *Fig. 2 Combline filter synthesis wizard and GUI for the filter shown in Figure 1.*



▲ *Fig. 3 Simulation results for a top capacitance loaded combline filter with tuner-down resonators.*

here. Furthermore, for filters and arrays, appropriate synthesis wizards provide good starting values for subsequent EM optimizations. To illustrate these features graphically, consider the following design examples.

COMBLINE FILTERS

Due to their compactness and suitability for low-cost mass-production, combline filters have found widespread applications. It is widely recognized that such filters pose a challenge to CAD packages in terms of efficiency due to their complex structure. To address this issue, version 7.0 of WASP-NET incorporates new basis functions that provide high accuracy and flexibility in combination with extremely high efficiency.

Figure 1 shows a tapped resonator combline filter with circular posts without tuning screws with the measurement results using version 7.0. This analysis has a calculation speed of about 0.2 seconds per frequency point on a normal 2.3 GHz Core2Duo PC.

Providing the initial design values for combline filters, ***Figure 2*** shows WASP-NET version 7.0's user-friendly filter synthesis wizard with the new GUI that incorporates all features expected of a modern CAD interface. Simply starting from desired specifications, after typically about 15 to 30 minutes, the synthesis tool yields the complete full-wave design to be immediately visualized by WASP-NET's graphics output tool and to be optimized further, if necessary.

Figure 3 demonstrates the high flexibility combined with the high efficiency of the new approach through

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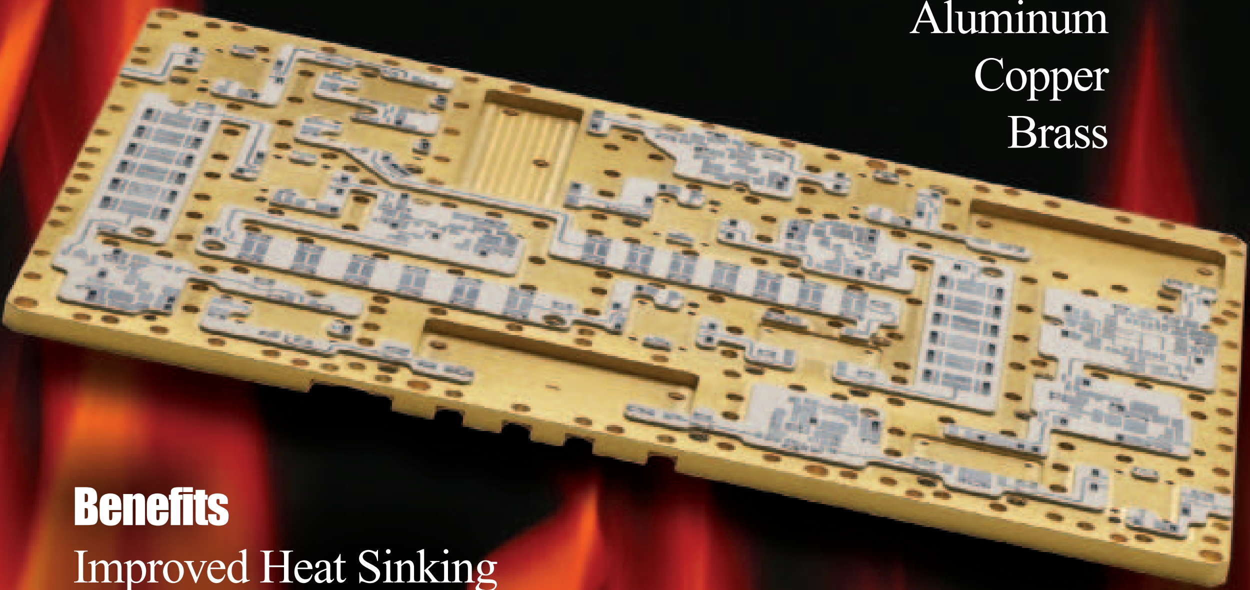

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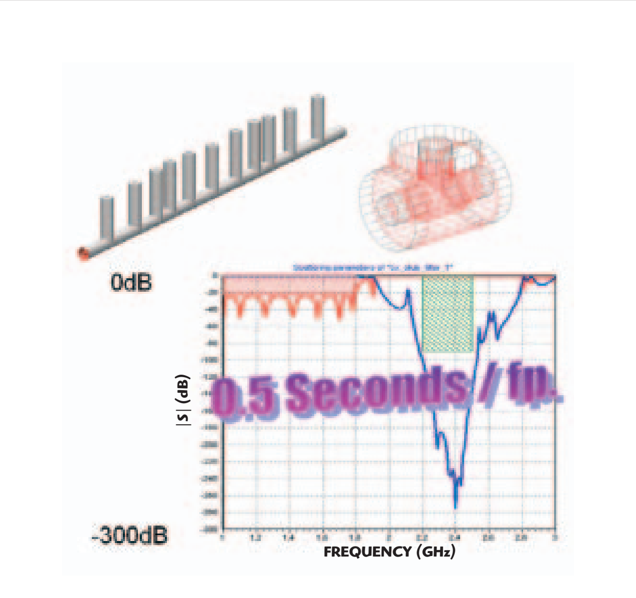
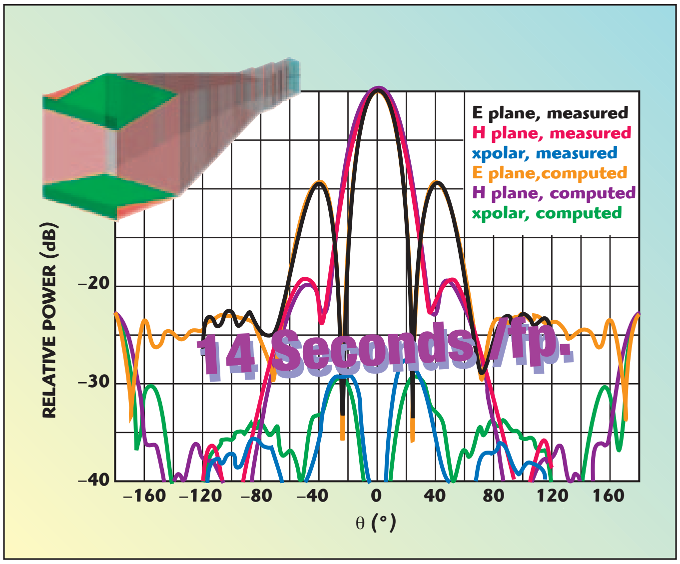


▲ *Fig. 4 Optimization results for a coaxial stub loaded filter.*



▲ *Fig. 5 Theory/measurement results for a horn loaded with dielectric slabs (horn dimensions and measured results courtesy of Dr. Ratajczak, France Telecom R&D).*

the example of a more complicated combline filter with top capacitance loaded tuner-down resonators. The calculation speed of only about 0.7 seconds per frequency point (2.3 GHz Core2Duo PC) demonstrates that direct EM design and optimization of such filters using WASP-NET version 7.0 can result in extremely short design-cycles.

COAXIAL STUB LOADED FILTER

The next example of a coaxial stub loaded filter (see ***Figure 4***) giving a simulation speed of 0.5 seconds per frequency point (2.3 GHz Core2Duo PC) illustrates that the utilization of the interactive design from scratch, by conveniently using building-blocks such as the coaxial T-junction, and subsequent optimization yields the desired specifications. Figure 4 also demonstrates the extremely high dynamic range (> 300 dB) of the new CAD approach that facilitates the clear identification of possible spikes and their elimination during optimization.

DIELECTRIC LOADED HORN

The first antenna example for which measurements are available is a dielectric loaded horn that the European Space Agency (ESA) also uses for benchmarking purposes. ***Figure 5*** demonstrates that even with dielectric material to consider, the calculation time using WASP-NET version 7.0 is still 14 seconds per frequency point (2.3 GHz Core2Duo PC).

SLOT ARRAYS AND FEEDS

In order to demonstrate the tool's performance when used for large arrays, a 1,200 slot array example is shown in ***Figure 6***. A convenient slot array synthesis wizard provides initial design values within about 60 seconds (first pattern). The second pattern is

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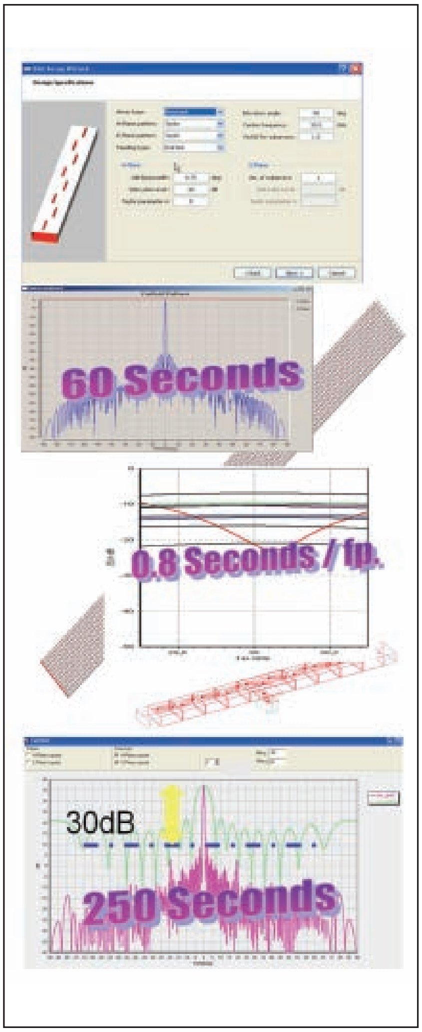

▲ *Fig. 6 A 1,200 slot array showing the synthesis wizard, synthesis result, feed optimization and overcall simulation results.*

the result of the rigorous overall simulation in WASP-NET that takes about 250 seconds (on a 2.3 GHz Core2Duo laptop, 2 GB RAM). Waveguide feeds, e.g. with inclined slots, can, because of the high calculation speed, be conveniently optimized towards the desired specifications. First optimized as an individual sub-circuit (taking 0.8 seconds per frequency point), and then within the overall structure.

VERSATILITY

The versatility of the new CAD tool can drastically reduce design cycles for a large range of industrial design projects involving structures such as waveguide filters, couplers, transformers, transitions, hybrids, diplexers and multiplexers; coaxial components, combline/interdigital filters and diplexers; polarizers, orthomode transducers (OMT) and phase shifters; dielectric resonator filters and dielectric loaded waveguides; waveguide and coaxial dissipative filters; corrugated horns, choked horns, horn clusters, reflectors, sub-reflectors, lenses and radomes; and slot arrays, side-slots with shield, etc.

ADVANCED FEATURES

As well as those already outlined, WASP-NET version 7.0 includes all of the features that would be expected of the latest CAD tool. These include full 64-bit capability, a parallelized code for multiprocessors, adaptive sweep and a direct antenna pattern optimization capability.

CONCLUSION

The demands on modern EM-based CAD software used for designing microwave components and antennas require a new dimension of efficiency and simulation speed. Version 7.0 of MIG's comprehensive hybrid EM CAD tool WASP-NET meets this speed challenge, together with flexibility and accuracy, by evoking fast hybrid MM/FE/MoM/FD techniques and hence utilizing the advantages of all solvers while largely avoiding their disadvantages. The breakthrough in speed improvement, the new GUI and extended synthesis wizards provide the microwave engineer with advanced EM design efficiency standards. Based on industrial customers' specifications, immediate, direct, accurate, EM interactive design and optimization performance for microwave components and antennas can be achieved by combining EM accuracy with extremely short design and optimization cycles. ■

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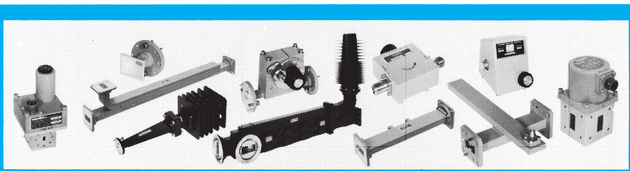

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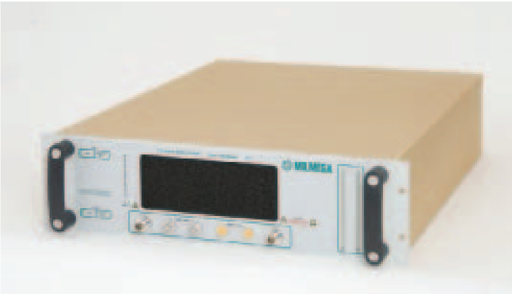

GALLIUM NITRIDE POWERS NEW AMPLIFIER RANGE

A new range of high power, broadband amplifiers has been developed to capitalize on the inherent advantages of Gallium Nitride (GaN). With instantaneous bandwidths of 2 to 6 GHz and high reliability, the AS0206 family of amplifiers is well suited to several markets. In particular, its inherent reflected-power tolerance makes it appropriate for the needs of the EMC test industry (RF immunity testing to 61000-4-3) and for the testing of high power RF components. High reliability combined with compact size and light weight also make the family suitable for use in commercial applications where space is at a premium and portability can be used advantageously. The product incorporates a number of important key features including a comprehensive built-in test (BIT) capability and the potential for retrospective upgrading of the amplifier's initial power capability.

THE GaN ADVANTAGE

The inherent properties of GaN have a number of advantages to offer the amplifier designer. A major one is that the transistor structure enables the development of product that allows operation into high VSWR loads, including short and open circuits, without the need for protective circuits or isolators. The higher gains of GaN transistors, compared to those of competing technologies, reduce both the overall transistor count and the number of combining stages required. Operation from high voltages results in a less complex power supply design, an important feature in determining the overall reliability of an amplifier structure.

Compared to packaged GaAs MESFETs, GaN HEMTs have lower input and output capacitances that, when combined with a higher F_t, simplifies the design task of matching over multiple octave bands. This may in turn lead to a subsequent reduction in production tuning requirements when compared with similar GaAs FET-based multi-octave band amplifiers.

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	Parameter	Spec
Passive	MIM Capacitance	600 pF/mm²
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e-pHEMT	Idss	0.5 uA/mm
e-pHEMT	Idmax	320 mA/mm
e-pHEMT	BVdg	20 V
e-pHEMT	Vth	0.35 V
e-pHEMT	Fmin	0.3 dB
e-pHEMT	Ft	32 GHz
d-pHEMT	Gm_Peak	340 mS/mm
d-pHEMT	Idss	320 mA/mm
d-pHEMT	Idmax	450 mA/mm
d-pHEMT	BVdg	20 V
d-pHEMT	Vp	-1.15 V
d-pHEMT	Ron	1.5 Ohm-mm
d-pHEMT	Fmin	0.3 dB
d-pHEMT	Ft	23 GHz

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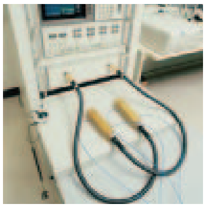
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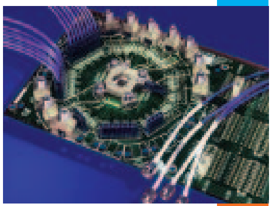
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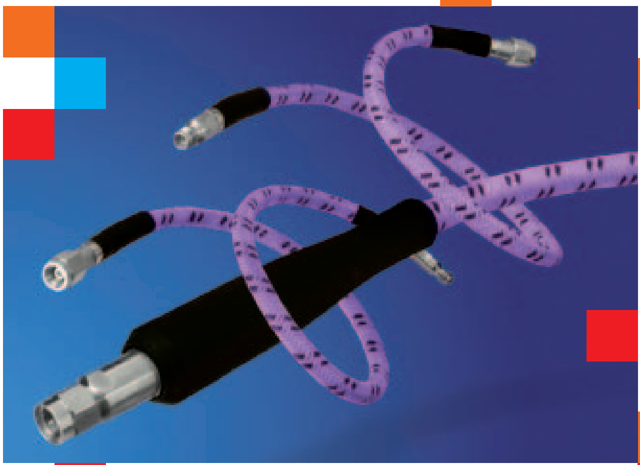
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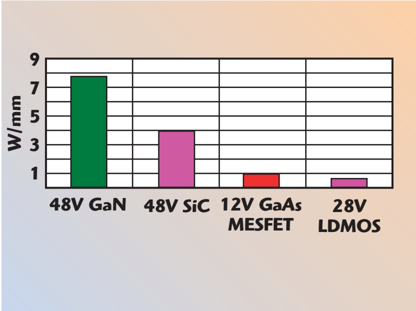

▲ *Fig. 1 Power density comparison of competing solid-state technologies.*

GaN has a power density at P1dB, in W/mm, of around eight times that of GaAs. This power density can lead to significant size and weight reduction in applications that demand it. ***Figure 1*** compares the power densities, at P1dB, of competing power technologies.

AS0206 ARCHITECTURE

The amplifier topology adopts a Corporate Structure Architecture (CSA) approach, as shown in ***Figure 2***. The name comes from the similarity of the layout of the microwave building blocks to that of a corporate organization chart, but turned 90° clockwise. The advantages of the CSA design methodology have been proven in the company's existing microwave range and the new amplifier family derives identical benefits from that topology.

The building block of the amplifier's output rank is a 2 to 6 GHz, 19 W P1dB power module, with a typical gain of 15 dB. Concentrating on the development of a single common power module has the virtue that a high percentage of engineering resources (microwave, electrical, thermal, mechanical) can be focused to design a component around which a reliable system can be built.

OUTPUT RANK POWER MODULE

The transistor at the heart of this module is the CGH-40010, a Gallium Nitride HEMT from Cree Inc. A combination of simulation work using the supplied large-signal model, supplemented by data collected within MILMEGA, has brought about the development of high quality matching networks that require minimal tuning to be applied at the manufacturing stage. These matching circuits

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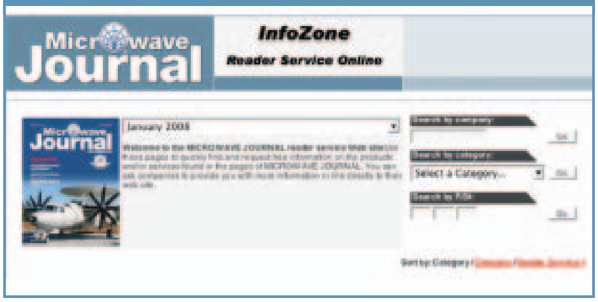

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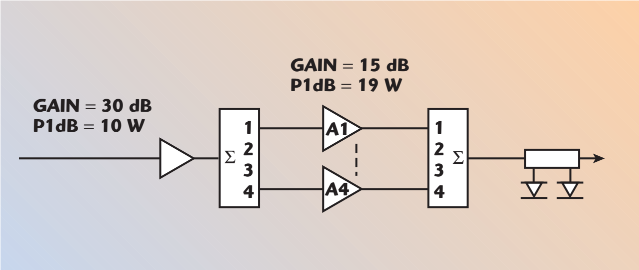


▲ *Fig. 2 AS0206 topology follows a Corporate Structure Architecture approach.*

are optimized for P1dB performance and the transistor is used in a balanced pair configuration.

Power is developed within the module by combining two balanced pairs in parallel, using one level of quadrature combining. This, in addition to the inherent robustness of the GaN devices, enables the modules to absorb 100 percent reflected power, even when the module is operating at full output power. This can be a significant benefit to the system designer if the amplifier is required to operate into high VSWR conditions. The power performance of the module over the band of interest is shown in ***Figure 3***.

AUTOMATED BIASING

Each module has the capability of performing an automated bias routine when commanded via an external ASCII communications terminal. The individual device current settings, which need to be imposed to optimise system performance, are input to the module. Each individual device is then interrogated and its pinch off voltage and quiescent operating point determined. With this information stored, the modules can then be biased optimally for the required mode of operation.

OUTPUT COMBINER

In designing the final output combiner it was vital that the insertion loss from input to output was kept to an absolute minimum, thus reducing the gain and power requirements on the system pre-amplifier stages. The final design consists of a two-layer cascade of two input, resistorless Wilkinson style combiner structures. The resistors are not required as all inputs are matched in phase and amplitude.

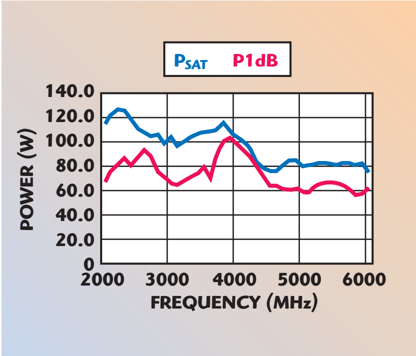
The completed combiner/coupler operates over the 2 to 6 GHz range and has an integrated coupler that provides forward and reverse outputs for sampling and measurement of incident/reflected power. ***Figure 4*** shows the typical measured through path performance for this structure.

BIT AND CONTROL SYSTEM

The overall control and sensing of the amplifier system is partitioned between three separate processors. The first processor, the central control processor, controls and monitors all system modules and provides the BIT functionality. Key parameters, including voltage and current consumption, are monitored for all modules. Modules in the output rank are monitored via direct connections to the central control processor. Less critical modules are monitored every few milliseconds via a multiplexer. A fault causes one of a column of LEDs to light. For convenience, the column is visible through the amplifier front panel.

A second processor, the local control processor, acts as the interface between the front panel control/indicator and the central control processor. It also senses and displays the forward and reflected RF power levels.

Finally, the communications processor acts as the interface between the central control processor and the outside world. Each processor has in-circuit programming capability, enabling the software to be updated.



▲ *Fig. 5 Final system power performance.*

THE FINAL SYSTEM

The amplifier features internal couplers for ease of measurement of reflected and incident power removing the need to utilize an external component with the associated power loss. The power achieved in the final system is shown in Figure 5. The AS0206 delivers a P1dB performance of 50 W minimum, with a Psat minimum of 75 W and a typical gain of 47 dB.

CONCLUSION

The inherent benefits of GaN power transistor technology have been combined with the CSA design approach, together with distributed embedded intelligence to create a robust power amplifier family providing high reliability, exceptional power density, ease of power upgrade and portability across the 2 to 6 GHz band.

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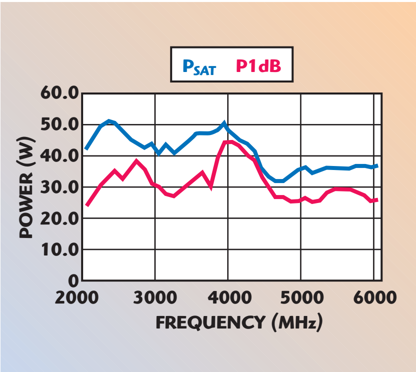
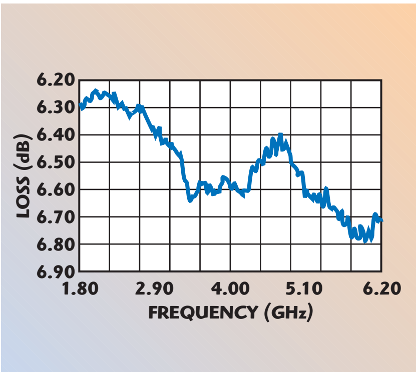


▲ *Fig. 3 P1dB performance of the 20 W module vs. frequency.*



▲ *Fig. 4 Performance of the four-way combiner.*

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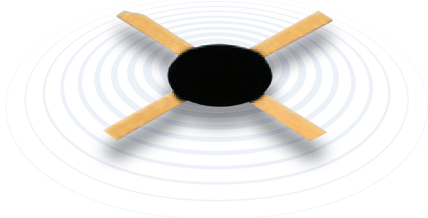

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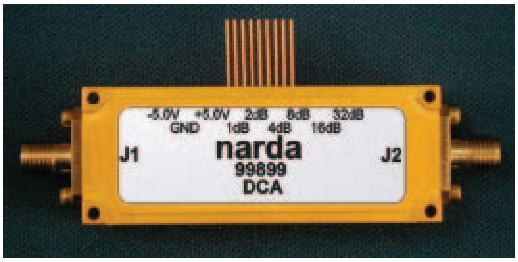

DIGITALLY-CONTROLLED, HIGH-SPEED 63 DB ATTENUATORS

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The digitally-controlled attenuator (DCA) is a fundamental element of any system that combines microwave components and embedded digital control in its architecture. It consists of a bank of fixed attenuator pads, each of which can be switched in or out to adaptively select the optimum signal level for a given situation. Typical applications for DCAs include receiver automatic gain control (AGC), sensitivity time control (STC) in radar receivers, transmitter output power control, and waveform generation for communications and electronic warfare (EW) systems. Choosing a DCA can be a daunting process because of conflicting requirements such as frequency range, accuracy, switching speed, power consumption and size. For example, a DCA that meets a designer's requirement for fast switching speed may be too large or consume too much power. Narda developed its DCA Series of 63 dB attenuators to reduce or eliminate some of the compromises that users of DCAs typically experience. The attenuators combine fast switching speed, full monotonicity and low power consumption previously unavailable in FET-based or PIN diode-based DCAs. The DCA series includes 2-b, 3-b and 6-b models in frequency ranges of DC to 6 GHz or DC to 18 GHz. They consume only 50 mW from their ±5 VDC power supplies, far less than what is typical of DCAs that employ PIN diode switches.

WHY DIGITAL?

DCAs have a number of advantages over their analog counterparts. They lend themselves better to microcontroller-based applications because they are controlled by digital words and do not require an analog-to-digital converter to develop a control voltage. Like all digital components, DCAs are immune to noise on the digital control lines in contrast with an analog control voltage that can experience noise on the control line, affecting attenuation. In addition, their switching speeds are limited only by the speed of the microwave switches and their associated driver circuits, so DCAs are the best choice when fast response time is an important consideration. DCAs also have higher and more consistent output

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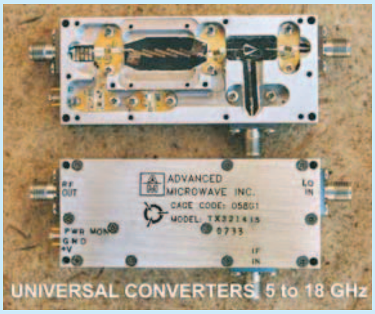

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TABLE I
PERFORMANCE SPECIFICATIONS FOR DCA SERIES 63 dB DIGITALLY-CONTROLLED ATTENUATORS

Versions	2-b, 3-b, 6-b
Attenuation range	0 to 63 dB in 1 dB steps
Frequency Range	DC to 6 GHz, DC to 18 GHz
Resolution	+/-0.25 dB
Settling time (20% to 90% of final value)	< 100 ns; 30 ns typ.
Least significant bit	1
Operating temperature range	-55° to +95°C
Power supply	+5 VDC, -5 VDC
Power consumption	50 mW maximum
Dimensions	2.2 x 0.84 x 0.38 in.
Weight	1.1 oz.

compression points because the individual switching elements are linear (resistive pads are either in or out), in contrast with continuously-variable, FET-based attenuators whose compression points vary significantly with attenuation level.

SWITCHING SPEED VERSUS POWER CONSUMPTION

Traditional high-speed DCAs utilize switches based on PIN diodes, FETs, or PHEMTs. PIN diodes offer the fastest switching times, but consume the most power. FET- and PHEMT-based switches use much less power and are advertised with very fast settling times (some as fast as 3 ns), but these settling times are specified for 20 to 80 percent. The last 20 percent is reached after tens or even hundreds of microseconds in some devices. In a six-stage DCA application, 12 switches (two per stage) are cascaded. For a change of attenuation from 31 to 32 dB, for instance, all six stages are switched at once. The DCA series attenuators settle to within 1 dB of final value when each of the 12 switches has reached its 98 percent point. To achieve the best combination of fast switching speed and low power consumption, Narda evaluated a variety of FET and PHEMT switches and identified a family of PHEMT types that achieve 1 dB, 100 ns settling time in a six-stage DCA design. The DCA series attenuators have a resolution of 1 dB, guaranteed monotonicity over their entire attenuation range and typical step accuracy of ±0.25 dB. Hermetic sealing is offered as an option, which together with an operating temperature range of –55° to +95°C make the devices well suited for aerospace and defense applications. More detailed specifications are shown in ***Table 1***.

REINVENTING THE MIC

Narda pioneered the development and manufacture of microwave integrated circuits (MIC), delivering its first production quantities over 25 years ago for EW receiver programs. These products used carrier-based technology to integrate a variety of microwave components into multi-functional assemblies that were housed in hermetic machined packages. Many of these designs are still in production. Over the past few years, Narda has rapidly enhanced its ability to produce these products using advanced microwave and digital technology, resulting in its Ultimate Microwave Integrated Circuit technology. It combines microwave hybrid manufacturing with multilayer printed circuit boards that incorporate advanced digital devices. These MICs surpass their predecessors by achieving very dense integration of microwave, analog and digital functions, improving reliability and enabling high-volume production at a much lower cost.

The DCA Series attenuators measure 2.2 x 0.84 x 0.38 in. and weigh 1.1 oz. In addition to the standard 2-b, 3-b and 6-b models that have operating frequencies up to 18 GHz, custom versions can be created that optimize specific performance parameters. Additional components such as filters and other active and passive components can be integrated as well to form a multi-function module that will typically occupy less space than a design fabricated with conventional MIC techniques.

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S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	-0.5, +0.8
S30W2	S30W5	N30W5	30	±0.85
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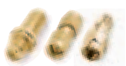

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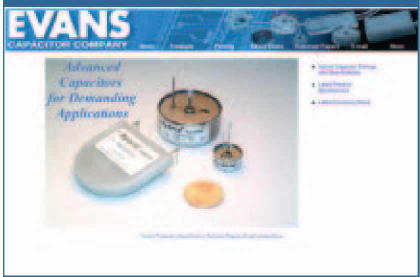

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This web site shares technical information, white papers, specs and pricing for the company's energy-dense Hybrid® capacitors and Hybrid capacitor banks. High performance aircraft, including the Joint Strike Fighter and the Apache helicopter, use Evans Hybrid Capacitors for laser targeting, communications modules, controls, cockpit displays, phased-array radars and fire control systems. Evans tantalum, hermetic, Hybrid capacitors have over 4x the energy density of any military-style capacitor.

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East Providence, RI 02914

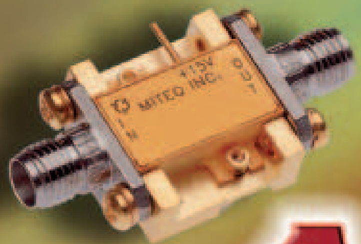
www.evanscap.com

ICs, Modules and Subsystems

Hittite's new web site contains new features including a crisp webpage design and a dynamic homepage featuring new products, markets, press releases and featured articles. Users will find information quickly with its new search feature button. Comprehensive individual product splash pages containing in-depth product information and technical content are located on one easy to navigate page. Users will find improved product support, quality and reliability pages as well.

Hittite Microwave Corp.,
20 Alpha Road,
Chelmsford, MA 01824

www.hittite.com



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Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	0.12-.25	38	0.50	0.9	2.0:1	2.0:1	+10	125
AFS3-00250050-08-10P-4	0.25-0.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-06-10P-6	0.5-1	38	0.75	0.6	2.0:1	1.5:1	+10	150
AFS3-01000200-05-10P-6	1-2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-06-10P-6	1.2-2.4	34	1.00	0.6	2.0:1	2.0:1	+10	150
AFS3-02000400-06-10P-4	2-4	32	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6-5.2	28	1.00	1.0	2.0:1	2.0:1	+10	125
AFS3-04000800-07-10P-4	4-8	32	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8-12	28	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8-16	28	1.00	1.5	2.0:1	2.0:1	+8	100
AFS4-12001800-18-10P-4	12-18	28	1.50	1.8	2.0:1	2.0:1	+10	125
AFS4-12002400-30-10P-4	12-24	24	2.00	3.0	2.0:1	2.0:1	+10	85
AFS3-18002650-30-8P-4	18-26.5	18	1.75	3.0	2.2:1	2.2:1	+8	125
MULTIOCTAVE BAND AMPLIFIERS								
AFS3-00300140-09-10P-4	0.3-1.4	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS2-00400350-12-10P-4	0.4-3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	0.5-2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-10-10P-4	1-4	30	1.50	1.0	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2-8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-24-10P-4	2-18	35	2.00	2.4	2.5:1	2.5:1	+10	175
AFS4-06001800-22-10P-4	6-18	25	2.00	2.2	2.0:1	2.0:1	+10	125
AFS4-08001800-22-10P-4	8-18	28	2.00	2.2	2.0:1	2.0:1	+10	125
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	0.1-1	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-00100200-10-15P-4	0.1-2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS1-00040200-12-10P-4	0.04-2	15	1.50	1.2	2.0:1	2.0:1	+10	50
AFS3-00100300-12-10P-4	0.1-3	32	1.00	1.2	2.0:1	2.0:1	+10	125
AFS3-00100400-13-10P-4	0.1-4	30	1.00	1.3	2.0:1	2.0:1	+10	125
AFS3-00100600-13-10P-4	0.1-6	30	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	0.1-8	28	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	0.1-12	34	1.50	2.2	2.0:1	2.0:1	+10	150
AFS4-00101400-23-10P-4	0.1-14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-S-4	0.1-18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	0.1-20	20	2.50	3.0	2.5:1	2.5:1	+10	125
AFS4-00102650-42-8P-4	0.1-26.5	24	2.50	4.2	2.5:1	2.5:1	+8	135

Note: Noise figure increases below 500 MHz.

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EM Field Solver

The EMPIRE XCcel web site has been completely redesigned. It features the latest news and upcoming events on the home page in order to give the visitor a quick update on the activities around EMPIRE XCcel. The site provides an overview of the software features and its specifications as well as customer feedback. The applications page shows a broad range of application examples along with a detailed explanation for each example. Further pages show the typical usage of the software and many new tutorials.

IMST GmbH, Carl-Friedrich-Gauss-Str. 2, D-47475 Kamp-Lintfort, Germany

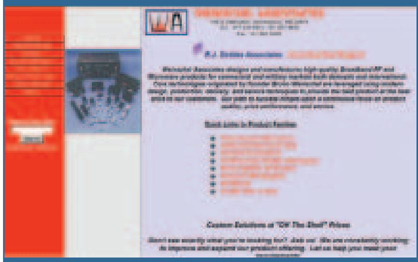
www.empire.de

Microwave Components and Subsystems

The Lorch Microwave web site has been updated to include high pass and low pass options in the Lorch Filter Select Plus software. The site has been designed with ease of navigation in mind and includes more product information on the complete line of filters, RF products and integrated assemblies.

Lorch Microwave,
1725 N. Salisbury Boulevard,
Salisbury, MD 21802

www.lorch.com



Broadband RF and Microwave Products

Weinschel Associates designs and manufactures high-quality broadband RF and microwave products for commercial and military markets both domestic and international. Products include fixed attenuators, terminations, variable attenuators, power splitters and dividers, RF adapters, DC blocks, RF tuners and custom components. Request your copy of the new 2009 products catalog.

Weinschel Associates Inc.,
19212 Orbit Drive,
Gaithersburg, MD 20879

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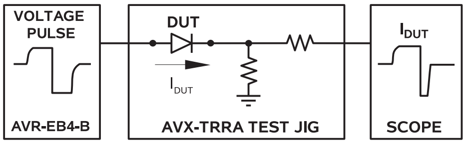
The AVR-EBF6-B is intended for forward recovery tests of most diode types.



Online data sheets and pricing - www.avtechpulse.com/semiconductor

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Spurious Suppression	60 dBc (Typ.)
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Step Size	Programmable to 1 Hz
Bias Voltage	+5 / +3.3 V
Output Power	+10 dBm (Typ.)
Spurious Suppression	60 dBc (Typ.)
Harmonic Suppression	10 dBc (Typ)
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NEW WAVES: EuMW Product Showcase

The following booth numbers are complete at the time of going to press.

GPU-based Cluster Solution

Acceleware's C30-16 is a commercially available GPU-based cluster solution. This solution combines the company's new clustering technology with its portfolio of designed-for-parallel computational algorithms to harness the power of 64 GPUs, delivering unprecedented performance and scalability for enterprise customers. Based on NVIDIA Tesla GPU computing technology, the new cluster solution is available in four pre-defined configurations, allowing for customers to match their processing needs. This solution brings together all the advantages of clustering – scalable commodity performance, enterprise-class computing capacity – with the advantages of GPU acceleration – compelling performance gains, higher compute densities and lower total cost of ownership from superior power, cooling and space utilization.

Acceleware Corp., Calgary, Alberta, Canada (403) 249-9099, www.acceleware.com.
Booth 1011 RS 216

Two-way Wilkinson Power Dividers

These two-way Wilkinson power dividers are available in octave and multi-octave bandwidths. The dividers achieve excellent isolation, loss and phase characteristics while offering an economic solution for various market applications.

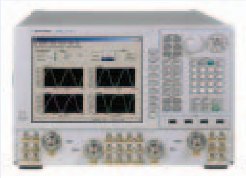
Aeroflex/Inmet, Ann Arbor, MI (734) 426-5553, www.aeroflex-inmet.com.
Booth 514 RS 218

Dual-band Tower Mounted Amplifier

The ATMA-1800/2100 module is a dual-band GSM/UMTS tower mounted amplifier (TMA) that consists of 12 high Q bandpass filters, four low noise amplifiers (LNA) with low loss switches for bypass mode and DC via the RF cable. These TMAs are integrated to provide compact size, light weight and a high performance reliable unit. This solution offers improved base station sensitivity with an affordable cost. Indoor and outdoor solutions are offered. Custom designs that satisfy even the most challenging electrical and mechanical requirements are possible with the development cycle as short as a few weeks.

Actipass R &M Co. Ltd., Gyeonggi-Do, Korea 031-353-5001, www.actipassrnm.com.
Booth 1215 RS 217

Nonlinear Vector Network Analyzer

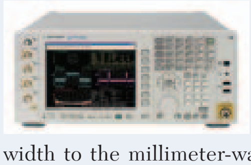


This nonlinear vector network analyzer (NVNA) capability is designed for its PNA-X microwave network analyzer and establishes a new industry standard in RF nonlinear network analysis from 10 MHz to 26.5 GHz. Requiring minimal external hardware, the Agilent NVNA software effectively converts a four-port PNA-X into a high-performance nonlinear analyzer. Featuring nonlinear component characterization, new nonlinear scattering parameters called X-parameters, and nonlinear pulse envelope domain capabilities, it is ideal for R&D engineers and scientists researching and designing active RF components.

Agilent Technologies, Component Test Division, Santa Rosa, CA (800) 829-4444, www.agilent.com.
Booth 703 RS 220

PSA and MXA Analysis Capabilities

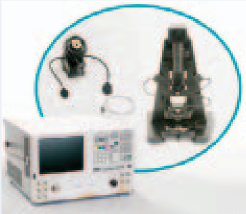
These new analysis capabilities are designed for its PSA high-performance spectrum analyzer and mid-range MXA signal analyzer, including the addition of up to 80 MHz analysis bandwidth to the millimeter-wave PSA spectrum analyzer and two-channel, analog baseband analysis for the N9020A MXA signal analyzer. Agilent's addition of up to 80 MHz analysis bandwidth on the 44 and 50 GHz millimeter-wave PSAs (E4446A/E4448A) provides a 50 GHz spectrum analyzer with a 14-bit, 80 MHz bandwidth digitizer. The added bandwidth allows R&D engineers working on millimeter-wave digital communications in the satellite and emerging wireless communications, aerospace and defense industries to analyze complex signals with higher symbol rates, which are carried by millimeter-wave frequencies.



Agilent Technologies, Signal Analysis Division, Santa Rosa, CA (800) 829-4444, www.agilent.com.
Booth 703 RS 221

Highly Sensitive Imaging Mode

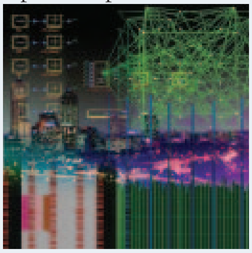
Scanning microwave microscopy (SMM) mode is a unique imaging technique that combines the comprehensive electrical measurement capabilities of a performance network analyzer (PNA) with the spatial resolution of an atomic force microscope (AFM). The ability to provide calibrated, high-sensitivity, complex electrical and spatial measurements make SMM mode particularly useful for semiconductor test and characterization. The new technique works on all semiconductors, including Si, Ge, III-V and II-VI, and does not require an oxide layer. SMM Mode enables complex impedance (resistance and reactance), calibrated capacitance, calibrated dopant density and topography measurements. Operation at multiple frequencies – variable up to 6 GHz – is supported.



Agilent Technologies, Life Sciences and Chemical Analysis Business Unit, Santa Clara, CA (800) 829-4444, www.agilent.com.
Booth 703 RS 222

Simulation Library

Agilent's Advanced Design System (ADS) 2008 Update 2 provides new updated wireless verification models that are compliant with Version 8.3 of the emerging 3GPP Long Term Evolution (LTE) standard. The new models support creation of Frame structure 1 – FS1 (FDD) multiple input-multiple output (MIMO) signals in 2×2 downlink configurations. Using the powerful co-simulation of Agilent ADS, designers of early radios can now verify their RF front-end design performance when working together with new MIMO antenna systems. Leakage between antennas, which results in corruption of modulated signal performance, can be easily verified with this updated Agilent library.



Agilent Technologies, EEsof Division, Santa Rosa, CA (800) 829-4444, www.agilent.com.
Booth 703 RS 223

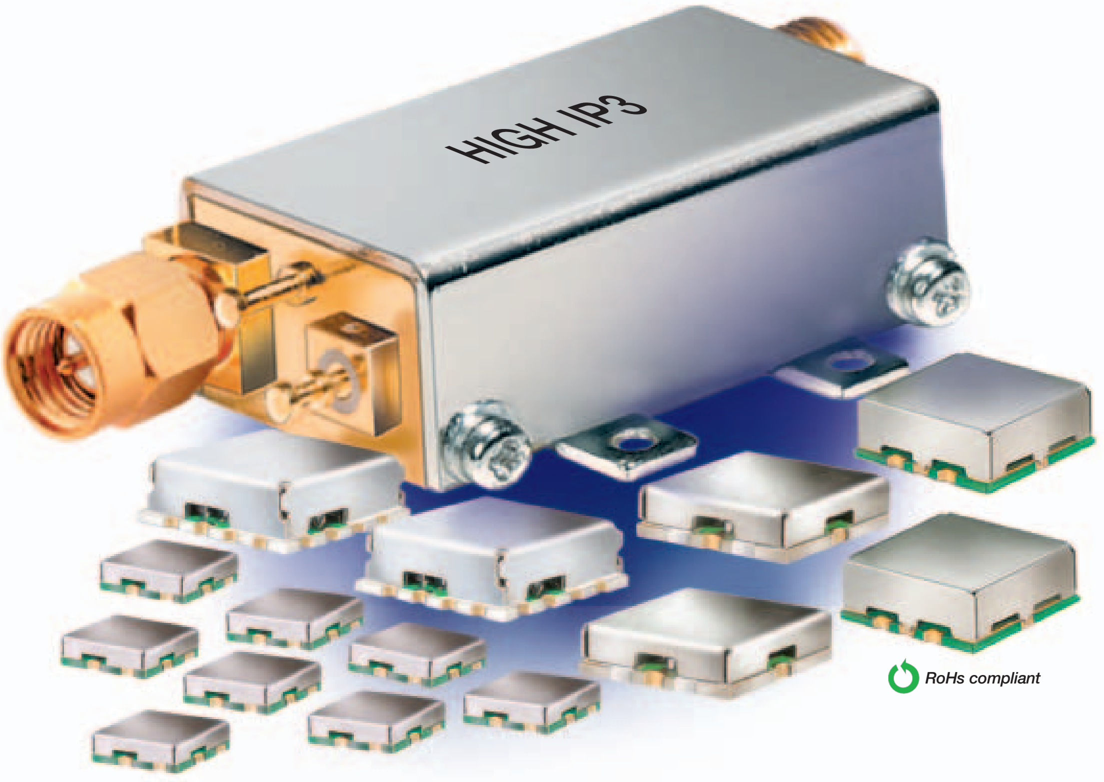
IV/RF Measurement System

AMCAD Engineering has just introduced its new generation high power pulsed IV/RF measurement system, designed for GaN or LDMOS high power devices characterization. The PIV-240-10 high-power pulse pattern generator (240 V, 10 A) can be used as a standalone application for semiconductor pulsed IV characterization (or integrated in a load-pull environment), combining input/output synchronized pulse units (power heads) and voltage and current acquisition. Moreover, synchronized with Agilent PNA-X through a user-friendly software, it offers a versatile, robust and accurate

Constant Impedance

VVAs

10 to 3000 MHz



from $3.95 ea. qty.10-49

Voltage Variable Attenuators (VVAs) deliver as high as 40 dB attenuation control over the 10 MHz through 3.0 GHz range. Offered in both 50 and 75 Ω models these surface-mount and coaxial low-cost VVAs require no external components and maintain a good impedance match over the entire frequency and attenuation range, typically 20 dB return loss at input and output ports. These high performance units offer insertion loss as low as 1.5 dB, typical IP3 performance as high as +56 dBm, and minimal phase variation low as 7°.

Mini-Circuits VVAs are enclosed in shielded surface-mount cases as small as 0.3" x 0.3" x 0.1". Coaxial models are available with unibody case with SMA connectors. Applications include automatic-level-control (ALC) circuits, gain and power level control, and leveling in feedforward amplifiers. Visit the Mini-Circuits website at www.minicircuits.com for comprehensive performance data, circuit layouts, environmental specifications and real-time price and availability.

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NEW WAVES

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AMCAD Engineering,
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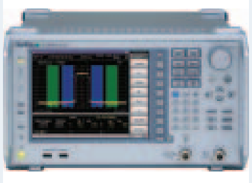
Booth 1211 **RS 224**

EDGE Evolution Test Solution

Two new measurement software packages can be incorporated into the MS269xA series that allow the signal analyzers to support 2.5G GSM/EDGE and G EDGE Evolution (EGPRS2) mobile phone systems, giving design and production engineers a system for measuring the RF Tx characteristics of EDGE Evolution base stations, mobile terminals, and devices and components. Installing the MX269013A GSM/EDGE Measurement Software and the MX269013A-001 EDGE Evolution Measurement Software in the MS269xA Signal Analyzers eliminates the need for a PC to control measurements and achieves fast, accurate results with excellent reproducibility. The small system footprint makes the analyzers well suited for both R&D environments, where bench top space is at a premium, and on production lines, where a PC controller is difficult to incorporate.



Anritsu Co., Richardson, TX
(800) 267-4878,
www.anritsu.com.
Booth 811 **RS 225**

Visual System Simulator

Version 2008 of the company's Visual System Simulator (VSS) software suite is designed for the end-to-end design and optimization of communications systems. The latest release of VSS significantly enhances the flexibility for users while adding many new features and capabilities. VSS, an integral part of the AWR Design Environment™, allows the impact of "real-world" signal impairments and other factors to be evaluated early in the design cycle when they can be most effectively dealt with. It gives designers the ability to create the best system architecture by optimizing each of its components from the behavioral through component levels in conjunction with AWR's Microwave Office® software, and then use actual measurements to validate the final design.

Applied Wave Research Inc.,
El Segundo, CA (310) 726-3000,
www.appwave.com.
Booth 711 **RS 226**

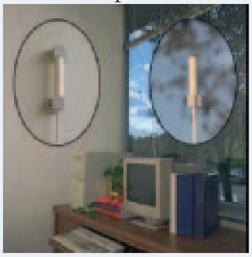
Magnetic Immunity Amplifier

AR RF/Microwave Instrumentation unveiled a new magnetic immunity amplifier for susceptibility testing. Model 350AH1 (350 W, 10 Hz to 1 MHz) is powered by a high efficiency switching supply with auto-ranging AC input circuitry that automatically accepts voltages from 90 to 260 VAC in the 47 to 63 Hz frequency range. The new amplifier, which has low output impedance, will be used primarily for susceptibility testing for magnetic and audio frequency tests in MIL-STD-461D/E, D0160D/E, and a variety of automotive test standards. It can also be used as an AC voltage source, for watt-meter calibration, and as a driver for higher-power amplifiers.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.
Booth 207 **RS 227**

3 dBi Omni-directional Dipole Antenna

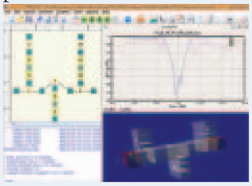
This 3 dBi omni-directional dipole antenna provides a low profile, indoor/outdoor extended range solution for voice or data device applications. These antennas were initially developed for Wireless Local Loop (WLL) phone terminals as an alternative to the standard fix mount whip antenna. The cable length allows the user to place the antenna in a convenient location within a room for the improvement of signal quality. Several connector types are also available. Electrically, the antenna has a power handling capability of 10 W. It is vertically polarized with an elevation pattern of 60 degrees and 360 degrees in azimuth. The VSWR is 2.1. Mechanically, the PCD antennas are $^1/_2$" in diameter and range from 4.5" to 8.5" long, depending on the model.



Astron Wireless Technologies Inc.,
Sterling, VA (703) 450-5517,
www.astronwireless.com.
Booth 501 **RS 228**

FEST3D Software Tool

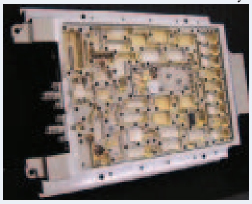
The European Space Agency through the companies Aurora Software and Testing S.L. and ITLink srl announce a commercial release of the "Full-Wave Electromagnetic Simulation Tool" FEST3D. For a full DEMO version freely downloadable, visit: www.fest3d.com/download.php. FEST3D is a software tool capable of analyzing complex passive microwave components based on waveguide technology in extremely short computational times with a high accuracy. This is achieved by the use of the most advanced electromagnetic algorithms such as the integral equation technique combined with the BI-RME method and network theory. The product offers all the tools necessary for the design of passive components such as optimizer features or tolerance analysis.



Aurora Software and Testing S.L.,
Paterna (Valencia), Spain +34 96 354 32 63,
www.aurorasat.com.
Booth 305 **RS 229**

Super Heterodyne Receiver

The new microwave Super Heterodyne Receiver (SHR) is based on multilayer technology. This module is a wideband, compact size down converter for use in EW payloads with Radar Warning Receivers (RWR). The new technology enables the ability to mix RF (up to millimeter-waves), IF and digital sections in one multilayer module, while maintaining high isolation between the channels.



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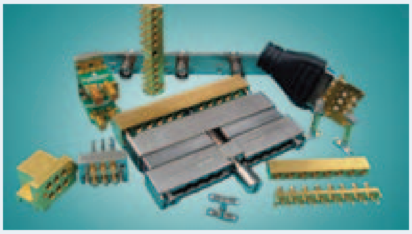
www.mw-elisra.com.
Booth 210 **RS 230**

MRI Connectors and Modular Customization



Johnson, a product line of Emerson Network Power Connectivity Solutions, offers the medical industry a combination of expertise in non-magnetic and custom modular connectivity. MMCX multipack modules can provide 0.150" (3.81 mm) center to center coax arrays that terminate to micro-coaxial cables. Modules can be configured as rails, blocks and cable handles that provide rapid RF coil hook and change out. Emerson Connectivity Solutions continues to work with its customers to develop new solutions as the MR industry transitions to high-end field applications and improved resolution at greater physical depths with the body.
Emerson Network Power Connectivity Solutions, Bannockburn, IL
(847) 739-0354,
www.emerson.com.
Booth 913 **RS 231**

8×8 MIMO Analyzer

The 8x8 MIMO Analyzer® Series E100 offers the advantages of direct measurements of implemented Diversity Gain (Apparent, Effective, Ideal and Actual), spurious radiation outside operating bands, embedded radiation efficiency, maximum available Shannon capacity, capacity loss due to efficiency, all united in one single and intuitive interface. Upcoming Series E200 will include Total Radiated Power (TRP), receiver sensitivity (TIS), Mean Effective Gain (MEG), Angle of Arrival (AoA), MultiPath Components (MPC) and Number of Scatters (NS), among other output parameters. The E100 Series supports operation for any wireless communication standard.
EMITE Ing., Murcia, Spain
+34 968 100 181, www.emite-ing.com.
Booth 1316 **RS 232**

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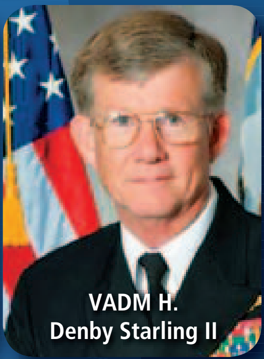

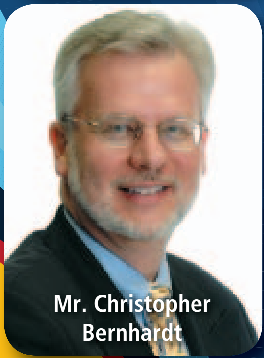

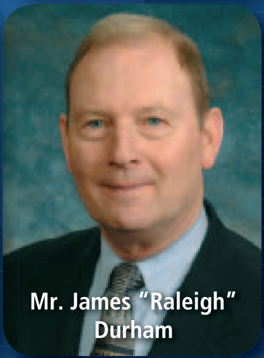

Maj. Gen. Thomas J. Owen is Commander, Warner Robins Air Logistics Center, Air Force Materiel Command, Robins AFB, Ga. He is selected for reassignment as Director, Logistics and Sustainment, Headquarters Air Force Materiel Command, Wright-Patterson AFB, Ohio

VADM H. Denby Starling II is Commander of Naval Network Warfare Command

Mr. Christopher Bernhardt, President, ITT Electronic Systems and Vice President, Strategy & Business Development, ITT Defense

Mr. James "Raleigh" Durham, Director, Joint Advanced Concepts, OSD AT&L

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- Brig Gen Janet Wolfenbarger, HQ AFMC/A2/5
- CAPT Steven Kochman, PMA-234, Naval Air Systems Command
- Col Robert Schwarze, AF/A5RE, HQ USAF
- Col Stan VanderWerf, 542 CBSG/CC, AFMC
- Mr. Steve Pizzo, I2WD, CERDEC, US Army
- Mr. Robert Harvell, TSMO, US Army
- Mr. Noe Duarte, NSWC Crane
- Lt Col Doug Melancon, HQ AF Test and Evaluation Directorate
- Maj Lynn Berg, Joint EW Center, US Strategic Command
- Mr. Bob Pollick, AFRL
- Mr. Terry Christian, AFRL/XPT, US Air Force

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NEW WAVES

High-linearity Broadband LNAs

These three high-linearity broadband low noise amplifiers (LNA) preserve signal purity by minimizing the nonlinear contributions. The amplifiers simultaneously achieve several high performance characteristics in a unique wideband design, and are available in three frequency bands of 0.5 to 2 GHz (JCA02-4000), 2 to 4 GHz (JCA24-4001) and 4 to 8 GHz (JCA48-4000). They feature noise figures of under 2 dB up through C-band, output P1dB levels of +24 dBm, and output IP3 headroom levels of 15 dB or greater above the output P1dB compression point.

Endwave Corp., San Jose, CA (408) 522-3100, www.endwave.com.
Booth 304 **RS 233**

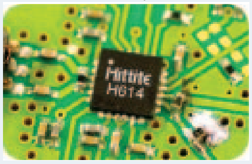
LTCC Foundry Service

Providing the design kit, HIRAI supports the RF design and the inspection tests up to 67 GHz for its LTCC foundry service, and ships in-house plated LTCC substrates in a week after the design freeze. The novel and small BPFs achieved extremely low loss with HIRAI's LTCC technologies for higher Q and the micro- or mm-wave SiP is realized integrating a slot antenna, post-wall waveguide, tapered line, etc. The evaluation samples will be available soon.

HIRAI SK Corp., Shibuya-ku, Tokyo, Japan +81 334 99 1351, www.hirai.co.jp.
Booth 1304 **RS 234**

RMS Power Detector

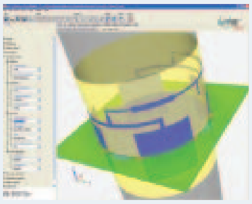
The HMC614LP4E is the industry's first device to simultaneously measure true RMS power and instantaneous RF envelope power from 100 MHz to 3.9 GHz. A peak-to-average output signal provides a direct read of signal crest factor, and the differential input sensing range is 72 dB to ±1 dB detection accuracy up to 3.9 GHz. The HMC614LP4E exhibits less than ±0.1 dB measurement deviation at +12 dB crest factor. Specified from –40° to +85°C, the HMC614LP4E is available in a 4×4 mm leadless QFN package and operates from a +5 V supply.



Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.
Booth 515 **RS 235**

EMPIRE XCel™ 5.2

The new 3D EM solver EMPIRE XCcel 5.2 offers the Perfect Geometry Approximation (PGA) algorithm to yield more accurate results for curved structures, even with coarse meshes. The most complicated designs are modeled quickly and precisely. The unique on-the-fly code generation for each model and processor produces up to 1600 million FDTD cells per second on a conventional PC supporting the complete RAM. Thus very complex structures can be modeled very fast and are highly accurate.



IMST GmbH, Kamp-Lintfort, Germany +49 2842 981 0, www.empire.de.
Booth 1201 **RS 236**

Hybrid Simulation Tools

These simulation tools were developed specifically for engineers and scientists who design radio frequency, high frequency and microwave devices and components. Integrated's tools provide solutions to a wide variety of electromagnetic field models, which can be obtained based on the Method of Moments (MoM) approach for open region problems and Finite Element Method (FEM) for closed region problems. Designers can analyze radiation patterns and other radiation characteristics of ar-

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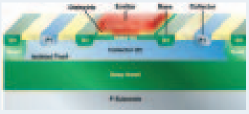
bitrarily shaped linear antennas, microstrip antennas and dielectric resonator antennas. Horn antennas and reflector antennas covered by radomes can be analyzed as well with these software tools.

Integrated Engineering Software, Winnipeg, Manitoba, Canada (204) 632-5636, www.integratedsoft.com.

Booth 113 ***RS 237***

SiGe BiCMOS Process

Jazz offers its 0.18-micron Silicon Germanium (SiGe) BiCMOS platform (SBC18) to enable customers to deliver next generation green, energy efficient analog ICs. Jazz SBC18 provides a next-generation solution for ultra low power, integrated wireless and networking products that require high-performance bipolar transistors with high-quality passives together with high density logic. Jazz also offers a Vertical PNP (VPNP) module for the SBC18 SiGe BiCMOS process that can be paired with a SiGe NPN to enable the design of analog circuits that require high voltage, complementary drive or amplification beyond the capability of standard CMOS.

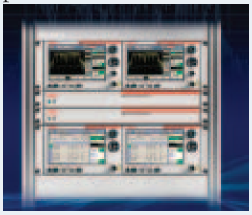


Jazz Semiconductor, Newport Beach, CA (949) 435-8181, www.jazzsemi.com.

Booth 1415 ***RS 238***

8x8 MIMO Test System

Keithley is extending its lead in RF MIMO (multiple-input, multiple-output) test with the measurement-grade 8×8 MIMO system. The system is used for primary research of next-generation RF MIMO devices and technologies. Keithley introduced the 4×4 MIMO test equipment for R&D product development in late 2007. The new 8×8 MIMO system is built on the same measurement platform that provides capability and performance including: support for MIMO research applications ranging from two channels now up to eight; flexible system configurations with individual system component instruments; phase and amplitude control of the RF carrier; and less than ±1 nanosecond signal sampler synchronization.



Keithley Instruments Inc., Cleveland, OH (800) 688-9951, www.keithley.com.

Booth 1111 ***RS 239***

Waveguide Terminations

These medium-power waveguide terminations feature a one-piece construction. The AML-2 terminations are machined from a single aluminium flange extrusion, resulting in a more compact, rugged and reliable design. The range comprises 16 rectangular-waveguide models and eight double-ridge models. The rectangular versions come in various lengths, with frequencies ranging from 1.12 to 40 GHz and mean power handling capabilities as high as 1500 W, while the double-ridge versions span the frequency range 2 to 40 GHz and offer mean power ratings up to 250 W. Ideal for a variety of microwave test and measurement applications, the AML-2 terminations are designed for convection cooling and deliver a VSWR of better than 1.1 over the full frequency range.

Link Microtek Ltd., Basingstoke, Hampshire +44 (0) 1256 355771, www.linkmicroteked.com.

Booth 602 ***RS 240***

EM-Software Tool

Version 7.0 of the company's EM-software tool µWave Wizard™ will be released during fourth quarter 2008. This new release will be available in a 64-bit version with multithreading for the 3D FEM solver. Further improvements with this release are several new features for existing elements, new elements, the consideration of ferrite materials and extended capabilities for antenna far field optimization. Version 7.0 of the

See us at EuMW Booth 813

GaN Power Amplifiers GA Series

Low Cost GaN FET Amplifiers

Need Power Amp? Ask R&K!

Model Number	Frequency (GHz)	Power
GA0538-4540-M	0.5～3.8	10W(min)
GA0538-4540-R	0.5～3.8	10W(min)
GA0830-4344-M	0.8～3.0	25W(min)
GA0830-4344-R	0.8～3.0	25W(min)
GA0830-4747-M	0.8～3.0	50W(min)
GA0830-4747-R	0.8～3.0	50W(min)
GA0827-4552-M	0.8～2.7	150W(min)
GA0827-4552-R	0.8～2.7	150W(min)
GA0827-4754-R	0.8～2.7	250W(min)
CON0827-150W-R	0.8～2.7	150W Peak

* Suffix "-M" is Module type, "-R" is Rack type.

R&K Company Limited

info@rkco.jp
http://www.rk-microwave.com
Country in Origin

SEKI TECHNOTRON USA
A subsidiary of SEKI TECHNOTRON CORP.

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http://www.sekitechusa.com
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www.microtoolinc.com

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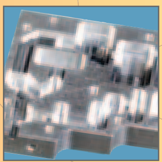


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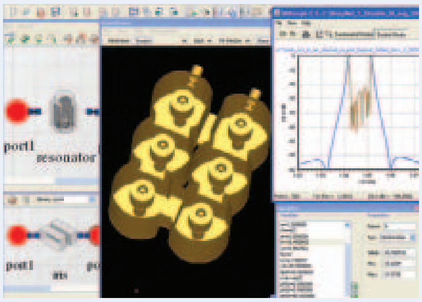
NEW WAVES

µWave Wizard will be demonstrated in October 2008 at EuMW.

Mician GmbH, Bremen, Germany +49 (421) 16899351, www.mician.com.
Booth 510 **RS 241**

Fast EM CAD and Optimization Tool



WASP-NET®´s new version features a further breakthrough in EM CAD speed. Based on its unique, proven hybrid MM/FE/MoM/FD CAD engine, advanced algorithms provide EM precision in seconds. A new graphical user interface (GUI) utilizes modern operational and user-defined conveniences for highest user-friendliness. WASP-NET application examples include: Fast optimization of all types of waveguide components and aperture antennas/arrays; full-wave synthesis of waveguide, combline filters and slot arrays; cross-coupled and LTCC filters; dielectric resonator filters; dielectric loaded horns; shaped subreflectors; squarax and stripline elements; very large sized structures, e.g. slot arrays, reflectors, antennas with radomes, etc.

Microwave Innovation Group (MiG) GmbH & Co. KG, Bremen, Germany +49-421-223-79660, www.mig-germany.com.
Booth 1407 **RS 242**

QFN Packaged Receiver

The model XR1015-QH is a 10 to 16 GHz GaAs PHEMT SMT packaged receiver that integrates a low noise amplifier (LNA), image reject mixer and LO buffer amplifier within a fully molded 4×4 mm QFN package. This RoHS-compliant, packaged receiver has a noise figure of 2.5 dB and conversion gain of 12 dB. The image reject mixer eliminates the need for a bandpass filter after the LNA to remove thermal noise at the image frequency. This device is well suited for point-to-point radio, LMDS, SATCOM and VSAT applications. The device is 100 percent RF and DC tested. Engineering samples are available today from stock, with a lead time of 14 weeks for production quantities.

Mimix Broadband Inc., Houston, TX (281) 988-4600, www.mimixbroadband.com.
Booth 1406 **RS 243**

Miniature Digital SP3T Switch

This reflective single-pole three-throw (SP3T) switch, model SW3-005180RN3NF-S0001, covers the frequency range from 500 MHz to 18 GHz with a minimum of 55 dB isolation and VSWR of 2.0. The three-bit input control word is TTL compatible and the time between the 50 percent point of the input control pulse to the 10 to 90 percent point of detected RF is within 100 ns. The power handling capability is 20 dBm.

MITEQ Inc., Hauppauge, NY (631) 436-7400, www.miteq.com.
Booth 1214 **RS 244**

Phase Trimmer

The model 4572B is a phase trimmer that provides a fixed amount of phase shift for electrically adjusting the length of coaxial cables between two devices. This model provides phase adjustment of ±2° between 3 and 18 GHz with linearity of ±2° from 3 to 12.4 GHz and ±5° from 12.4 to 18 GHz. The rugged device weighs only 19 g and measures 1.6" long (with connectors) by 0.32" diameter. It can handle 30 W CW and has an operating temperature range of –54° to +100°C. Maximum VSWR is 1.35.

Narda Microwave-East, Hauppauge, NY (631) 231-1700, www.nardamicrowave.com/east.
Booth 103 **RS 245**

Horn Antennas

The model 120DL5 is the latest in its line of high power broadband horn antennas. This new dual linearly polarized antenna operates over the 6 to 18 GHz frequency range, providing high radiation efficiency over the entire 3:1 bandwidth. Model 120DL5 is available with either TNC or SMA jack connectors. The antenna has been designed to maintain equal E- and H-plane beamwidths. This antenna is suitable for use in the extreme environment of high dynamic aircraft, for which Nurad can also provide a protective radome for a complete airborne antenna system.

Cobham Defense Electronic Systems – Nurad Division, Baltimore, MD (410) 542-1700, www.cobhamdes.com.
Booth 1001 **RS 257**

mmWave Transceiver

The mmWave transceiver operates in the Ka frequency band and integrates a pulsed transmitter and a low noise receiver used on a millimeter-wave radar seeker for military applications. The Ka-band transmit signal is created by up-convert-

ing the L-band IF input signal utilizing an injected LO input signal. The Ka-band receiver has four antenna inputs that are selected using low loss switches and down-converted to the IF utilizing the LO input signal. The mmWave transceiver exhibits an 8 dB maximum noise figure and spurious of –50 dBc maximum over all operating conditions encountered in airborne military environments.
REMEC Defense & Space Inc., a division of Cobham Defense Electronic Systems, San Diego, CA (858) 560-1301, www.remecrds.com.
Booth 1001 **RS 246**

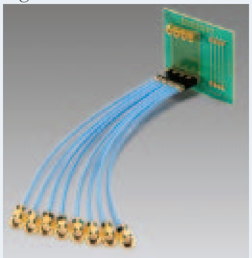
Thermally-enhanced GaN 30 W Device

These thermally-enhanced gallium nitride devices, including RT233C, RT240JC and RT243C, offer 36, 43 and 45 dBm measured Psat output power each, from DC to 6 GHz applications. They are available with standard, or earless type designs, and its wideband capable characteristics can give 50 to 2500 MHz wideband applications and other design opportunities. Patent-pending thermally-enhanced technology has been used to improve high temperature reliability and provide added power when used at pulsed applications or Class-A amplification.

RFHIC Corp., Suwon, Korea (82) 31-250-5011, www.rfhic.com.
Booth 107 **RS 247**

Multiport Coax Connections

This range of multiport coax connections is designed for semiconductor test equipment applications. These multiport coax connections are available as two-, four- or eight-port versions and can be used – depending on product type – in numerous configurations for versatile applications up to 40 GHz to achieve the density and frequency requirements of new chip testing devices. The product range includes coax pogos with spring-loaded pins or bellows, mini-coax PCB connections or even high performance pogo blocks.



Rosenberger Hochfrequenztechnik GmbH & Co. KG, Fridolfing, Germany +49 08684 18-263, www.rosenberger.de.
Booth 1115 **RS 258**

Signal Analyzer

The R&S FSV is a new signal analyzer that sets standards in the mid-range. Virtually all of its performance characteristics exceed those offered by other instruments in its class. In addition, the R&S FSV is alone in offering an analysis bandwidth of 40 MHz. This means it covers a wide range of wireless standards – from 3GPP LTE up to WLAN 802.11n. Moreover, the R&S FSV makes measurements more user-friendly with an innovative operating concept that includes a touch screen. The R&S FSV is a powerful analyzer for development and production.
Rohde & Schwarz, Munich, Germany +49 89 4129 13774, www.rohde-schwarz.com.
Booth 803 **RS 248**

Spiral Antennas

Cobham SASL's ASO-2154 two-inch diameter spiral antennas provide superior performance for use in applications requiring circular polarization. With excellent input VSWR, these antennas provide smooth broadband gain, low axial ratios and consistent pattern performance over 2 to 18 GHz. This model was designed and developed for applications requiring extremely close unit-to-unit amplitude and phase matching, and is an excellent choice for airborne interferometry and direction finding systems. The two-inch diameter spirals allow close element spacing in arrays to satisfy geometry for upper frequency ambiguity resolution. The ASO-2154 uses a SMA Female connector axially located about the center of the antenna to allow for "clocking" of the elements.

Sensor and Antenna Systems, Lansdale Inc., a division of Cobham Defense Electronic Systems, Lansdale, PA (215) 996-2416, www.cobhamdes.com.
Booth 1001 **RS 249**

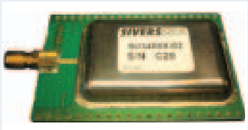
LTCC Substrate Foundry Service

The LTCC substrate foundry services are designed for wireless module makers. Sentec invested tremendously in the most advanced manufacturing systems available for the establishment of the world class LTCC foundry both in Taiwan and China. Aside from the state-of-the-art facilities, Sentec transferred a patented "Non-Shrinkage" process from Panasonic to enhance highly accurate dimensions control (± 0.05 percent of the design specifications) that greatly increase product yield, manufacturing stability and product reliability. Advantages of patented "Non-Shrinkage" LTCC substrate include: high dimension control; smaller footprint; higher RF performance and better production yield; production efficiency with reduced mounting time; cost reduction and component simplicity and quick sampling lead time.

Sentec E&E Co. Ltd., Lungtan, Taoyuan, Taiwan +886 (0) 910-116-758, www.sentecee.com/ltcc.asp.
Booth 1404 **RS 250**

10 GHz FMCW Transceiver

The SU3400X/02 is a 10 GHz synthesized FMCW radar front-end transceiver. It is very flexible and can be used in several different configurations: with an internal or external reference



RF Power Amplifiers ALM Series

Low Cost GaAs FET Amplifiers

Need Power Amp? Ask R&K!

Model Number (Module Type)	Frequency (MHz)	Power
ALM000110-2840FM-SMA(F)	1 ～ 1000	10W(min)
ALM00110-2840FM-SMA(F)	10 ～ 1000	10W(min)
ALM1015-2840FM-SMA(F)	1000 ～ 1500	10W(min)
ALM1520-2840FM-SMA(F)	1500 ～ 2000	10W(min)
ALM1922-2840FM-SMA(F)	1900 ～ 2200	15W(min)
ALM00505-4546-SMA	50 ～ 500	40W(min)
ALM0105-4748-SMA	100 ～ 500	60W(min)
ALM0510-3846-SMA	500 ～ 1000	25W(min)
ALM2527-4547-SMA	2500 ～ 2700	50W(min)

* A bench top type is also available that features 100-240V AC.

R&K Company Limited
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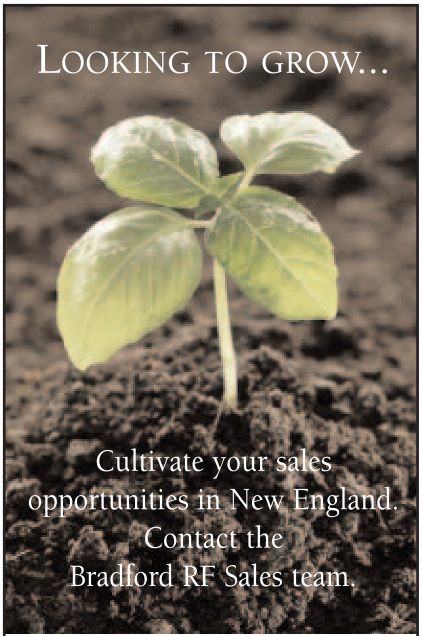

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E-mail: mike@bradfordrfsales.com
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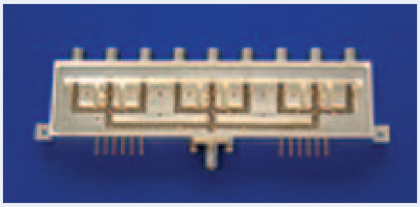
NEW WAVES

frequency source and with a single-ended or differential, down-converted baseband output port. The frequency is digitally-controlled via a standard, three-wire serial interface, which programs a modern high performance synthesizer circuit. A complete kit for controlling the unit through an RS-232 or USB from a PC for easy evaluation is also available.

Sivers IMA AB, Kista, Sweden +46-8-703 68 00, www.siversima.com.
Booth 914 **RS 251**

9-way PIN Diode Switch



This nine-throw PIN diode switch is a representative example of Specialist Microwave Solutions' SMS-1-034 series of wideband switches, designed for multi-channel receivers and test equipment applications in the defense and instrumentation market sectors. With an instantaneous bandwidth of 100 MHz to 18 GHz and the fast switching and high reliability associated with hybrid PIN diode technology, the switch is offered both individually and in combinations to form switching assemblies. Designed and manufactured in the UK, variants can be tailored to customer's specific needs. Assemblies can be supplied combining any reasonable number of input/output ports with optimized bandwidth.

Specialist Microwave Solutions Ltd., Bedfordshire, UK +44 (0) 1234 756 034, www.smslimited.co.uk.
Booth 414 **RS 252**

High Frequency Contacts

To meet the requirements of customers looking to simplify system level interconnect, SV Microwave introduces a new family of high frequency contacts for Series 1 and 3 MIL-DTL-38999 connectors. Based on SV's proven blindmate technology to accommodate mis-alignment during mating, the product line consists of size 8 contacts with the option of 18 GHz or 40 GHz performance and size 12 contacts operating to 65 GHz, all of which fit into standard cavities and are fully removable using standard extraction tools. Designs are available for common cable sizes, custom versions can be produced for special cables and PCB mount applications.

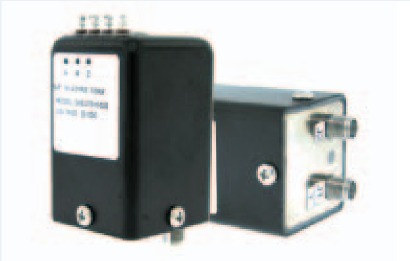
SV Microwave Inc., West Palm Beach, FL (561) 840-1800, www.svmicrowave.com.
Booth 1305 **RS 253**

Miniature Synthesizers

The MTS2500DS is a series of miniature synthesizers that offer a resolution of 1 Hz and outstanding phase noise and excellent spurious suppression. The first model introduced, the MTS2500-110250, covers the frequency range from 1100 to 2500 MHz. It is available in four versions, version one and two have 5 V and 3.3 V supply only and use an external reference of 10 MHz or 1.6 GHz, respectively, the other two versions require 28 V, 5 V and 3.3 V supply voltage and use either 10 MHz or 1.6 GHz references.

Synergy Microwave Corp., Paterson, NJ (973) 881-8800, www.synergymwave.com.
Booth 1214 **RS 254**

3-State Attenuated Switch



This 3-state attenuated switch CAS-37 is designed for frequencies from DC to 25 GHz. The 3-state attenuated switch was designed to allow users to switch between three different states: through path (low loss), attenuated path (known high loss) and open state (with path for user to ground). Internally implemented functionalities eliminate the use of external cables or attenuators maximizing RF characteristics and minimizing space and weight. The 3-state attenuated switch is ideal for test and measurement applications in which high frequency signal attenuation is needed over the bandwidth range. This special switch offers linear attenuation up to 25 GHz.

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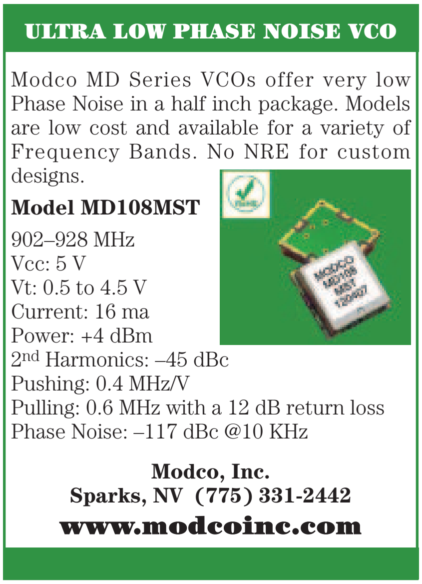

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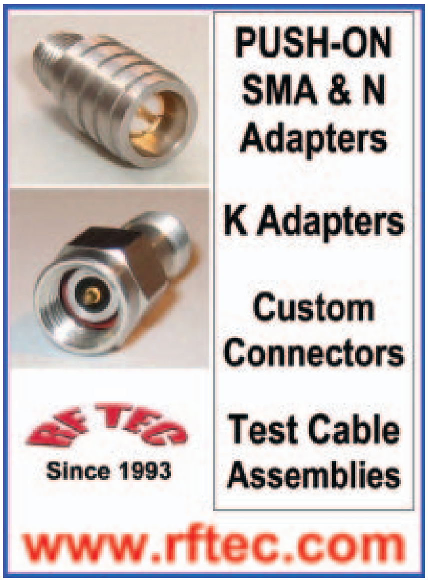

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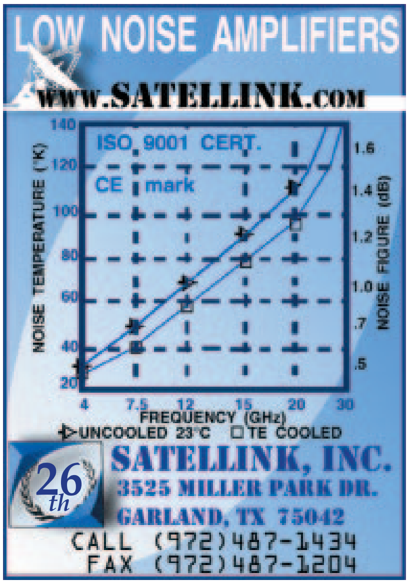

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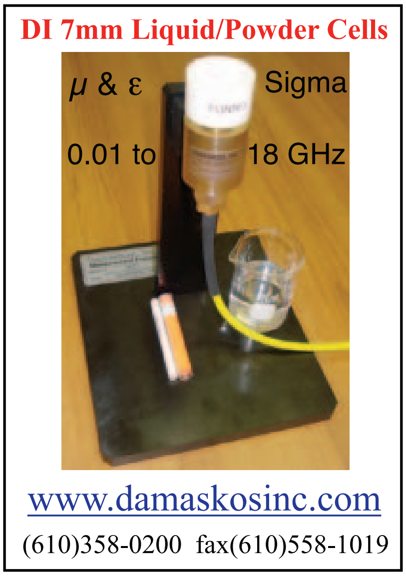

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www.agilent.com.

RS No. 200

ENHANCED CATALOG

With 62 pages, the new 2008 AtlanTecRF catalog is bigger than ever. It features many new additions to the product ranges, most notably: synthesized local oscillators, a new phase-locked oscillator with internal TCXO reference (APL-04), mixers, terminations, medium power attenuators, filters, PIN switches and cable assemblies. The catalogue offers detailed specifications for each product including dimensional diagrams. It also contains information on the ranges of custom equipment, components, cable assemblies and waveguide products.

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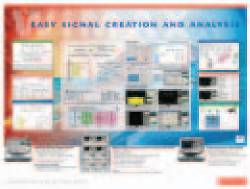

A free WiMAX technology poster is available upon request from Keithley Instruments Inc., providing an overview of the company's RF testing solutions, including the Series 2800 Vector Signal Analyzers and Series 2900 Vector Signal Generators. To request a free copy, visit www.keithley.com/at/554.

Keithley Instruments Inc.,
Cleveland, OH (800) 588-9238,
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ACCESSORIES CATALOG

This catalog of accessories vastly expands the functionality and value of Fluke test tools. Fluke accessories can turn a Fluke digital multimeter into a thermometer, an amp-meter or even a pressure gauge. The catalog lists products by popularity and includes photos of each product, multiple compatibility charts to help users match accessories to the appropriate test tools, an index and application information.

Fluke Corp.,
Everett, WA (888) 308-5277,
www.fluke.com.

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CD-ROM

This CD-ROM includes several new and updated brochures and catalogs including the newest edition of the LMR® Wireless Products Catalog that now includes T-RAD™ leaky feeder cables, LMR-lite, LMR Bundled Cable, SilverLine and TuffGrip test cables and SilverLine QMA Adaptor kits. The CD-ROM features an easy-to-use menu for navigation within each catalog. There are also invaluable 'how-to' installation videos including several new ones to assist users of LMR low loss coaxial cable products and two handy calculators for determining both coaxial cable attenuation and conversion of VSWR-to-return loss.

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

RS No. 204

PRODUCT CATALOG

Weinschel Associates, a manufacturer of high-quality broadband RF and microwave products for commercial and military markets both domestic and international, has just released the 2009 edition of its full-line catalog. The company's goal is to serve you, the customer, with an ever increasing usefulness of product line.

Weinschel Associates Inc.,
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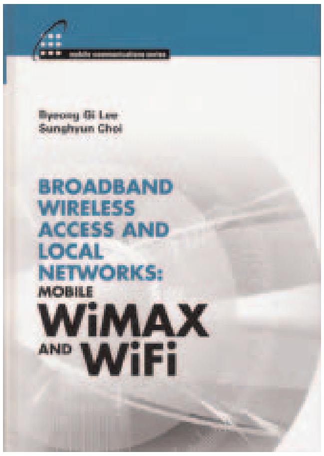
Broadband Wireless Access and Local Networks: Mobile WiMAX and WiFi



Byeong Gi Lee and Sunghyun Choi
400 pages; $149, £79 · Artech House
ISBN: 978-1-59693-293-7

This authoritative resource introduces the network technologies adopted by mobile WiMAX for the implementation of IP-based broadband mobile wireless access and the WiFi technologies that have steadily evolved for the past ten years, establishing a firm foundation for IP-based wireless local network access. These access and local technologies have many things in common, most prominently that both are oriented toward IP traffic and standardized by IEEE 802 working groups. The book is organized in two parts, separately addressing mobile WiMAX and WiFi, plus a preliminary chapter to provide a common ground of discussion for the two network technologies. Collecting the most recent experience of design and field engineers from leading organizations, the book introduces the network technologies adopted by mobile WiMAX for the implementation of IP-based broadband mobile wireless access. Moreover, it covers the WiFi technologies that have steadily evolved over the past decade, establishing a firm foundation for IP-based wireless local network access. It reflects the experiences of design and field engineers involved in the development and deployment of mobile WiMAX systems, the knowledge of an IEEE 802.11 standards author and input from collaborating vendors involved in the deployment of these IP-oriented wireless network technologies. Part I covers an introduction to mobile WiMAX networks, network initialization and maintenance, OFDMA OHY framework, MAC framework, bandwidth management and QoS, mobility support and security control, multiple antenna technology and WiBro. Part II includes an introduction to WiFi networks, PHY protocols, baseline MAC protocol, QoS provisioning, security mechanisms and mobility support, spectrum and power management, and on-going evolution of WiFi covering IEEE 802.11n and IEEE 802.11s.

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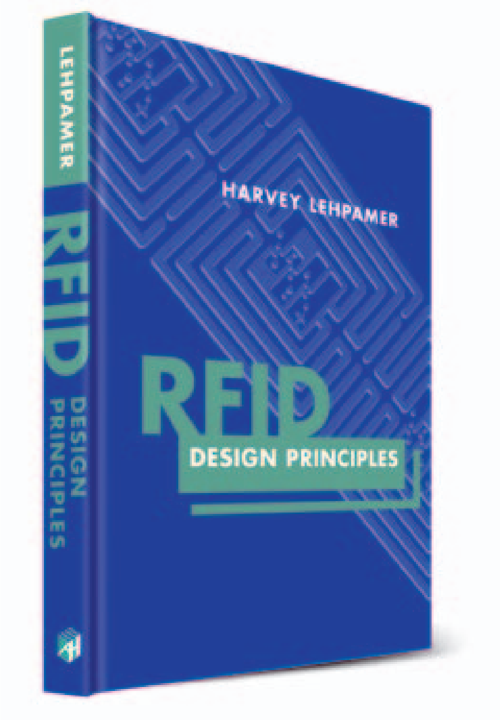

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CAREER CORNER

Short on RF Engineers? Consider H1B

This column advocates for considering non-US professionals to fill in the steadily growing shortage of RF engineers. In addition to presenting the practical and fiscal advantages, this article also highlights the contribution of "imported" engineering talent to securing future domestic jobs.

Unlike the days of the high-tech boom in the late 1990s, employers today do not seem very keen to go through the work permits process. This may be explained by the Visa sponsorship process (which might be perceived harder because it is subject to national security) and the general atmosphere of a stumbling economy and lost jobs to offshore locations.

Attracting Overseas Engineering Talent Supports Future Domestic Jobs

On the other hand, it is evident that the ongoing shortage in RF engineers (documented in numerous articles since 2003 and until now) is far from over. This shortage is global and therefore corporations are forced to establish their centers where the engineers are located. It is an opportunity to counter off-shoring. The US has a unique appeal and employers have an extraordinary advantage attracting foreign talent. Filling in those vacant RF engineering jobs quickly will ensure that these positions remain domestic regardless of the country where the engineer was born.

More Reasons for Employers to Make the Extra Effort with Non-resident Engineers:

Unless the nature of the company is strictly defense business, employers may consider "importing" engineering talent for the following reasons:

1. The past two decades have proven immigration to be a valuable resource for creative, high-quality engineering talent in a wide range of science and engineering fields.

2. Throughout the history of the US, first-generation immigrants have always proven to be hard-working and dedicated employees.

3. Offering an opportunity to work and live in the US gains employers an opportunity to boost their engineering resources with the best among the scientists and engineers that the world has to offer, and for fair and reasonable compensation.

4. What is the cost of a delayed project due to under-staffing? Hard to say and certainly not cheap. One can definitely put a cap on the cost of sponsoring an H1B Visa.

5. The immigration process has actually become more efficient in the past several years, while at the same time, the queues have shortened (other industries aren't necessarily doing so well these days).

For many employers the RF engineering resources problem can be turned into an opportunity. An opportunity to boost the company's engineering resources, bypass the competitors and at the same time be supporting domestic economy.

Employers wishing to inquire about the Visa sponsorship process please e-mail VisaSposorshipInfo@ElectroMagneticCareers.com.

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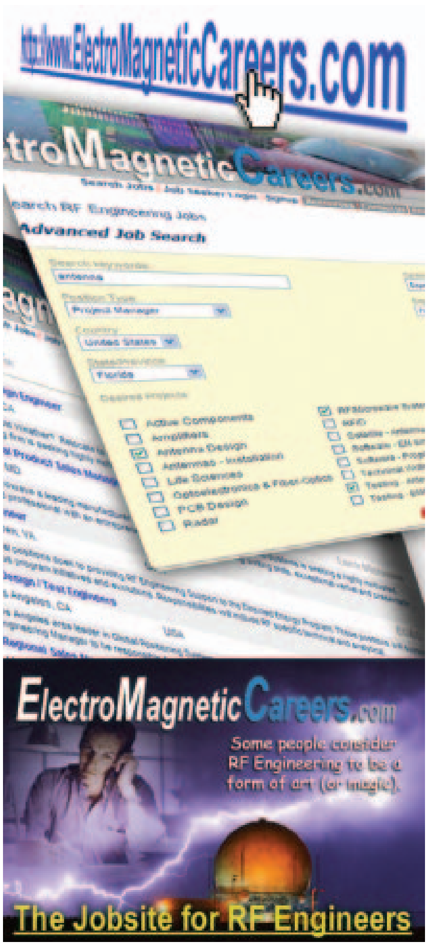

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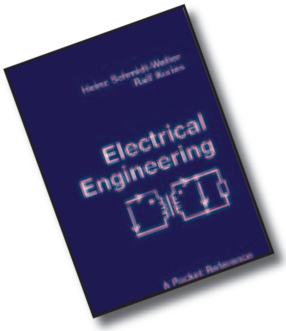

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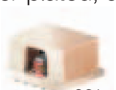

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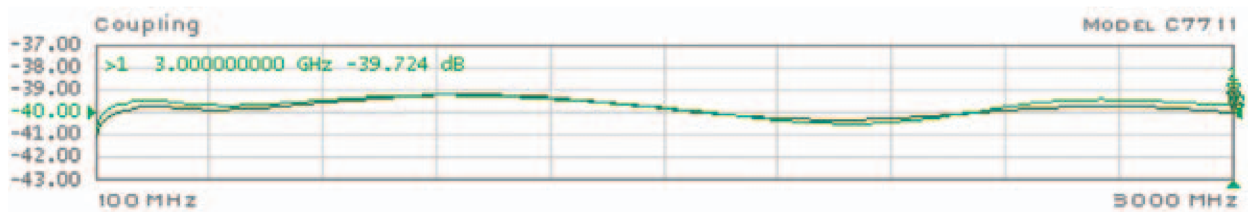

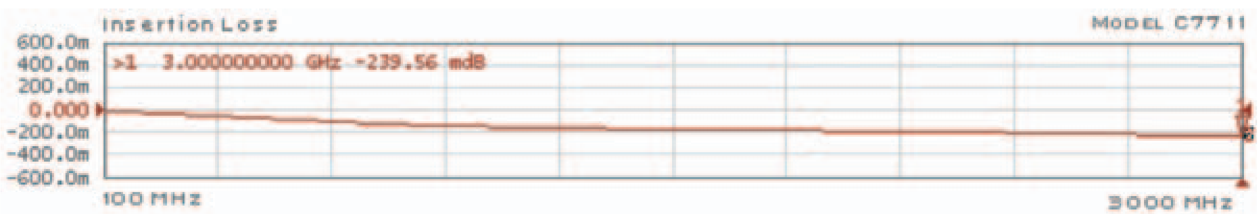

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C7148	Bi Directional	60-600	200	10	±1.0	0.35	1.20:1	20	6.0 x 4.0 x 0.75
C7711	Dual Directional	100-3000	100	40	±1.0	0.35	1.25:1	18	3.0 x 2.2 x 0.7
C7783	Bi Directional	200-1000	200	20	±0.75	0.2	1.20:1	20	3.0 x 1.5 x 0.53
C6600	Bi Directional	200-2000	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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White Paper

50 V RF LDMOS:
An Ideal RF Power Technology for ISM, Broadcast, and Radar Applications

Pierre Piel, Wayne Burger, David Burdeaux, Warren Brakensiek

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I. INTRODUCTION

RF LDMOS (RF Laterally Diffused MOS), hereafter referred to as LDMOS, is the dominant device technology used in high power wireless infrastructure power amplifier (PA) applications for frequencies ranging from less than 900 MHz to 3.8 GHz. LDMOS began to be widely deployed in high power cellular infrastructure PA applications in the early 1990's. This device technology offers significant advantages over the previous incumbent device technology, the silicon bipolar transistor, including superior linearity and efficiency, high gain, and compatibility with low cost packaging platforms. Within a few years of introduction to the cellular infrastructure market, LDMOS became the dominant technology and essentially completely displaced silicon bipolar transistors. LDMOS technology has continued to evolve to meet the ever more demanding requirements of the cellular infrastructure market, achieving higher levels of efficiency, gain, power, and frequency[1-8].

The LDMOS device structure is highly flexible. Although the traditional cellular infrastructure market has been focused on 28-32 Volts (V), Freescale Semiconductor has been developing 50 V versions of 28 V platforms for many years. Several years ago Freescale focused its 50 V development on applications outside the cellular infrastructure market, including the Industrial, Scientific and Medical (ISM), Broadcast, and Radar markets (hereafter referred to as the RF Power market), where higher power density and compatibility with commercial 48 V DC supplies are key competitive advantages. Many of the same attributes that led to the displacement of bipolar transistors from the cellular infrastructure market in the early 1990's are equally valued in the broad RF Power market – high power, gain, efficiency and linearity, low cost, and outstanding reliability. In addition, the RF Power market demands the very high RF ruggedness capability that LDMOS can deliver.

The initial 50 V products designed by Freescale for the RF Power market, fabricated using what is known as the Very High Voltage 6th generation (VHV6) platform, have been fully qualified and are shipping in volume. This paper will describe the VHV6 device structure, including advantages over competing device technologies. Ruggedness requirements for RF Power are more stringent than for cellular infrastructure; this paper will include device and design considerations that specifically target enhancing ruggedness performance. Design features of the products in this platform will also be presented.

II. LDMOS DEVICE TECHNOLOGY

The schematic shown in Figure 1 depicts a cross section of a single finger of a typical LDMOS transistor. It includes a source metal region to electrically connect the N+ source to the P+ sinker, which in turn is connected to the back side source metal through the P+ substrate. This patented feature significantly lowers the source inductance to improve performance, but also allows the die to be directly attached onto an electrically and thermally conductive package flange to accommodate low cost packaging platforms.

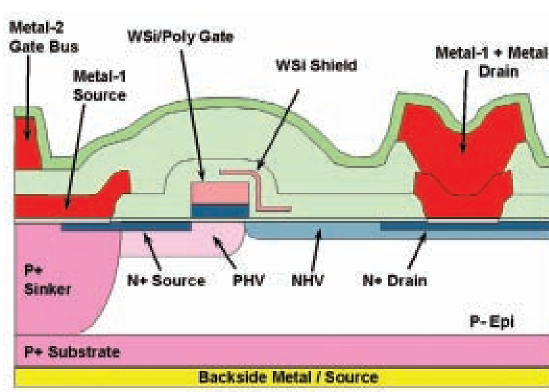

Figure 1: Cross-Section of an LDMOS device

The boron p-type "PHV" diffusion establishes the threshold voltage and turn-on characteristics of the device. The WSi/polysilicon gate provides a low gate access resistance, important for the large dimensions typical of RF power devices. A low doping concentration arsenic n-type "NHV" drift region between the gate and the highly doped N+ drain region is designed to support high breakdown voltages, low on-state resistance (R_{DSon}), and good Hot Carrier Injection (HCI) reliability. The stacked aluminum drain metal is designed to meet electromigration specifications for high reliability. A metal-2 gate bus running parallel to the gate makes periodic connections to the gate WSi/polysilicon stack to reduce its resistance. Grounded shield structures (the ground strap is not shown in this figure) are also employed to reduce feedback capacitance between the drain and gate, and to control surface electric fields to allow for improved device performance without sacrificing breakdown voltage or HCI margin.

Another Freescale innovation pioneered in the cellular infrastructure market that is incorporated into the 50 V LDMOS RF Power product portfolio is an enhanced ESD protection structure that can tolerate moderate reverse bias conditions being applied to the gate lead (see Figure 2). An example of when this enhanced device is very beneficial is Class C operation at high input RF power levels. The RF swing could easily turn on a standard ESD structure during a small negative voltage swing, while the enhanced ESD device remains off. The enhanced structure employed in the RF Power products is much more robust against a broad range of operating conditions that may be encountered during operation.

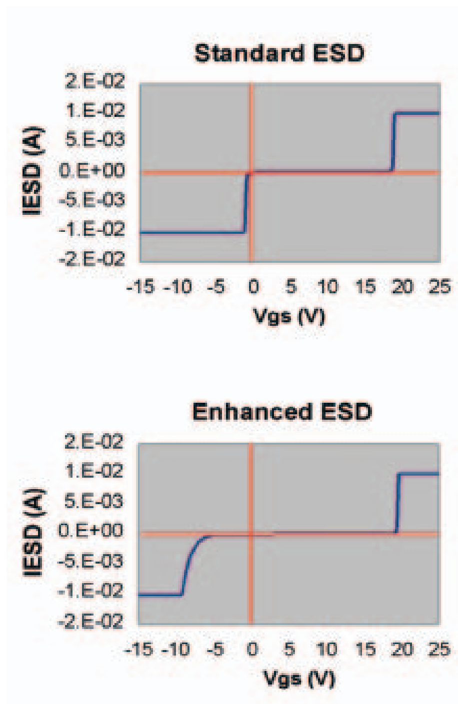

Figure 2: I-V characteristics of a standard and enhanced ESD protection device

B. Technology Comparison

The primary competitive technologies in the RF Power market are the silicon VMOS (Vertical MOS) device, and to a lesser extent 28 V LDMOS. Compared to the LDMOS device, which is primarily a laterally fabricated device, the VMOS device has a significant vertical component to achieve the appropriate breakdown voltage. Vertical dimension and doping level control is inherently limited compared to surface or horizontal fabrication; vertical structures typically rely on silicon epitaxy for both doping and thickness control, whereas lateral structures can leverage the deep sub-μm photolithography capability in modern fabs, while doping is determined with a high level of precision using ion implantation techniques (the same advanced techniques used in leading edge CMOS technologies).

Attribute	Si VMOS	28V RF-LDMOS	50V RF-LDMOS
CW eff. at P1dB	3	5	5
Power Gain	3	5	5
Thermal resistance	3	4	5
CW Packaged Power Density	3	3	4
High Intrinsic Zin / Zout (wideband)	3	3	4
On-Die Passives Integration	2	4	4
Variability / Performance spread	2	4	4
Technology Maturity	5	5	4
Reliability	4	5	5

Table 1: Comparison of RF Power attributes vs. device technology

A performance comparison of these three technologies (VMOS, 28 V LDMOS, and 50 V LDMOS) is shown in Table 1 utilizing various metrics that are important for success in the RF Power market. The color coding is red = poor, yellow = neutral, and green = strength.

The scale ranges from 1 to 5, with 5 being highest, or best. Starting down the metric list, LDMOS has superior gain and efficiency that can be traced to developments originally driven by the cellular infrastructure market where these parameters have long been of paramount importance, along with device structure advantages such as deep sub-µm self-aligned gates and shields to reduce feedback capacitance. The LDMOS devices have thermal resistance benefits as a result of having a backside source that can be connected directly to the thermally and electrically conductive package flange, which in turn is directly mounted to the heat sink. Typical VMOS devices have the drain on the backside of the wafer and require attaching the die to an electrically isolating flange material which increases the effective thermal resistance of this device structure. The excellent thermal conductivity of the LDMOS packaged products allows then to achieve significantly higher CW power levels in a given package, especially the 50 V technology with its inherently higher power density compared to the 28 V variant. In addition, 50 V LDMOS typically has 35% less output capacitance per Watt (W) than competing 50 V Si technologies, making it ideal for broadband applications.

LDMOS products in the cellular infrastructure market are typically manufactured with integrated matching networks, making the availability of on-die passives (inductors, capacitors) an LDMOS strength. The lateral nature of the LDMOS manufacturing flow leverages fab processes that can be controlled to very high precision levels, compared to VMOS that requires less well-controlled processes such as silicon epitaxy to form certain critical active regions of the structure, increasing variability and performance spread. Although VMOS and LDMOS are mature device technologies, the 50 V LDMOS variant is a relative newcomer to the RF Power market. Finally, LDMOS technology has a demonstrated track record of providing outstanding reliability with nearly 20 years of widespread deployment in the demanding cellular infrastructure market.

C. Technology Development Trends

Freescale has a unique advantage in having robust development programs for both 28 V and 50 V LDMOS, and in being a leading supplier to both the RF Power and cellular infrastructure markets. This cross-fertilization of development programs accelerates development in both markets, and extends the impact of R&D investments across a broader product space.

Several trends have emerged over the past few years. Figure 3 highlights four that are applicable to both the cellular infrastructure and RF Power markets. The first is increased frequency of operation, with products already qualified for operation up to 3.8 GHz for 28 V. Freescale's next 50 V platform will support products with frequencies exceeding 3 GHz. The second trend is the release of high power multi-stage ICs, or discrete devices with integrated input and output matching networks. These high power RF devices are common in the

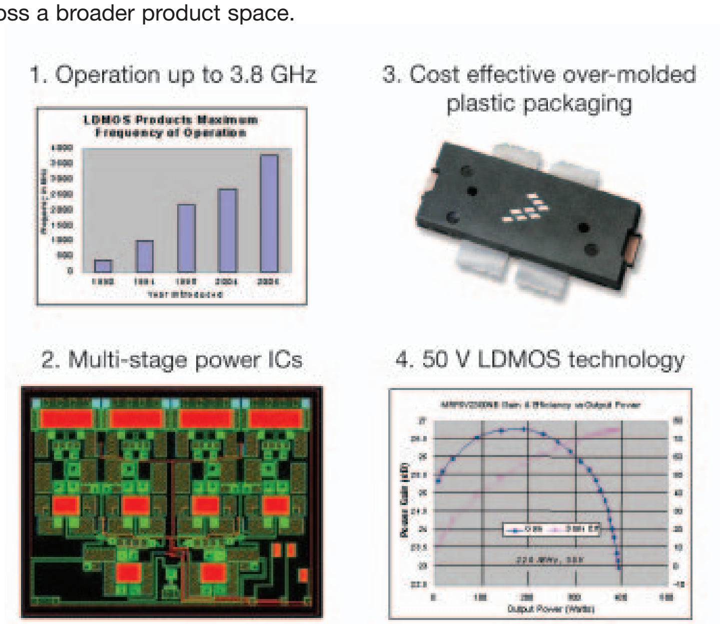

Figure 3: LDMOS development trends

cellular infrastructure market. Products are in development for the RF Power market that include integrated matching networks to simplify ease of use while maintaining broadband performance.

The third major trend is the adoption of over-molded plastic (OMP) for high power RF applications. OMP is the lowest cost packaging technology available; Freescale has a strong leadership position after pioneering OMP for cellular infrastructure applications, and has leveraged this experience into the RF Power product portfolio. Package development within Freescale continues, with the primary emphasis on increasing the power level that can be accommodated. The final trend is to continue to invest heavily in 50 V LDMOS development for the RF Power market. And, in somewhat of a turn of events, to leverage development originally targeted for the 50 V RF Power market back into products for the cellular infrastructure market.

III. RUGGEDNESS ENHANCEMENT

A. Ruggedness in MOSFETs

Ruggedness failure in MOSFETs is catastrophic thermal failure of the device due to internal power dissipation. They do not occur as a result of normal operation of the device within a power amplifier designed according to established RF design and mechanical engineering principles. The ruggedness failure of the MOSFET is the result of a drain breakdown (impact ionization) event. The ionization event occurs due to the distribution of charges internally within the MOSFET which are driven by the intrinsic gate and drain terminal waveforms. Figures 4a and 4b show a generic common source PA circuit using a MOSFET and a more detailed schematic diagram of a MOSFET.

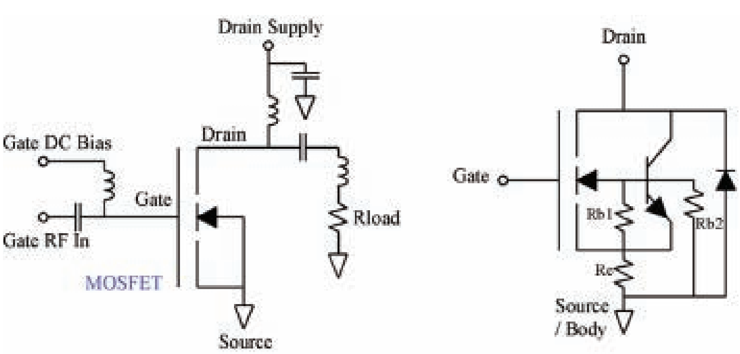

Figure 4a and 4b: Common source PA and MOSFET schematic

There are three basic ruggedness failure mechanisms that occur as a result of a drain impact ionization event which can result in extremely high power dissipation within the MOSFET and the associated thermal damage – and all of these mechanisms are illustrated by the schematic in Figure 4b. The first two mechanisms involve the basic breakdown of the MOSFET drain junction – either laterally across the channel or vertically across the drain to source junction isolation. The third mechanism is triggered by an impact ionization event and is the self biasing and 'snapback' of the parasitic bipolar device - a drain ionization event being a necessary pre-condition to this behavior. If sufficient internal MOSFET power dissipation occurs from one of these ionization events which exceeds the normal thermal design of the device, catastrophic device failure can be the result. The bipolar snapback behavior is particularly problematic as there is a positive feedback mechanism with temperature which can result in the well- documented thermal runaway phenomena for bipolar junction transistors (BJTs).

B. LDMOS Ruggedness Improvement

The ruggedness behavior of a MOSFET cannot be separated from the matching networks of the PA or the source and loads provided to the PA. Fundamental device improvements can, however, be incorporated into the MOSFET which improve the ability of the device to withstand the stresses applied by the PA. Internal device structure changes can be made which address the three impact ionization mechanisms to alter the conditions under which the ionization events occur and to change the parasitic bipolar device characteristics. Figure 5 illustrates a cross section of a VHV6 LDMOS device from source to drain and shows impact ionization rates and locations for three different designs.

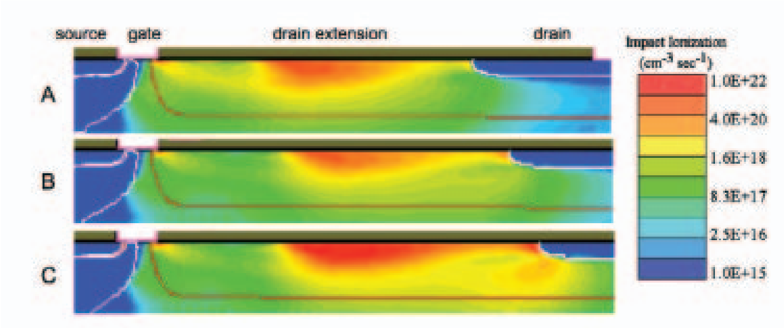

Figure 5: Impact ionization for VHV6 LDMOS device designs

Practical ruggedness characterization for RF PAs like LDMOS generally involve altering the operating characteristics of the PA (load mismatch, larger drain supply voltage, shorter signal rise time) to increase the stress on the MOSFET to determine the point of failure. Figure 6 shows a ruggedness objective function (a composite measure of these practical ruggedness stress factors) vs. three different device designs for the VHV6 LDMOS MRF6V10250HS pulsed device for applications at 1030 to 1090 MHz.

As these charts show, very significant improvements in VHV6 LDMOS ruggedness performance can be achieved for the same PA circuit and stresses by careful design of the MOSFET. As a point of reference, Figure 6 Style A meets a 5:1 VSWR condition at P3dB (well above rated power output). The LDMOS VHV6 platform was developed based upon the High Voltage 6th generation (HV6) 32 V platform and previous experience on internally developed 50 V LDMOS designs. Significant internal device modifications were required to achieve a reliable 50 V platform and this opportunity was also used to incorporate some of these internal device design modifications to achieve significant improvements in ruggedness performance.

Figure 6: Ruggedness failure of MRF6V10250HS vs. device design

IV. DESIGN FEATURES

This section will discuss the design features for the 50 V RF power devices. RF performance, thermal characteristics, device impedances, and device models will be discussed focusing on two categories. The first is the industrial, scientific and medical (ISM) frequency bands for VHF and UHF. Examples of ISM applications include MRI, CO_2 lasers and plasma generators. The second category is L-band (20cm) for pulsed radar applications such as air traffic management systems.

A. 50 V ISM Power Devices

Freescale offers eight different 50 V power devices targeting the ISM band. These 50 V devices are available at different power levels and package styles. Table 2 shows the 50 V LDMOS product offerings currently available from Freescale. Power levels range from a 10 W driver to a 1000 W final stage device. Frequency ranges cover 10 MHz to 600 MHz.

Product Name	Power Level	Frequency	Package Style	Package Type
MRF6V2010N	10 W	10-450 MHz	TO-270-2	Over-Molded Plastic
MRF6V2150N	150 W	10-450 MHz	TO-270 WB-4	Over-Molded Plastic
MRF6V2300N	300 W	10-600 MHz	TO-270 WB-4	Over-Molded Plastic
MRF6V4300N	300 W	10-600 MHz	TO-270 WB-4	Over-Molded Plastic
MRF6VP2600H	600 W	10-250 MHz	NI-1230	Air-Cavity Ceramic
MRF6VP11KH	1000 W	10-150 MHz	NI-1230	Air-Cavity Ceramic
MRF6VP21KH	1000 W	10-235 MHz	NI-1230	Air-Cavity Ceramic
MRF6VP41KH	1000 W	10-450 MHz	NI-1230	Air-Cavity Ceramic

Table 2: Freescale 50 V ISM product offering

For this discussion the 50 V MRF6V2300N device will be described. This device has been shown to be a very versatile device. It is designed in an over-molded plastic package, capable of 300 W CW or may be used for pulsed applications. Because this is an unmatched device, excellent RF performance can be achieved across the VHF and UHF frequency bands. Table 3 shows a summary of application circuits that have been built and tested by Freescale. These circuits are available for our customers to demonstrate Freescale's device performance.

Frequency	Power	Power Gain	Drain Efficiency
27 MHz	300 W	31 dB	61%
64 MHz	300 W	28 dB	68%
88 -108 MHz	300 W	25 dB	68%
130 MHz	300 W	25 dB	70%
175 - 225 MHz	300 W	25 dB	68%
220 MHz	300 W	26 dB	68%
425 MHz	300 W	23 dB	62%
450 MHz	300 W	22 dB	60%

Table 3: MRF6V2300N RF performance at various frequencies

B. 50 V Radar Power Devices

Freescale currently has three 50 V product offerings for the radar frequency bands. These include the MRF6V10010N, MRF6V10250HS, and the MRF6V14300H. The MRF6V10010N is in a low cost over-molded plastic package and is intended as a 10 W pulsed driver device. The MRF6V10250HS is in an air-cavity ceramic package and is capable of 250 W pulsed for final stage applications. Both the MRF6V10010N and the MRF6V10250HS are radar devices for the 960 to1215 MHz band. The MRF6V14300H is designed for the 1.2 to 1.4 GHz band and is designed as a P3dB 330 W pulsed final stage device. A performance summary of these 50 V LDMOS power devices is shown below in Table 4.

Product Name	Frequency	Power Level	Power Gain	Drain Efficiency	Package Style	Package Type
MRF6V14300H	1.2-1.4 GHz	330 W	18 dB	61%	NI-780	Air-Cavity Ceramic
MRF6V10250HS	1090 MHz	250 W	21 dB	60%	NI-780S	Air-Cavity Ceramic
MRF6V10010N	1090 MHz	10 W	25 dB	69%	PLD 1.5	Over-Molded Plastic

Table 4: Freescale 50 V LDMOS Radar devices

C. Examples of 50 V Power Devices

As mentioned previously, the MRF6V2300N is a versatile device and can be used in many applications. An excellent example of this device can be seen in an available customer circuit for the VHF TV band (175 to 225 MHz). This device under two-tone operation shows a gain greater than 23 dB and a drain efficiency greater than 43% with the third order products at -30 dBc for a power level of 300 W peak This application fixture has been successfully demonstrated and provided to multiple customers. Performance was achieved by using the simple circuit board match shown in Figure 7.

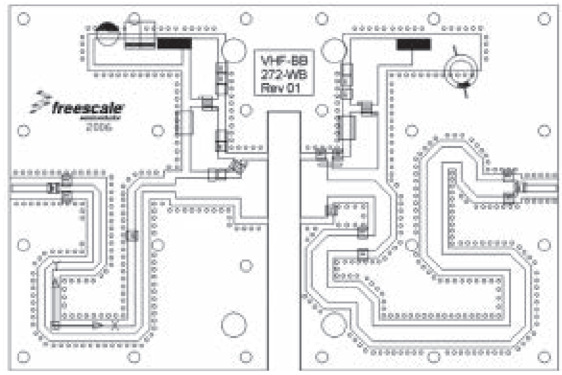

Figure 7: MRF6V2300N VHF TV application circuit

Figure 8 shows the broadband performance for the 175 to 225 MHz application test fixture.

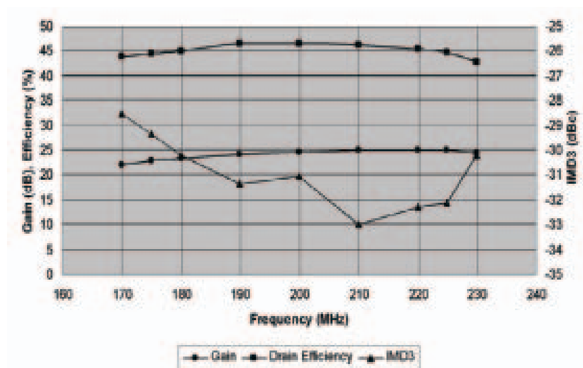

Figure 8: MRF6V2300N VHF TV circuit performance

As another example, the MRF6V14300H has been designed for the 1.2 to 1.4 GHz L-band radar application. This device has been internally matched for optimal performance and impedance matching. This device provides a high gain, greater than 17 dB at P3dB, and excellent drain efficiency of greater than 58% at P3dB. A typical application circuit is provided below in Figure 9. The typical broadband performance is shown in Figure 10. In this test circuit the gain flatness, at a constant 330 W, is seen to be better than 0.7 dB and a drain efficiency flatness of 2%. The excellent thermal performance of this device is seen by the less than 0.4 dB of pulse droop for a 300µsec pulse width.

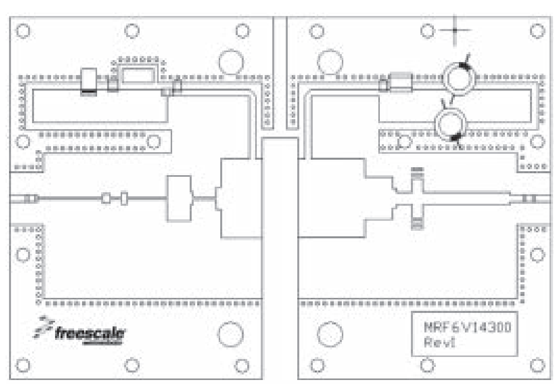

Figure 9: MRF6V14300H Radar application circuit

D. 50 V LDMOS Thermal Performance

The 50 V LDMOS devices have been designed for excellent RF performance and for excellent thermal performance for the intended applications. The ISM products have been optimized thermally for pulse applications and CW applications.

Figure 11 shows a plot of the maximum transient thermal impedance (MTTF) for the MRF6VP11KH device for a given pulse width and duty cycle. The bottom axis shows pulse width in seconds and a family of curves is shown for three different duty cycles. As an example, a pulse width of 100µsec and a duty cycle of 20% show a θ_{jc} of 0.03°C/W. From this graph the CW θ_{jc} can also be inferred to be 0.18°C/W.

Figure 12 shows the MTTF versus junction temperature for CW conditions. This graph assumes a power output of 1000 Watts CW, a drain voltage of 50 Vdc and a drain efficiency of 70%. As an example, the graph shows, for the stated RF performance, that at 150ºC, the MTTF is approximately 5,000,000 hours. This would require sufficient cooling for a flange temperature of about 70ºC.

For the MRF6V14300H, the thermal performance was optimized for best pulse droop and RF performance. The typical pulse droop for this device is less than 0.4 dB for a pulse width of 300µsec and a duty cycle of 12%. At a pulse width of 200µsec and a duty cycle of 10%, the pulse droop is less than 0.3 dB. The thermal resistance of this device is 0.13°C/W at 330 W, 300µsec pulse width, and 12% duty cycle.

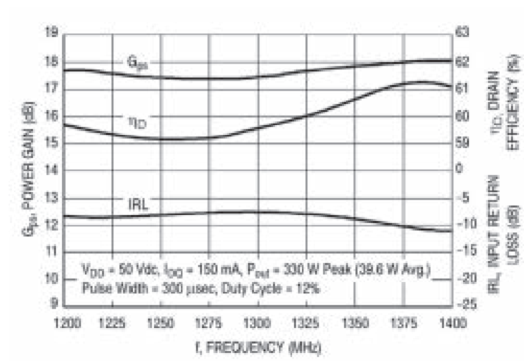

Figure 10: MRF6V14300H Radar circuit performance

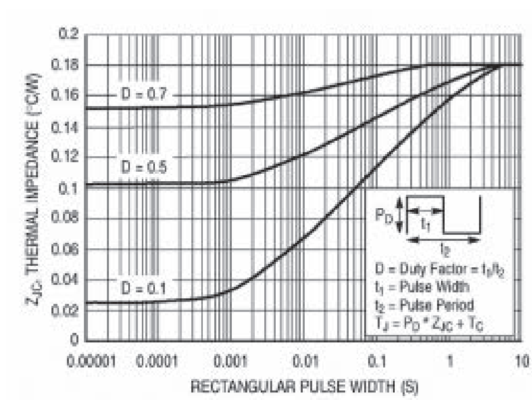

Figure 11: Maximum transient thermal impedance (MTTF)

E. 50 V LDMOS Device Impedances

Impedance measurements of various frequencies are shown in Table 5 for the MRF6V2300N. This table shows that the unmatched 50 V LDMOS device is capable of supporting various frequency bands in ISM VHF and UHF. This table is actual impedance measurements of constructed PCBs that were tuned for the specific frequency. Table 6 shows a similar set of impedances for the pulsed transistors.

Frequency	Zsource (Ω)	Zload (Ω)
27 MHz	10.5 + j 19	3.5 + j 0.190
98 MHz	5.48 + j 2.24	3.01 + j 1.05
130 MHz	1.75 + j 3.59	3.07 + j 2.09
220 MHz	1.23 + j 3.69	2.43 + j 2.04
450 MHz	0.5 + j 1.37	1.25 + j 0.990
All impedance measurements are of the PCB		

Table 5: MRF6V2300N impedances versus frequency

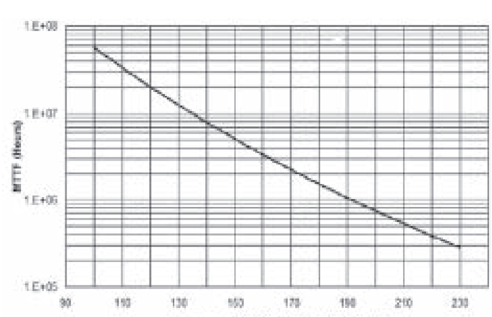

Figure 12: MTTF versus junction temperature

Product Name	Frequency	Zsource (Ω)	Zload (Ω)
MRF6V14300H	1400 MHz	7.01 - j 2.87	3.17 - j 1.78
MRF6V10250H	978 MHz	1.67 - j 2.04	4.30 - j 2.72
MRF6V10250H	1030 MHz	2.39 - j 2.23	5.66 - j 2.42
MRF6V10250H	1090 MHz	3.26 - j 3.72	5.85 - j 2.39
MRF6V10010N	1090 MHz	2.57 - j 7.33	14.1 - j 34.77
All impedance measurements are of the PCB			

Table 6: Radar power devices impedances

F. 50 V LDMOS ISM Device Models

Models for the various ISM devices are now available for customers to use with there amplifier design. Table 7 shows a list of the models currently available.

As an example of the benefits of using Freescale 50 V LDMOS product models, Figure 13 shows the measured versus simulated for the MRF6VP2600H at 98 MHz. This example is for a broadband test circuit for the 88 to 108 MHz VHF FM band. This application circuit is available to Freescale customers. Table 8 shows a comparison of measured versus modeled.

Product Name	Availability
MRF6V2010N	Yes
MRF6V2150N	Yes
MRF6V2300N	Yes
MRF6V4300N	Coming soon
MRF6VP21KH	Yes
MRF6VP41KH	Yes
MRF6V14300H	Coming soon
MRF6V10010N	Coming soon

Table 7: Freescale product models for ISM and Radar

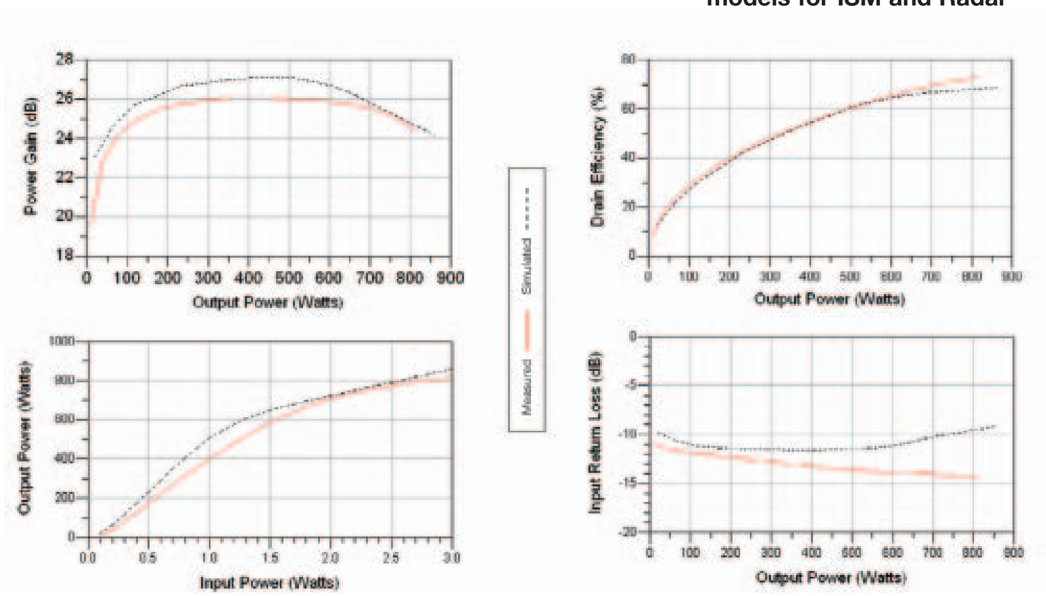

Figure 13: MRF6VP2600H RF Performance Curves, simulated versus measured

		Simulated		Measured	
Frequency	Power (W)	Gain (dB)	Drain Efficiency (%)	Gain (dB)	Drain Efficiency (%)
88 MHz	600	25.8	66.8	26.3	63.9
98 MHz	600	25.7	66.0	26.7	64.8
108 MHz	600	25	65.3	27.3	68.5

Table 8: MRF6VP2600H RF Performance, simulated versus measured

V. SUMMARY

Freescale has successfully leveraged its position as the world's leading supplier of high power RF LDMOS transistors to develop, qualify, and release to manufacturing a portfolio of 50 V LDMOS products specifically designed for the unique requirements of the ISM, Broadcast, and Radar markets. Compared to the existing technologies in these markets, Freescale's 50 V LDMOS provides superior power, gain, linearity, and efficiency, while leveraging cost effective over-molded plastic packaging to introduce products at breakthrough price points. This paper has described the device technology along with key features, presented details on how extreme ruggedness is designed into the devices and outlined design features of the portfolio. Freescale is committed to delivering compelling solutions to the RF Power market, including an aggressive development program made possible by Freescale's innovative leadership.

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Advanced Antenna
Engineering and Product Guidebook

The most important thing we build is trust.

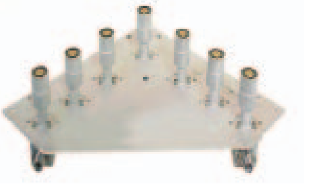
COBHAM
Defense Electronic Systems

Sensor and Antenna Systems, Lansdale, Inc.

Advanced Antenna Engineering and Products

Designed to meet the user's need for high performance from 1 MHz to 100 GHz.

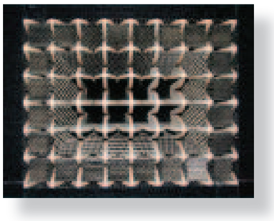
- Family of Antennas Cover 250 MHz to 100 GHz
- Phase and Amplitude Matching Available
- Bandwidths Exceeding 40:1
- Wide Variety of Standard and Custom Designs Available
- Airborne, Shipboard and Ground-based Deployment
- Integral Radomes



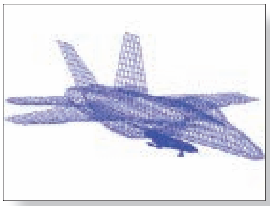
- 250 MHz to 40 GHz
- Available in Dual Linear and Circular Polarizations
- Bandwidths up to 20:1
- Standard Gain Horns for Testing and Calibration
- Broadband Horns for EW Transmit and Receive Applications
- High Power Horns for Transmit Applications

- Family of Antennas Covering 10 MHz to 18 GHz
- Bandwidths Exceeding 9:1
- Single or Dual Linear Polarization
- Available in Fixed or Folding Configurations for Rapid Deployment
- Masts and Mounts for Most Models

- Broadband Multifunction Arrays
- Conformal Embedded Antennas
- Structurally Embedded Antennas
- Low RCS Apertures
- Systems Ranging from Fighter Aircraft to Attack Submarines



Designed to meet the user's need for high performance.



MODELING TECHNIQUES ASSURE INSTALLED PERFORMANCE

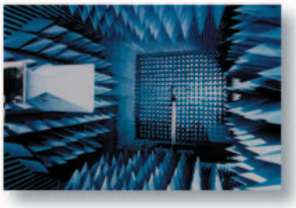
- Numerical Electromagnetic Code (NEC) Design and Analysis
- Finite Difference Time Domain (FDTD) Modeling
- X-Patch for Radar Cross Section Design and Development
- Geometric Theory of Diffraction Design and Analysis
- 3D Modeling and Simulation (HFSS)

DESIGN OPTIMIZATION TO MAXIMIZE SYSTEM PERFORMANCE

- Precision Direction Finding (DF) Arrays
- Multi-Element Interferometers
- Multi-Octave, Multi-Aperture Arrays, Polarization Diverse Antennas

MANUFACTURING FACILITY

- Single Radiating Elements to Highly Complex Antenna Arrays
- 145,000 Square Feet of Facilities
- Vertically Integrated Throughout
- Capable of High Rates: >10,000 Antennas Per Year



TEST AND MEASUREMENT

- Fully Automated Testing From 50 KHz to 110 GHz
- Ten (10) Indoor Anechoic Chambers
- Two (2) Outdoor Ranges
- Indoor Radar Cross Section (RCS) Testing and Compact Range

Spiral Antennas

Spiral antennas are designed to radiate or receive RF energy over very broad frequency ranges while maintaining constant beamwidth. Additional design considerations we evaluate to maximize your system performance are low axial ratio, minimal squint and very small size relative to the wavelength of the lowest operating frequency. Sensor and Antenna Systems, Lansdale, Inc. spiral antennas are designed to operate in severe airborne and ground-based environments. The antennas can also be amplitude and/or phase matched for precision DF systems.

Performance Parameters

MODEL NO. (See note 1)		FREQUENCY (GHz)	GAIN NOMINAL (dBiL)	VSWR (MAX.)	BEAMWIDTH NOMINAL (DEGREES)	AXIAL RATIO NOMINAL (dB)	POWER CW (WATTS)	ENVIRONMENT (See note 2)	CONN. TYPE	FIG. NO.
ASN-1232A,AA		0.2-4.0	2.0	3.0:1	75	3.0	2	A	N	S2
ASN-117A,AA		0.4-4.0	2.0	3.0:1	80	2.5	10	A	N	S2
ASN-115A,AA		0.5-2.0	2.0	2.0:1	80	2.0	10	A, P	N	S1
ASO-1950A,AA		0.5-2.0	1.0	2.5:1	80	1.5	5	A, P	SMA	S4
AST-1507A,AA, B, BB		0.5-4.0	2.0	2.0:1	80	1.0	10	A, E, P	TNC	S4
ASN-113A,AA		0.7-2.8	2.0	3.0:1	85	2.5	10	A, P	N	S1
ASO-1658A,AA		0.7-18.0	2.0	3.0:1	75	1.5	2	A	SMA	S4
ASN-112A,AA		1.0-4.0	2.0	3.0:1	75	2.0	10	A, P	N	S1
ASN-116A,AA		1.0-12.4	2.0	3.0:1	75	1.0	2	A, P	N	S2
ASN-114A,AA		2.0-8.0	2.0	2.5:1	75	1.0	5	A, P	N OR SMA	S1
ASO-1500A,AA		0.5-22.0	-30 to 0	2.5:1	80	2.0	1	A,E,P	SMA OR TNC	S4
AST-1547A,AA		2.0-18.0	1.0	2.5:1	80	1.5	1	A, P	TNC OR SMA	S4
ASO-1563AR,AAR		2.0-18.0	1.0	3.0:1	75	2.0	1	A, E	SMA	S4
ASO-1600A	Linear 45°	0.5-2.0	-27 to -15	6.5:1	80	>16 dB	1	A, P	SMA (2)	NA
	Circular	2.0-18.0	1.1	2.5:1	75	1 dB	1			
AST-1619A		2.0-18.0	1.0	2.0:1	75	1.0	1	A, E	TNC	S4
ASO-1639A		2.0-18.0	2.0	2.5:1	80	1.0	1	A, E	SMA	S4
ASO-1905A		2.0-18.0	1.0	2.0:1	75	1.0	1	A, P	SMA	S4
ASO-2072A		2.0-18.0	2.0	2.5:1	75	2.0	2	A, P	SMA	S4
AST-1960B,BB		2.0-18.0	1	2.5:1	80	1.5	1	A	TNC	S4
ASO-1995 (AMBIDEXTROUS ®)		2.0-18.0	1.0	3.0:1	75	2.0	1	A, P	SMA (2)	S6
ASO-2007A		2.0-18.0	1.0	2.5:1	75	1.0	1	A, P	SMA	S5
ASO-2009A		2.0-18.0	1.0	2.5:1	75	1.0	1	A, P	SMA	S4
AST-1462A		2.0-18.0	1.0	2.5:1	75	1.0	1	A, E	TNC	S5
AST-1492A,AA, B, BB		2.0-18.0	1.0	4.5:1	80	2.0	1	A, E	TNC	S4
ASO-1492A,AA		2.0-18.0	1.0	4.5:1	80	2.0	1	A, E	SMA	S4
AST-1492AR,AAR		2.0-18.0	1.0	4.5:1	75	2.0	1	A, E, S, C	TNC	S4
ASO-1492AR,AAR		2.0-18.0	1.0	4.5:1	75	2.0	1	A, E, S, C	SMA	S4
AST-1503A,AA		2.0-18.0	1.0	4.5:1	80	2.0	1	A, E	TNC	S4
ASO-1503A,AA		2.0-18.0	1.0	4.5:1	80	2.0	1	A, E	SMA	S4
AST-1591B,BB		2.0-18.0	1.0	3.0:1	80	1.0	1	A, E	T	S4
ASO-1591B,BB		2.0-18.0	1.0	3.0:1	80	1.0	1	A, E	SMA	S4
ASM-1874A		2.0-40.0	0.0	3.5:1	80	1.5	1	A, P	SSMA	S5
ASN-111A,AA		3.0-12.0	2.0	3.0:1	75	2.0	2	A, P	N	S1
ASO-111A,AA		3.0-12.0	2.0	3.0:1	75	2.0	2	A, P	SMA	S1
ASO-1571A,AA		4.0-18.0	1.0	3.0:1	70	1.5	1	A, E	SMA	S4
ASO-2031D, DD		6.0-18.0	1	2.5:1	80	1.5	2	A, E	SMA	S4
ASO-1665A,AA		8.0-18.0	1.0	2.0:1	80	1.0	1	A	SMA	S4
ASM-2010A		18.0-34.0	-2.0	3.0:1	80	3.0	1	A,P	SSMA	S4
ASO-2154A,AA		2.0-18.0	1.0	2.5:1	80	1.5	1	A	SMA	S5

FOOTNOTES

1. Suffix Codes: A, B, D = LHCP; AA, BB, DD = RHCP; R = Radome Available.

2. Environmental Codes: A: Airborne; E: MIL-E-5400; P: Requires Radome; C: Has Rain Erosion Coating; S: Supersonic

Figures

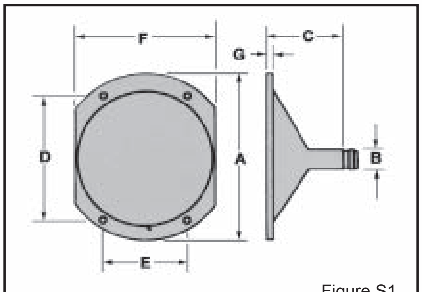


Figure S1

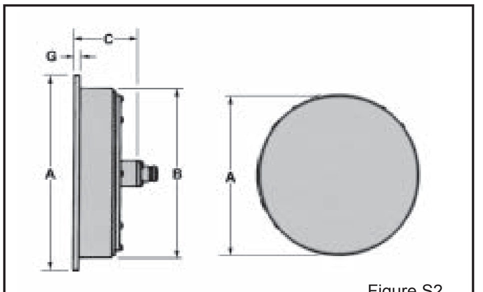


Figure S2

MODEL NO.	A	B	C	D	E	F	G
ASN-1232A,AA	19.00	18.16	10.65				0.27
ASN-117A,AA	13.25	11.91	5.21				.30
ASN-115A,AA	11.25	2.19	4.07	8.19	8.19	11.25	.31
ASO-1950A,AA	6.56	6.31	3.11				1.62
AST-1507A,AA, B, BB	9.00		4.00				2.75
ASN-113A,AA	8.88	2.00	3.40	6.56	6.56	8.88	0.32
ASO-1658A,AA	7.00		3.09				3.04
ASN-112A,AA	5.75	0.68	2.66	4.38	3.00	5.00	0.19
ASN-116A,AA	7.50	6.60	2.69				0.16
ASN-114A,AA	3.00	0.68	1.60	2.00	1.75	2.50	0.22
ASO-1500A,AA	2.43	2.38	1.85				1.58
AST-1547A,AA	2.43	2.38	1.76				1.53
ASO-1563AR,AAR	3.03	2.37	1.70	2.25	1.50		0.29
ASO-1600A	3.25	2.42	1.75				
AST-1619A	2.43	2.38	1.80				1.53
ASO-1639A	2.43	2.38	2.08				1.53
ASO-1905A	2.00	2.00	1.98				1.50
ASO-2072A	2.50	2.37	1.96				1.13
AST-1960B,BB	2.00	2.00	1.67				1.41
ASO-1995 (AMBIDEXTROUS ®)	2.43		0.513	0.325	0.539	0.219	1.55
ASO-2007A	2.50	2.37	1.84				1.00
ASO-2009A	2.43	2.38	1.76				1.53
AST-1462A	2.50	2.37	1.61				1.00
AST-1492A,AA, B, BB	2.43	2.38	1.85				1.58
ASO-1492A,AA	2.43	2.38	1.85				1.58
AST-1492AR,AAR	2.64		3.05				2.78
ASO-1492AR,AAR	2.64		3.05				2.78
AST-1503A,AA	2.43	2.38	1.80				1.53
ASO-1503A,AA	2.43	2.38	1.80				1.53
AST-1591B,BB	2.43	2.38	1.80				1.53
ASO-1591B,BB	2.43	2.38	1.80				1.53
ASM-1874A	3.00	3.00	1.44				1.44
ASN-111A,AA	2.50	0.68	1.32	1.90	1.10	2.00	0.19
ASO-111A,AA	2.50	0.68	1.32	1.90	1.10	2.00	0.19
ASO-1571A,AA	1.42		1.31				0.84
ASO-2031D, DD	1.05	0.925	1.48				0.92
ASO-1665A,AA	0.75		31.17				1.25
ASM-2010A	0.69	0.53	1.61				1.05
ASO-2154A,AA	2.00	1.75	1.5				

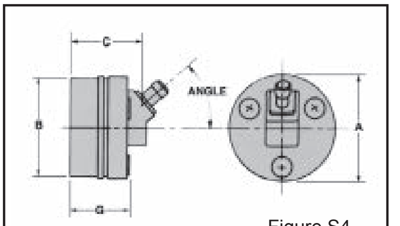


Figure S4

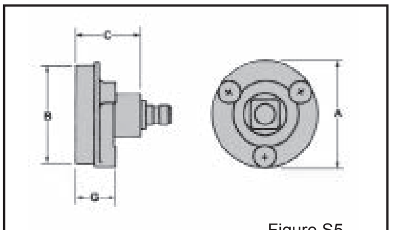


Figure S5

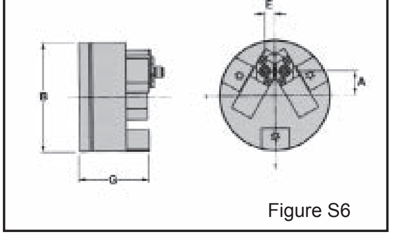


Figure S6

Horn Antennas

Sensor and Antenna Systems, Lansdale, Inc. builds two distinct types of horn antennas: Standard Gain or Calibration Horns, and Broadband Horns.

Standard Gain Horns are optimized for low VSWR and provide equal E- and H- plane 3dB beamwidths. These horns are most often used as gain standards for antenna testing. VSWR data are typically supplied with each horn. Calibration data is also available upon request.

Broadband Horns are optimized for high efficiency, constant gain and constant impedance versus frequency over multi-octave bandwidths. These horns are used for EMI/RFI measurement and radiation, antenna gain and pattern measurement, reconnaissance/surveillance and other applications.

Physical Dimensions

MODEL NO.	FREQ. (GHz)	GAIN (dB MIN.)	GAIN NOMINAL (dBiL)	VSWR (MAX)	VSWR (TYP.)	3dB BEAMWIDTH NOMINAL (DEG.) E	H	POL. SENSE	F-to-B RATIO (dB)	AXIAL RATIO (dB)	POWER CW (WATTS)	WAVE-GUIDE TYPE	CONN. TYPE	FIG. NO.
H-4801	0.25-0.5		11.5 to 17.0	3.0:1	1.4	30	35	L	25		500		N	H3
H-4901	0.5-1.0		11.5 to 17.0	3.0:1	1.4	30	35	L	25		400		N	H3
H-1734	0.5-6.0		6.0 to 12.0	2.5:1	2.0:1	50	45	L			250		N	H1
H-5001	1.0-2.5		11.5 to 17.0	3.0:1	1.4	30	35	L	25		400		N	H2
H-5000R	1.0-2.5		11.5 to 17.0	3.0:1	1.4	30	35	L	25		400		N	H2
H-1479	1.0-12.4		6.0 to 12.0	3.0:1	2.0:1	50	45	L			250		N	H1
H-1402R	1.25-3.1		11.5 to 17.0	3.0:1	1.4	30	30	L	25		200		N	H2
H-5100R	2.0-5.0		12.0 to 17.0	3.0:1	1.4	30	30	L	25		200		N	H2
H-5101	2.0-5.0		12.5 to 17.0	3.0:1	1.4	30	30	L	25		200		N	H2
H-1498	2.0-18.0		6.0 to 12.0	3.0:1	2.0:1	50	45	L			50		SMA	H1
H-1498T	2.0-18.0		6.0 to 12.0	3.0:1	2.0:1	50	45	L			100		TNC	H1
H-1498R	2.0-18.0		6.0 to 12.0	3.0:1	2.0:1	50	45	L			50		SMA	H1
H-5200R	4.0-10.0		11.5 to 16.0	3.0:1	1.4	30	30	L	25		150		N	H2
H-5201	4.0-10.0		11.5 to 17.0	3.0:1	1.4	30	30	L	25		150		N	H2
H-1675	8.0-18.0		15.5 to 17.5	2.0:1	2.0:1	25	25	L			34kW	WRD750	WRD750D24	H7
AHW-1810	8.0-18.0		7.0 to 9.0	3.0:1	1.5:1	65	65	L			200	WRD750	WRD750D24	H7
H-5300R	8.2-12.4		14.5 to 18.0	2.0:1	1.2	30	30	L	25		400		N	H2
H-5301	8.2-12.4		14.5 to 18.0	2.0:1	1.2	30	30	L	25		100		N	H4
H-5302	8.2-12.4		14.5 to 18.0	2.0:1	1.2	30	30	L	25		200	WR-90	UG40B/U	H5
H-6000	8.2-12.4	10.0		3.0:1	1.5:1	40	55	LH	25	3	150	WR-90	UG135/U	H6
H-1458	12.0-18.0		14.5 to 18.0	1.8:1	1.2	27	27	L	25		100kW	WR-62	UG419/U	H5
AHT-1857	Ku-Band	7.5			1.5:1	90	20	RH	25	3	100	WR-62	TNC	H6
H-6100	12.4-18.0	10.0		2.0:1	1.3:1	50	50	LH	25	3	150	WR-62	UG419/U	H5
H-1459	18.0-26.0		14.5 to 18.0	2.0:1	1.5	27	27	L	25		40kW	WR-42	UG595/U	H5
H-1629	18.0-26.5	15.0		1.5:1	1.5:1	18	26	RH	25	2	100	WR-42	UG595/U	H6
H-6200	18.0-26.5	10.0		3.0:1	1.3:1	50	50	LH	25	3	100	WR-42	UG597/U	H6
H-1798	18.0-40.0		5.0 to 7.0	2.0:1	1.5:1	60	70	L			200	WRD180	WRD180C24	H7
H-1630	26.5-40.0	15.0		1.5:1	1.5:1	18	26	RH	25	2	100	WR-28	UG599/U	H6
H-6300	26.5-40.0	10.0		3.0:1	1.3:1	50	50	LH	25	3	50	WR-28	UG599/U	H6
AHO-2036 DUAL	1.5-23.0		4.0 to 15.0	3.0:1	1.5:1	80/12	90/12	L	25		10		SMA	H7
AHO-2049 DUAL	6.0-18.0		12.0 to 25.0	3.0:1	2.0:1	15/8	15/8	L	25		5		SMA	H7

L=LINEAR **RH = RIGHT HAND** **LH = LEFT HAND** **R=Radome** **T=TNC Connector**

Figures

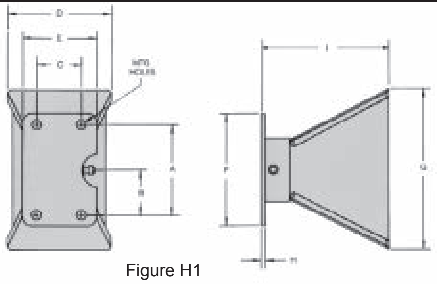
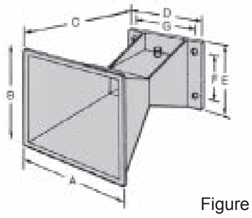


Figure H1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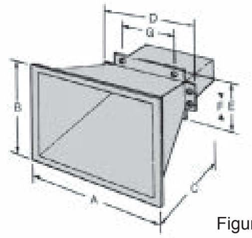
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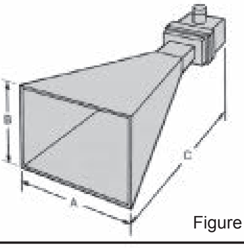
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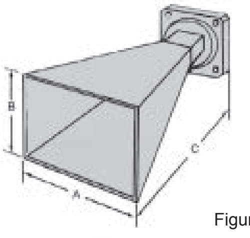


Figure H5

MODEL NO.	A	B	C	D	E	F	G	H	I
H-4801	67.00	51.00	69.00	33.063	15.125	6.00	16.00		
H-4901	35.500	27.500	34.500	19.250	10.250	3.00	8.00		
H-1734	8.12	4.06	6.06	12.13	7.00	9.06	19.13	0.38	15.44
H-5001	16.00	12.00	17.375	11.750	06.875	5.00	09.750		
H-5000R	16.688	12.688	17.780	11.750	06.875	5	09.750		
H-1479	4.56	2.28	3.00	6.40	3.94	5.25	9.75	0.25	7.93
H-1402R	13.563	10.375	14.00	10.00	5.875	4.000	8.000		
H-5100R	9.031	7.00	9.00	5.188	3.875	3	4.563		
H-5101	8.250	6.188	8.875	5.188	3.875	3	4.563		
H-1498	2.75	1.38	1.38	3.24	2.25	3.38	4.98	0.12	3.88
H-1498T	2.75	1.38	1.38	3.24	2.25	3.38	4.98	0.12	3.88
H-1498R	2.75	1.38	1.38	3.6	2.25	3.38	4.98	0.12	3.88
H-5200R	4.813	3.750	4.938	3.375	2.250	1.375	2.750		
H-5201	4.250	3.188	4.813	3.375	2.250	1.375	2.750		
H-1675	4.88	3.75	5.69						
AHW-1810	1.54	1.34	2.73						
H-5300R	3.688	2.938	6.438	3.250	2.250	1.375	2.500		
H-5301	3.063	2.250	6.250						
H-5302	3.063	2.250	4.875						
H-6000	2.250	4.060							
H-1458	2.125	1.625	3.188						
AHT-1857	3.700	4.500							
H-6100	1.680	2.880							
H-1459	1.500	1.125	2.250						
H-1629	2.00	3.49							
H-6200	1.25	1.94							
H-1798	0.96	0.75	1.36						
H-1630	1.60	2.44							
H-6300	1.00	1.41							
AHO-2036	4.5	4.5	5.29					0.12	3.88
AHO-2049	8.5	8.5	12.5						

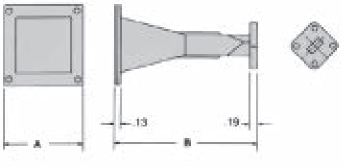


Figure H6

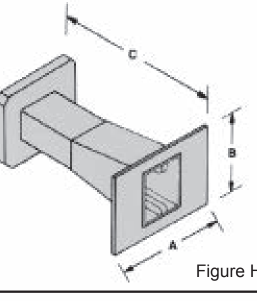


Figure H7

Log Periodic Antennas

Log periodic antennas are typically designed for broadband applications covering many octaves, and are designed to provide constant gain and constant beamwidth versus frequency. These antennas are linearly polarized, and planar versions are available that may be flush mounted for airborne and other low profile applications. Sensor and Antenna Systems, Lansdale, Inc. log periodic antennas feature wide bandwidth, single and dual-linear polarizations, integral radomes and custom designed masts and mounts.

Applications include broadband communications, telemetry, signal surveillance and feeds for parabolic and shaped reflectors.

Performance Parameters

MODEL NO.	STYLE (See note 1)	FREQUENCY (GHz)	GAIN NOMINAL (dBiL)	VSWR (TYP.)	3dB BEAMWIDTH NOMINAL (DEG.) E	H	F-to-B RATIO (dB)	TYPE of ELEMENT	POWER CW (WATTS)	CONN. TYPE	FIG. NO.
APN-1244	C+	0.02-0.1	5.0	3.0:1	70	130		Quick Connect	1000	N	LP2
APN-1244C	C+	0.02-0.1	5.0	3.0:1	70	130		Quick Connect	1000	N	LP2
APN-1509	C+	0.02-1.0	5.0	3.0:1	60	110		Quick Connect	1000	N	LP2
APN-1202A	C+	0.02-1.0	5.0	3.0:1	60	110		Bolt-on	1000	N	LP2
APN-1410	CF	0.03-0.076	5.0	3.0:1	60	130		Folding	1000	N	LP1
APN-1410A	C	0.03-0.076	5.0	3.0:1	60	130		Quick Connect	1000	N	LP1
APN-1596A	C+	0.03-0.09	6.0	3.0:1	70	130		Quick Connect	1000	N	LP1
APN-1696	C	0.03-1.0	6.0	3.0:1	55	110		Quick Connect	1000	N	LP1
APN-995B	CX	0.03-1.1	6.0	3.0:1	65	110		Quick Connect	1000	N	LP1
APN-113A	C	0.05-1.1	6.0	2.5:1	60	100		Bolt-on	1000	N	LP1
APN-107C	CF	0.05-1.1	6.0	2.5:1	70	120		Folding	1000	N	LP1
APN-109B	P	0.09-3.0	9.0	3.0:1	60	60	15	Fixed	250	N	LP6
APN-107BA	CF	0.1-1.0	6.0	2.5:1	70	120		Folding	1000	N	LP1
APN-107DA	C	0.1-1.0	6.0	2.5:1	70	120		Quick Connect	1000	N	LP1
APN-113B	C	0.1-1.0	6.0	3.0:1	60	100		Bolt-on	1000	N	LP1
APN-113E	C	0.2-1.1	6.0	3.0:1	60	125		Bolt-on	1000	N	LP1
APN-113C	C	0.25-1.1	6.0	2.5:1	60	125		Bolt-on	1000	N	LP1
APN-106A	P	0.3-3.0	9.0	3.0:1	45	50	15	Fixed	250	N	LP6
APN-106AA	P	0.4-3.0	9.0	3.0:1	50	45	15	Fixed	250	N	LP6
APX-254A	PDL	0.4-4.0	7.0	3.0:1	60	90		Fixed	50	TNC	LP5
APN-113D	C	0.5-1.1	6.0	2.5:1	60	110		Bolt-on	500	N	LP1
APO-1937B	R	0.7-12.0	2.0	3.1:1	70	70		Printed	2	SMA	
APN-101AB	P	0.9-11.0	7.0	3.5:1	60	60	15	Fixed	20	N	LP6
APN-101BR	P	1.0-11.0	7.0	4.0:1	60	60	15	Fixed	25	N	LP6
APN-101B	P	1.0-12.4	7.0	4.0:1	60	60	15	Fixed	25	N	LP6
APX-1293	PDL	1.0-12.4	7.0	3.0:1	50	80		Fixed	10	SMA	LP4
APO-1804	C	1.0-18.0	6.0	3.0:1	70	130		Printed	2	SMA	LP3
APO-1466	R	2.0-18.0	2.0	3.0:1	70	70		Printed	2	SMA	
APX-1348	PDL	0.1-1.0	7.0	3.0:1	55	85		Fixed	1000	N	LP5
APT-2139	R	0.5-2.0	6.0	4.0:1	70	80		Printed	2	TNC	

FOOTNOTES

1. Nomenclature: C = Coplanar; CX = Coplanar with Extendable Elements; C + = Additional Element Added to Eliminate Feed Line Resonance; CF = Coplanar Folding; P = Pyramidal, PDL = Pyramidal Dual Linear, R = Round.

Figures

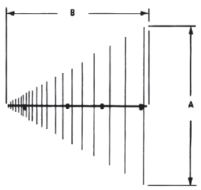


Figure LP1

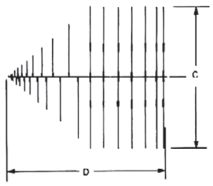
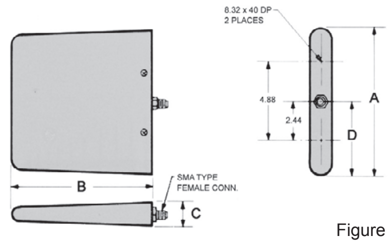


Figure LP2



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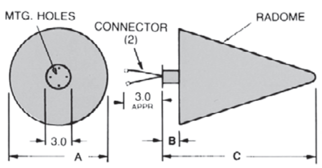


Figure LP4

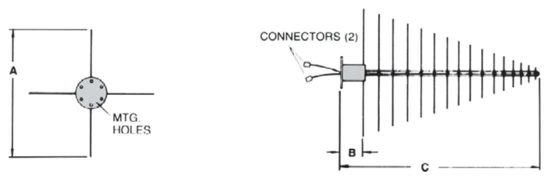


Figure LP5

MODEL NO.	A	B	C	D
APN-1244			156	164.50
APN-1244C			156	164.50
APN-1509			156	189.50
APN-1202A			156	189.50
APN-1410	198.50	57		
APN-1410A	198.25	57		
APN-1596A	204	128		
APN-1696	204.50	179		
APN-995B	158	104		
APN-113A	120	105		
APN-107C	122	105		
APN-109B	66	83	56	33.625
APN-107BA	60	52		
APN-107DA	59	52		
APN-113B	68	59.75		
APN-113E	44	40		
APN-113C	29	27		
APN-106A	30	25	24.625	
APN-106AA	25.50	21.125	20.875	
APX-254A	16.25	3.50	26.50	
APN-113D	16	13		
APO-1937B	7.5	DIAMETER x 2.9 DEEP		
APN-101AB	8.75	8	7.50	
APN-101BR	8.25	9	9	
APN-101B	7.25	6.50	6.125	
APX-1293	9.0	9.0	12.06	
APO-1804	8.98	8.08	1.38	4.88
APO-1466	2.38	DIAMETER x 1.97 DEEP		
APX-1348	67.62	20.12	97.00	
APT-2139	10	DIAMETER x 5.0 DEEP		

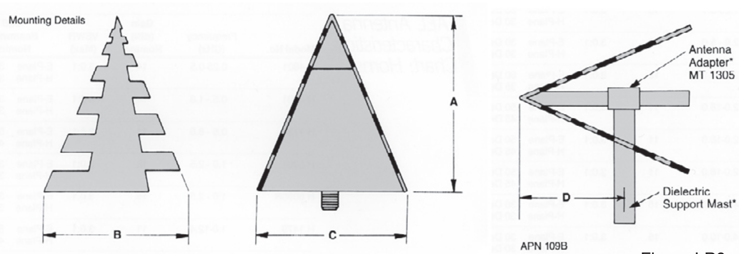
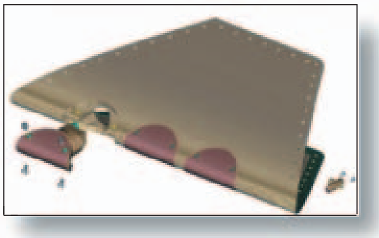


Figure LP6

Advanced Technology Apertures

CONFORMAL AND EMBEDDED ANTENNAS

- Low RCS Apertures
- Removable & Replaceable Elements
- Broadband Elements
  - Spiral
  - Horn
  - Tapered Notch
  - Log Periodic



BROADBAND MULTIFUNCTION ARRAYS

- Tilt-Face Quadrant DF
- Multi-Band Multi-Element Integration
- Conformal
- Structural Embedment
- Polarization Diversity

STRUCTURALLY EMBEDDED ANTENNAS AND ARRAYS

- Low Observable Installations
- Low RCS Installations
- Embedded in Advanced RCS Materials/Treatments
- Structural Aircraft Embedment
  - Leading /Trailing Edges
  - Fuselage Embedment

mmW Antennas

- Integrated Spiral Antenna with Schottky Diode Detector (Antector)
- Frequency Bandwidths of 5:1 up to 100 GHz
- High Efficiency Detection Through Millimeter Wave Frequencies

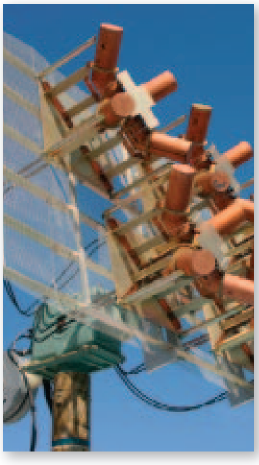
Custom Antennas and Accessories

MULTI-BAND INTERFEROMETERS

- Multi-Octave
- Planar Azimuth / Elevation
- Flush Mount
- DF Accuracy <1°

HELIX ANTENNAS

- Broadband
- Useful for Reflector Feeds
- Provide Unidirectional “Teardrop” Radiation Pattern

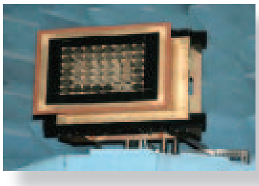


PARABOLIC REFLECTORS

- Linear Polarization, Adjustable Through 360°
- Available With Dual Linear Polarized Feeds

HIGH POWER ARRAYS

- Available in VHF, Microwave Frequencies
- Arrays Designed for Broad Azimuth Coverage
- Power Handling up to 10,000 Watts CW
- Polarization Diverse



MAST/MOUNTS AND ADAPTORS

- For Most Log Periodic Antennas
- Telescopic Versions Easily Transported and Erected
- Rugged Military Construction
- Allow Change of Antenna Polarization to Vertical, Horizontal, ±45° Orientations

RADOMES

- Custom Radomes Available for Most Antenna Products
- Available with Rain Erosion Coatings for Subsonic to Supersonic Applications
- Materials Include Quartz, Tefzel®, Noryl®, Duroid®
- Full Mil Qualification Available

Sensor and Antenna Systems, Lansdale, Inc.

Sensor and Antenna Systems, Lansdale, Inc. (SAS, Lansdale) is a leading supplier of Radar Warning Receiver/ESM, Electronic Attack, and CNI products. In Radar Warning and Electronic Support Measures, our systems seek, identify, and locate radar systems across the spectrum of frequency and application. These radar warning systems and subsystems are employed on the total range of aircraft, from the smallest observation helicopter to the most sophisticated tactical fighter aircraft.

SAS Lansdale's Electronic Attack technology covers a broad range of communication and radar threats. These systems are adaptable to ground-based, shipboard, and airborne platforms.

In the Antenna Product Area, SAS Lansdale offers a wide range of standard and custom products such as broadband spirals and horns, log periodics, parabolic reflectors, and high power dipole arrays to perform radar warning, electronic intelligence, and signal jamming functions for electronic warfare systems.

SAS Lansdale's facility is ISO 9001 registered and composed of highly skilled personnel utilizing state-of-the-art engineering and manufacturing facilities.

SAS Lansdale's antenna manufacturing and test capabilities include two outdoor test ranges and ten indoor anechoic chambers including radar cross section (RCS) testing, vertically integrated manufacturing and complete radome fabrication facilities, all geared to meeting your performance requirements.

SAS Lansdale is a division of Cobham Defense Electronic Systems and is located in Lansdale, Pennsylvania. Cobham Defense Electronic Systems, formerly Chelton Microwave, designs and manufactures all classes of antenna subsystems, positioners, active and passive microwave components and assemblies, composites and radomes, and rotating systems for the aerospace and defense industries. This division of Cobham is also the world leader in advanced digital military vehicle tactical communications systems, soldier situation awareness and integrated navigation management tools.

For more information, please contact
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Web www.cobhamdes.com

COBHAM Defense Electronic Systems

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FREQUENCY SOURCES

PRECISION / LOW NOISE

HIGH RESOLUTION

μs-SWITCHING

FREQUENCY SYNTHESIZERS

SYNTHESIZERS

FREQUENCY SYNTHESIZERS

PROGRAMMED TEST SOURCES, INC., 9 Beaver Brook Road, Littleton, MA 01460

FREQUENCY SYNTHESIZERS

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9 Beaver Brook Road, P.O. Box 517, Littleton, Massachusetts 01460 U.S.A. Tel. 978-486-3400 FAX: 978-486-4495
Email: sales@programmedtest.com Website: http://www.programmedtest.com

COMPANY PROFILE

Programmed Test Sources, Inc. is a major manufacturer of high performance frequency synthesizers which are designed for stand-alone and OEM uses.

In 1975 we announced our first product, which embodied the goals formulated at the company's inception: a high quality, fast-switching, low-noise synthesizer of modular construction. This approach would make it possible to adapt the instrument effectively to a broad spectrum of uses and do so at a price not available elsewhere.

Today, we offer one of the most complete lines of synthesizers available in the industry. Our models all use our own direct synthesis systems. Their advantages over competitive designs include excellent specifications for phase-noise, switching speed and spurious outputs along with low complexity.

The acceptance of our products has proven the value of our approach. Tens of thousands of PTS synthesizers have been shipped to an international roster of customers. We are proud to have served Analog Devices, Atmel, Boeing, Credence, G.E., Hughes, ITT, JEOL, LTX, Motorola, Philips, Raytheon, Siemens, Teradyne, Toshiba and others. The confidence we have in our products is reflected in our three-year warranty, and by our flat-rate service policy for years four through ten.

In this product guide our instruments are fully specified and priced. In addition to our products, we take pride and care in the services we render. You can count on immediate access to engineering personnel for technical questions, efficient fax, email or phone-quoting, order-taking and processing, on-time delivery and repair service within seven days. Finally, should you have any question about applicability or performance detail, demonstrator models are available for evaluations.

PROGRAMMED TEST SOURCES, INC.

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PTS FREQUENCY SYNTHESIZER SUMMARY CHART

	Frequency Range	Resolution	Switching Time[1]	Phase-Continuous Switching[2]	Phase-Rotation Option	Remote-Control Interface	Page	Notes
PTS 040	.1-40 MHz	optional .1 Hz to 100 KHz	1-20µs	optional	✓	BCD (std) or GPIB (opt)	9	
PTS 120	90-120 MHz	optional .1 Hz to 100 KHz	1-20µs	optional	✓	BCD (std) or GPIB (opt)	10	satellite communications synthesizer
PTS 160	.1-160 MHz	optional .1 Hz to 100 KHz	1-20µs	optional	✓	BCD (std) or GPIB (opt)	11	
PTS 250	1-250 MHz	optional .1 Hz to 100 KHz	1-20µs	optional	✓	BCD (std) or GPIB (opt)	12	
PTS 310	.1-310 MHz	1 Hz	1-20µs	standard	✓	BCD (std) or GPIB (opt)	13	space-saving 3½" cabinet
PTS 500	1-500 MHz	optional .1 Hz to 100 KHz	1-20µs	optional	✓	BCD (std) or GPIB (opt)	14	
PTS 620	1-620 MHz	optional .1 Hz to 100 KHz	1-20µs	optional	✓	BCD (std) or GPIB (opt)	15	
PTS 1600	1-1600 MHz	1 Hz	1-20µs	standard	✓	BCD (std) or GPIB (opt)	16	
PTS 3200	1-3200 MHz	1 Hz	1-20µs	standard	✓	BCD (std) or GPIB (opt)	17	
PTS 6400	1-6400 MHz	1 Hz	1-20µs	standard		BCD (std) or GPIB (opt)	18	
PTS x10	user specified 10 MHz decade	1 Hz	1-5µs	standard	✓	BCD (std) or GPIB (opt)	19	economical; 3½" cabinet
PTS D310	two channels .1-310 MHz	.1 Hz	1-20µs	standard	✓	BCD (std) or GPIB (opt)	20	
PTS D620	two channels 1-620 MHz	.1 Hz/.2 Hz	1-20µs	standard	✓	BCD (std) or GPIB (opt)	21	
PTS SX-51	various, see notes, select-able direct or F 1/10 mode	1 Hz 0.1 Hz	1-20µs	not applicable	not applicable	BCD (std) or GPIB (opt)	22	for PTS 160, 250 310 to obtain super-low phase noise in 1/10 mode

1 Switching Time is dependent on digit (decade) switched; see detailed instrument specifications.
2 For applicable digits, see detailed instrument specifications.

Often outpromised, seldom outperformed.

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TABLE OF CONTENTS

INTRODUCTION

PTS frequency synthesizers are precision frequency generators. They transfer the accuracy and stability of a frequency standard operating at 5.0 or 10.0 MHz, either built-in or external, to a selectable output frequency.

Each model is a direct frequency synthesizer capable of providing signals for many uses requiring stable and accurate sine-wave signals with low attendant spurious outputs, low phase noise and fast switching between selected frequencies. Typical applications include communications, spectrum analysis and surveillance, radar and automatic test systems with both narrow and wide-band coverage. Options based on a modular design concept permit a high degree of adaptation to a customer's specific needs.

Up to ten significant figures and resolution to 0.1 Hz are available; custom higher resolution is also available. All output frequencies are coherent with the standard frequency and reflect its stability and accuracy. Any frequency within the instrument's range may be selected by manual dial or by remote control. The output from the levelled system is +3 to +13 dBm (for most models) into 50 ohms and may be adjusted manually by the front panel control or remotely by analog voltage.

PTS synthesizers offer a *choice* of the two most widely-used remote interfaces. Instruments may be equipped with either the BCD-parallel (buffered) or the GPIB (IEEE 488) interface. In addition, PTS now offers the industry's fastest GPIB list-processing capability; this enhanced interface features full IEEE 488.2 and SCPI capability.

The PTS systems of synthesis drastically cut complexity and parts count. The attendant reduction of primary power-input and dissipation (less than 50% of that of competitive designs) is a major factor in the reliability which is further enhanced by a packaging system maximizing mechanical integrity and stability while keeping weight low. For ease of service, most modules are of plug-in design and used in all models.

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PTS QUALITY AND RELIABILITY

Since its founding, PTS has given top priority to reliability. This is reflected in both a management approach which constantly stresses reliability, and the practical implementation of a manufacturing process in which reliability is the key parameter from design to prototype to regular production. This system has ensured our quality for over 25 years.

Complex electronic equipment using modern semiconductor technology can be designed and produced to have very high reliability and long service life if certain ground rules are observed: low power consumption, small internal heat rise and conservative derating of components are all guidelines strictly observed in the design and manufacture of PTS products.

PTS uses only brand-name high quality components. After assembly, all internal modules are subjected to elevated temperature cycling to accelerate infant-mortality component failures, and 100% tested for electrical functionality. All completed instruments are again subjected to elevated temperature testing, 100% tested for electrical functionality, and individually tested to insure conformance to performance specifications.

Constant evaluation and monitoring of service data covering more than 30 years of manufacturing and over 40,000 units in the field demonstrate an actual MTBF of approximately 25,000 hours, and a yearly service rate of 3-4%. In addition, although our equipment is designed for commercial applications, calculations according to MIL 217 show a MTBF of 20,000 to 40,000 hours, depending on options and instrument configuration analyzed. Based on this outstanding record of demonstrated reliability, PTS was one of the first in the industry to offer a three-year warranty. Today, PTS is a key supplier to many blue-chip companies, and has been recognized through quality awards as outstanding in its field.

In addition, with life-cycle cost becoming the accepted criterion in the selection of capital equipment, we now offer complete predictability. Not only can the low 3-4% failure rate be used to project the incidence of required service, but the cost of that service is guaranteed: for years four through ten from shipment we will repair or recalibrate any PTS synthesizer for a flat rate of $495 (PTS 1600, PTS 3200, $935; PTS 6400, $1,190), if the customer has not attempted repairs and the unit was not subjected to unusual service conditions.

PTS synthesizers carry one or more of these approvals:

CE

TÜV PRODUCT SERVICE GS geprüfte Sicherheit

Safety tested Production monitored TÜV PRODUCT SERVICE C NRTL US

WARRANTY

PTS products are warranted for a period of three years from date of shipment against defects in material and workmanship.

Repair or replacement without charge, at PTS's option, will be made at the factory. Equipment must be shipped prepaid after return authorization has been obtained.

PTS is not liable for consequential damages, and no other warranty is expressed or implied.

GLOSSARY

The following is a brief list of terms used in characterizing synthesizer performance in general:

Frequency Range: The bandwidth over which the output frequency can be varied. Specified in MHz.

Resolution: The smallest increment by which the output frequency can be changed under local or remote control. Specified in MHz, KHz, Hz, etc.

Accuracy/Stability: The degree to which the output frequency is invariant with respect to time and temperature. Usually the same as the specification for the frequency standard. Specified in ppm or smaller fractions.

Output Level/ Flatness: The output power or voltage produced and the maximum deviation over the entire frequency range. Specified in dBm, V, dB.

Phase Noise (Broadband): The demodulated, integrated phase modulation from 0.5 Hz to 15 KHz produced by noise and discrete close-in sidebands (line or display related) expressed as a ratio to the carrier or absolutely in milli-radians, dBc.

Phase Noise (Spectral Density): The single-sided plot of the noise modulation, designated "$\mathscr{L}$"; it shows the ratio of the carrier to the noise power in a 1 Hz bandwidth as a function of the offset (modulation frequency) from that carrier. Specified in dBc/Hz.

Residual FM: The phase noise measured by an FM discriminator and expressed as a frequency deviation (for ready comparison with a normal deviation in a communication system). Various post-detection bandwidths are used and noise very close to the carrier, which is very significant in other applications, is usually not included.

Short-Term Frequency Stability: This is the extension of the concept of stability versus time, determined by the frequency standard, to time intervals of milliseconds to seconds, where residual contributions of phase disturbance of the synthesizing circuits can affect the overall behavior of the unit. In this case angle-modulation (noise) is measured by a counter. Many consecutive measurements are taken and used to calculate the "Allan variance" which broadly speaking represents the expected standard deviation, sigma, of the value of frequency during the observation interval. Specified in small fractions, e.g. 10^{-11}/sec.

Discrete Spurious Outputs: Non-harmonic signals which are present within the output bandwidth and may have any offset from the carrier. Specified in dB relative to the carrier amplitude.

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GLOSSARY (continued)

Phase-Continuous Frequency Switching:	The property that at a frequency switching point the amplitude or phase of the signal at both the “old” and the “new” frequency are equal, with no transients or discontinuities. Phase-continuous frequency switching is possible in a DDS because of its ability to maintain an accumulated phase value during a frequency switch, and after the next clock pulse begin generating the output signal at the new frequency from the phase value reached by the old frequency.
Phase-Coherent Frequency Switching:	This term actually does not address the switching behavior of an output signal, but rather defines the signal’s steady state phase. Beginning with two in-phase signals at frequency f_1, assume that one undergoes the switching sequence f_1, f_2, f_1. If, after the switching sequence, the two signals are again in phase, phase-coherent switching has occurred. In general, with arbitrary timing the phase transients required for phase coherence preclude phase continuity.
Phase-Zero Set/ Phase Reset:	To reset the phase of an output signal to zero. Phase-zeroing or resettability is possible in a DDS because of its ability to asynchronously zero out the phase accumulator, and then begin generating an output signal from zero phase.
Phase Rotation/ Digital Phase Modulation:	To rotate or shift the phase of an output signal a certain number of degrees or radians. Since the amount of phase rotation is specified by digital data indicating the number of degrees or radians to be shifted, this is also referred to as digital phase modulation.

FREQUENCY SYNTHESIZERS: Technology Overview

Synthesizers have become indispensable in many of today’s advanced measurement and production systems, as well as in stand-alone uses. Typical applications range from ATE and NMR medical imaging to satellite earth station oscillators, from magnetic storage media testing to crystal production, from mode-locking of lasers to ECM. Precision timing, radar simulations, Doppler systems, all make use of synthesizers.

Frequency synthesizers are basically variable radio-frequency generators which are very accurately and quickly settable and possess high stability. Within a specified frequency range they can be programmed either manually or remotely to practically any output frequency. This output frequency is as accurate and as stable as a built-in frequency standard, usually a crystal oscillator, or as accurate and stable as an external precision standard which may be connected to the synthesizer in lieu of its own standard. Where very high stabilities are desired, atomic or molecular standards are often used.

Most commercial frequency synthesizers use a decimal read-out or indicator system. The least-significant step or digit determines resolution, how closely the synthesizer can be set to any arbitrary frequency. Resolution ranges from megahertzs to microhertzs, depending on use; some synthesizers offer a choice of resolution to match capability (and price) to users’ need. (Although read-out or indication of setting is normally decimal, remote control frequency setting may use other coding.)

The ideal of a pure frequency, a single spectral line, is not attained in practical synthesizers. All produce unwanted frequencies, called spurious outputs, and they also have, like any oscillator, harmonics. While harmonics are at least one octave removed and thus not often troublesome, the suppression of other unwanted frequencies is a major challenge of synthesizer design; units differ widely in this respect, and this is of major impact regarding cost. The same is true of the very close-in noise around the carrier that constitutes unwanted phase-modulation. These perturbations are variously called broadband phase noise, spectral density distribution of phase noise, residual FM, and short term fractional frequency deviation.

Today’s synthesizers use three technologies, singly or in combination, to generate an output frequency from a reference standard: direct analog, indirect and direct digital.

Direct analog synthesis makes use of a limited number of auxiliary or standard frequencies which are derived from the reference. The output band is covered solely by arithmetic operations on these auxiliary frequencies, using fixed-tuned filters, RF switches, mixers, multipliers and dividers. The “mix-and-divide” direct synthesis approach permits the use of many identical modules, producing arbitrarily fine resolution and low spurious output.

Indirect synthesis uses phase-locked loops to produce an output frequency. This approach may take various forms: divide-by-n for one or more digits, fractional-n with multi-digit capability, and mix-and-divide with loops embedded. In each case, the loop is governed by some derivative of the frequency standard. Again, the mix-and-divide approach permits the use of many identical modules.

Direct digital synthesis makes use of digital technology. Using adder circuitry, phase is accumulated at a rate dependent on the frequency selected. Phase value is then used to address a PROM, which stores discrete values of the sine function. A D/A converts the digital output of the PROM to a sine wave which is low-pass filtered to remove the clock frequency, aliases and D/A glitches. The theoretical maximum output frequency obtainable is one-half the clock frequency, although practical filtering considerations limit the output frequency to less than 45% of the clock.

PTS synthesizers use direct analog and direct digital technologies. Indirect schemes, although cost-effective for multi-digit high resolution, are not used because the switching speed demanded for PTS synthesizers (µseconds) is not attainable. The most significant digits down to 1 MHz are produced by direct analog synthesis. When switching speed and signal purity are considered, there is no better approach. Direct digital synthesis is faster switching, but at this time the technology does not provide the low level of spurious outputs demanded by sophisticated applications at VHF/UHF frequencies.

For the digits from 100 KHz down to 0.1 Hz, PTS offers a choice of repetitive mix-and-divide modules or direct digital synthesis. The direct analog technology permits a close match to customer resolution requirements, while direct digital synthesis provides fast, phase-continuous switching and allows digital phase modulation.

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REMOTE CONTROL INTERFACES

For remote-control or computer-controlled applications, all PTS synthesizers are equipped with either a standard parallel BCD interface, or optional GPIB-compatible interfaces. (Lower-cost remote-only units are available which include no manual control capability.) With both interfaces, output signal frequency, output signal level, and remote/local mode control are programmable.

Parallel BCD Interface

The parallel BCD interface employs a 50-pin Amphenol 57-40500-compatible connector on the equipment, and requires an Amphenol 57-30500-compatible connector for control.

In the standard parallel BCD interface, output signal frequency programming and remote/local mode control programming use TTL-level negative true logic. Output signal level programming uses a DC control voltage.

The programming format for frequency control is parallel, 4 bit BCD coding for each digit (decade). All frequency programming connects to, and can be driven by, industry-standard 74HCT-type ICs. By default, all frequency control lines are internally pulled to a high (false) state; to program a specific frequency the appropriate pins must be brought to the low (true) state.

Data latches are included which provide storage when a “latched” or “buffered” mode of operation is required. By default, all Latch Enable (LE) pins are internally pulled to a high (false) state, disabling the latches. To store remote frequency programming input, the LE pins are brought to the low state. To operate in a “transparent” (i.e., non-latched) mode, the LE pins may be left unconnected. A separate LE line is provided for each digit pair (8 bits) so that operation with serial frequency programming data bytes is possible.

The output signal level is programmed via a DC control voltage. The RMS RF output voltage is one-half (0.5) the DC analog voltage present on the output-level control pin (0.63 to 2.0 VDC, corresponding to 0.315 to 1.0 Vrms output into 50 ohms).

GPIB Interface

The GPIB interface employs an IEEE-488 24-pin female connector on the equipment, and requires an IEEE-488 24-pin male connector for control.

PTS offers two versions of the GPIB interface:

-a fast-switching legacy version which is IEEE 488.1(1987)-compliant. It allows the synthesizer to act as a basic listener device (no talk capabilities), and provides control of the two device-dependent functions output signal frequency and level. Output signal frequency can be programmed in 30 µseconds or less to the instrument’s full resolution; signal level is programmed from +4 dBm to +13 dBm in 1 dB steps.

-a fully IEEE 488.2/SCPI-compliant interface. It allows complete control over all instrument functions and status. Switching speeds are 5 - 10 mseconds, or less than 250 µseconds in the LIST mode of operation.

The PTS GPIB can be controlled via special-purpose GPIB controllers. Alternatively, a number of manufacturers provide low-cost board-level products for microcomputers which implement the IEEE-488 interface. The PTS GPIB remote-control interface is compatible with such products.

FREQUENCY SWITCHING BEHAVIOR

In all PTS synthesizers, the most significant digits down to 1 MHz (all produced by direct analog technology) have phase-coherent frequency switching.

For applications requiring high-speed, phase-continuous frequency switching, PTS offers the Direct Digital Synthesis Table Look Up (DDS-TLU or DDS) option. With this option, the standard direct analog low-resolution subsection of an instrument is replaced with a direct digital subsection capable of generating the required low-resolution frequency increments. The DDS can provide phase-continuous frequency switching, and less than 1 μs switching time (with 2 μs delay). The following versions are available:

•Version H — DDS option replaces the 100 KHz through 0.1 Hz subsection. Phase continuity can be maintained during frequency switches involving the 100 KHz through 0.1 Hz digits. Spurious outputs are – 60 to – 70 dBc.

•Version K — DDS option replaces the 10 KHz through 0.1 Hz subsection. Phase continuity can be maintained during frequency switches involving the 10 KHz through 0.1 Hz digits. Spurious outputs are – 65 to – 75 dBc.

The DDS option is available for PTS models 040, 120, 160, 250, 500 and 620. (DDS high speed, phase-continuous switching is standard in the PTS model 310, 1600, 3200, 6400, x10, D310 and D620.) Note that the spurious specifications for the versions differ, reflecting the tradeoff between bandwidth coverage and spurious output; consult instrument specifications for details.

In instruments using the analog mix-and-divide technology for steps from 100 KHz down to 0.1 Hz, frequency switches have limited, though arbitrary, phase discontinuities. In principle, a frequency switch using the 100 KHz digit may have at most a 180° phase jump, a frequency switch using the 10 KHz digit at most an 18° phase jump, 1 KHz at most 1.8°, 100 Hz at most 0.18°, 10 Hz at most .018°, 1 Hz at most .0018°, and 0.1 Hz at most .00018°. For all practical purposes, frequency switches of 100 Hz or less may be considered phase-continuous in these instruments.

FREQUENCY STANDARDS

The output frequency of a PTS synthesizer reflects directly the accuracy of the controlling frequency standard, either internal or external. PTS offers a choice of two internal standards, a high-stability oven-controlled crystal oscillator (OCXO) or a moderate-stability temperature-compensated crystal oscillator (TCXO).

All quartz crystal oscillators are secondary standards which require a primary reference for calibration. PTS oscillators are set to within 1×10^{-7} of nominal at the time of delivery from the factory. Thereafter, these oscillators are subject to the time-drift and temperature-drift given in the specifications. Both PTS oscillators include field-adjustment capability for up to five years of aging.

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SPECIFICATIONS

Frequency	Range:	0.100 000 0 MHz to 39.999 999 9 MHz
	Resolution:	0.1 Hz to 100 KHz, optional in decades
	Accuracy	same as frequency standard
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)

Switching Time (to within 0.1 radian at new frequency)

	10 MHz digit:	20 µseconds
	1 MHz - 0.1 Hz digit:	5 µseconds
Output	Level:	+3 to +13 dBm (1V max, 50 Ω), metered in dBm and volts (rms)
	Flatness:	±0.4 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-75 dBc
	Harmonics:	-35 dBc at full output (– 40 dBc at lower level)
	Phase Noise:	-75 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathcal{L}$(1Hz):	100 Hz/ -125 dBc, 1 KHz/ -135 dBc, 10 KHz/ -135 dBc, 100 KHz/ -137 dBc
	Noise Floor:	-138 dBc/Hz

Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		

General	Operating Ambient:	0 - 55ºC, 95% R.H.
	Power:	105 - 125V, 50 - 400 Hz, 40W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	35 lbs

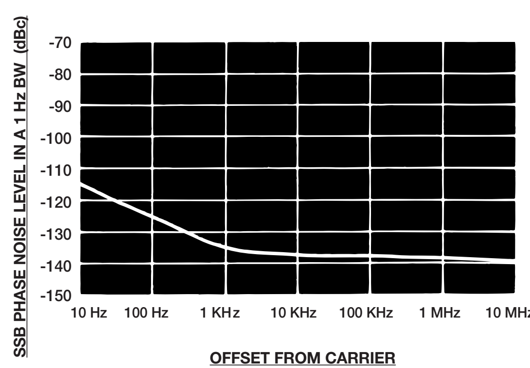
PTS 040 FREQUENCY SYNTHESIZER

- 0.1 MHz to 40 MHz
- + 3 to + 13 dBm output
- choice of resolution
- very low phase noise
- fast switching, 5 - 20µs
- fully programmable, BCD or GPIB
- modular flexibility, remote-only versions
- low power consumption, high reliability
- 7 decades of DDS resolution available with phase continuous switching

NOTE:
PTS 040 shown for illustration in “R” and “M” cabinets.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.

For units equipped with a **DDS-TLU option**, specifications are modified as follows:

DDS Option	**H**	**K**
Phase-Continuous Switching Range	100 KHz thru 0.1 Hz digits (~1 MHz bandwidth)	10 KHz thru 0.1 Hz digits (~100 KHz bandwidth)
Frequency Resolution	0.1 Hz	0.1 Hz
Optional Phase Rotation	0-360° in .36° steps	N/A
Switching Time	(within phase-continuous range) <1µs transient, 2µs delay	
Spurious Outputs Discrete:	-65 dBc	-75 dBc
Phase Noise:	-65 dBc	-70 dBc



PTS 120

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency	Range:	90.000 000 0 MHz to 119.999 999 9 MHz
	Resolution:	0.1 Hz to 100 KHz, optional in decades
	Accuracy	same as frequency standard
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	100 MHz - 10 MHz digit:	20 µseconds
	1 MHz - 0.1 Hz digit:	5 µseconds
Output	Level:	+3 to +10 dBm (.7V max, 50 Ω), metered in dBm and volts (rms)
	Flatness:	±0.5 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
Spurious Outputs		(at full power output, +10 dBm)
	Discrete:	-75 dBc within ±30 MHz of carrier,-55 dBc outside; line related, -80 dBc
	Harmonics:	-55 dBc
	Phase Noise:	-75 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	10 Hz/ -105 dBc, 100 Hz/ -118 dBc, 1KHz/-128 dBc, 10 KHz/-132 dBc, 100 KHz/ -132 dBc
	Noise Floor:	-135 dBc/Hz

Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm1 \times 10^{-8}$/0 - 50ºC		$\pm1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year

	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)
General	Operating Ambient:	0 - 55ºC, 95% R.H.
	Power:	105 - 125V, 50 - 400 Hz, 40W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	35 lbs

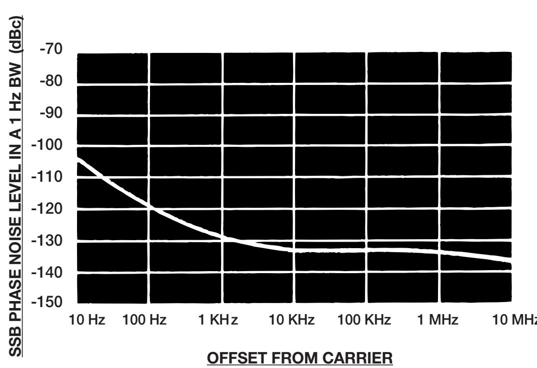
PTS 120 FREQUENCY SYNTHESIZER

- 90 - 120 MHz
- + 3 to + 10 dBm output
- choice of resolution
- very low phase noise
- fast switching, 5 - 20µs
- fully programmable, BCD or GPIB
- modular flexibility, remote-only versions
- low power consumption, high reliability
- 7 decades of DDS resolution available with phase continuous switching

NOTE:
PTS 120 shown for illustration in “M” cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.

For units equipped with a **DDS-TLU option**, specifications are modified as follows:

DDS Option	**H**	**K**
Phase-Continuous Switching Range	100 KHz thru 0.1 Hz digits (~1 MHz bandwidth)	10 KHz thru 0.1 Hz digits (~100 KHz bandwidth)
Frequency Resolution	0.1 Hz	0.1 Hz
Optional Phase Rotation	0-360° in .36° steps	N/A
Switching Time	(within phase-continuous range) <1µs transient, 2µs delay	
Spurious Outputs Discrete:(±30 MHz of f_{out})	-65 dBc	-75 dBc
Phase Noise:	-65 dBc	-70 dBc



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PTS 160

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

PTS 160 FREQUENCY SYNTHESIZER

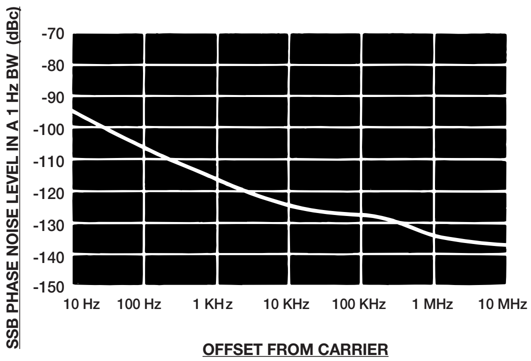
- 0.1 MHz to 160 MHz
- + 3 to + 13 dBm output
- choice of resolution
- very low phase noise
- fast switching, 5 - 20µs
- fully programmable, BCD or GPIB
- modular flexibility, remote-only versions
- low power consumption, high reliability
- 7 decades of DDS resolution available with phase continuous switching

NOTE:
PTS 160 shown for illustration in “B” cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.

Frequency	Range:	0.100 000 0 MHz to 159.999 999 9 MHz		
	Resolution:	0.1 Hz to 100 KHz, optional in decades		
	Accuracy	same as frequency standard		
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)		
Switching Time (to within 0.1 radian at new frequency)				
	100 MHz - 10 MHz digit:	20 µseconds		
	1 MHz - 0.1 Hz digit:	5 µseconds		
Output	Level:	+3 to +13 dBm (1V max, 50 Ω), metered in dBm and volts (rms)		
	Flatness:	±0.5 dB		
	Impedance:	50 Ω		
	Control:	manual by front panel control; remote by analog voltage		
Spurious Outputs		(at full power output, +13 dBm)		
	Discrete:	-75 dBc		
	Harmonics:	-35 dBc at full output (– 40 dBc at lower level)		
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz) including effects of internal standard		
	$\mathscr{L}$(1Hz):	100 Hz/ -105 dBc, 1 KHz/ -115 dBc, 10 KHz/ -123 dBc, 100 KHz/ -127 dBc		
	Noise Floor:	-135 dBc/Hz		
Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		
General	Operating Ambient:	0 - 55ºC, 95% R.H.		
	Power:	105 - 125V, 50 - 400 Hz, 40W (100, 220, 240V optional)		
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)		
	Weight:	35 lbs		

For units equipped with a **DDS-TLU option**, specifications are modified as follows:

DDS Option	**H**	**K**
Phase-Continuous Switching Range	100 KHz thru 0.1 Hz digits (~1 MHz bandwidth)	10 KHz thru 0.1 Hz digits (~100 KHz bandwidth)
Frequency Resolution	0.1 Hz	0.1 Hz
Optional Phase Rotation	0-360° in .36° steps	N/A
Switching Time	(within phase-continuous range) <1µs transient, 2µs delay	
Spurious Outputs Discrete:	-65 dBc	-75 dBc
Phase Noise:	-63 dBc	-63 dBc



SPECIFICATIONS

Frequency		
	Range:	1.000 000 0 MHz to 249.999 999 9 MHz
	Resolution:	0.1 Hz to 100 KHz ,optional in decades
	Accuracy	same as frequency standard
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	100 MHz - 10 MHz digit:	20 µseconds
	1 MHz - 0.1 Hz digit:	5 µseconds
Output	Level:	+3 to +13 dBm (1V max, 50 Ω), metered in dBm and volts (rms)
	Flatness:	±0.5 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-70 dBc
	Harmonics:	-30 dBc at full output (– 40 dBc at lower level)
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	100 Hz/ -105 dBc, 1 KHz/ -115 dBc, 10 KHz/ -123 dBc, 100 KHz/ -127 dBc
	Noise Floor:	-135 dBc/Hz

Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		
General	Operating Ambient:	0 - 55ºC, 95% R.H.		
	Power:	105 - 125V, 50 - 400 Hz, 45W (100, 220, 240V optional)		
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)		
	Weight:	35 lbs		

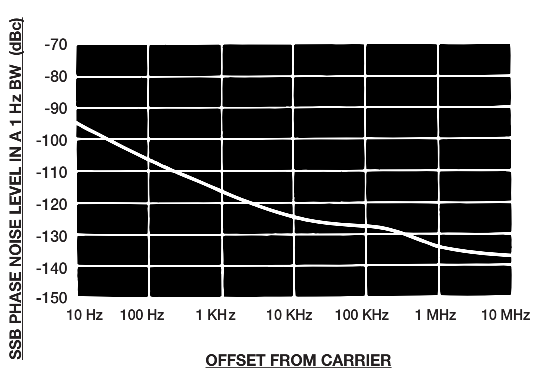
PTS 250 FREQUENCY SYNTHESIZER

- 1 MHz to 250 MHz
- + 3 to + 13 dBm output
- choice of resolution
- very low phase noise
- fast switching, 5 - 20µs
- fully programmable, BCD or GPIB
- modular flexibility, remote-only versions
- low power consumption, high reliability
- 7 decades of DDS resolution available with phase continuous switching

NOTE:
PTS 250 shown for illustration in “R, X-6” cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.

For units equipped with a **DDS-TLU option**, specifications are modified as follows:

DDS Option	**H**	**K**
Phase-Continuous Switching Range	100 KHz thru 0.1 Hz digits (~1 MHz bandwidth)	10 KHz thru 0.1 Hz digits (~100 KHz bandwidth)
Frequency Resolution	0.1 Hz	0.1 Hz
Optional Phase Rotation	0-360° in .36° steps	N/A
Switching Time	(within phase-continuous range) <1µs transient, 2µs delay	
Spurious Outputs Discrete:	-65 dBc	-70 dBc
Phase Noise:	-63 dBc	-63 dBc



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PTS 310

FREQUENCY SYNTHESIZERS

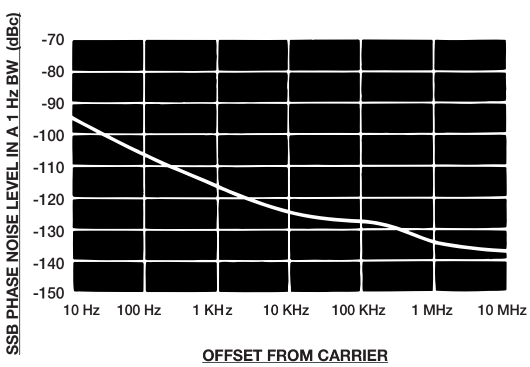
SPECIFICATIONS

Frequency	Range:	0.100 000 0 MHz to 309.999 999 9 MHz	
	Resolution:	1 Hz	
	Accuracy	same as frequency standard	
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)	
Switching Time (to within 0.1 radian at new frequency)			
	100 MHz - 10 MHz digit:	20 µseconds	
	1 MHz digit:	5 µseconds	
	100 KHz - 1 Hz digit:	<1µs transient, 2µs delay, phase continuous	
Output	Level:	+3 to +13 dBm (1V max, 50 Ω)	
	Flatness:	±0.5 dB	
	Impedance:	50 Ω	
	Control:	manual by front panel control; remote by analog voltage	
Spurious Outputs		(at full power output, +13 dBm)	
		Type 1	**Type 2**
	Discrete:	-65 dBc	-60 dBc
	Harmonics:	-30 dBc	-30 dBc
	Phase Noise:	-68 dBc	-63 dBc
		(0.5 Hz to 15 KHz) including effects of internal standard	
	$\mathscr{L}$(1Hz):	100 Hz/ -105 dBc, 1 KHz/ -115 dBc, 10 KHz/ -123 dBc, 100 KHz/ -127 dBc	
	Noise Floor:	-135 dBc/Hz	-135 dBc/Hz
	Optional Phase Rotation:	0°, 90°, 180°, 270° in 90° steps	0 - 360° in .225° steps
Frequency Standard	Internal:	OCXO	or TCXO
		3×10^{-9}/day	1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC	$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year	2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 50 Ω; 5 MHz, 0.5-2.0 Vrms into 50 Ω	
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)	
General	Operating Ambient:	0 - 55ºC, 95% R.H.	
	Power:	105 - 125V, 50 - 400 Hz, 40W (100, 220, 240V optional)	
	Dimensions:	19 x 3.5 x 17.5 inches (relay rack or bench cabinet)	
	Weight:	20 lbs	

PTS 310 FREQUENCY SYNTHESIZER

- 0.1 MHz to 310 MHz
- new standard in performance/price, with choice of spurious suppression
- DDS standard with phase-continuous switching
- flexible phase rotation options
- +3 to +13 dBm output
- 1 Hz resolution
- fully programmable, BCD or GPIB with remote-only versions available.
- space-saving 3.5” cabinet

NOTE:
PTS 310 shown for illustration in “M and V” cabinets.
Consult pages 28, 29 for full cabinet style listing.
Consult page 27 for cabinet mechanical specifications.



PTS 500

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency		
	Range:	1.000 000 0 MHz to 499.999 999 9 MHz
	Resolution:	0.1 Hz to 100 KHz, optional in decades
	Accuracy	same as frequency standard
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	100 MHz - 10 MHz digit:	20 µseconds
	1 MHz - 0.1 Hz digit:	5 µseconds
Output	Level:	+3 to +13 dBm (1V max, 50 Ω), metered in dBm and volts (rms)
	Flatness:	±0.5 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-70 dBc (-55 dBc, 1/2 & 3/2 f_{out} above 250 MHz)
	Harmonics:	-30 dBc at full output (– 40 dBc at lower level)
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	100 Hz/ -100 dBc, 1 KHz/ -110 dBc, 10 KHz/ -120 dBc, 100 KHz/ -125 dBc
	Noise Floor:	-135 dBc/Hz

Frequency Standard	Internal:	OCXO	or	TCXO
		3 x 10^{-9}/day		1 x 10^{-8}/day
		±1 x 10^{-8}/0 - 50ºC		±1 x 10^{-6}/0 - 50ºC
		1 x 10^{-6}/year		2 x 10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		

General	Operating Ambient:	0 - 55ºC, 95% R.H.
	Power:	105 - 125V, 50 - 400 Hz, 50W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	35 lbs

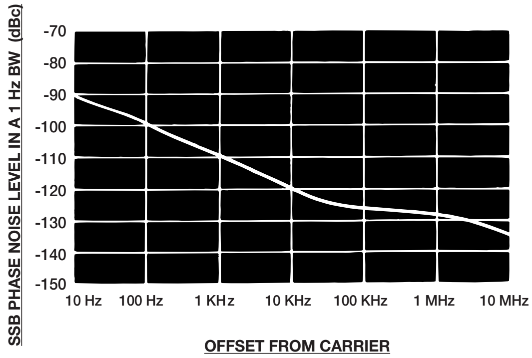
PTS 500 FREQUENCY SYNTHESIZER

- 1 MHz to 500 MHz
- + 3 to + 13 dBm output
- choice of resolution
- very low phase noise
- fast switching, 5 - 20μs
- fully programmable, BCD or GPIB
- modular flexibility, remote-only versions
- 7 decades of DDS resolution available with phase continuous switching

NOTE:
PTS 500 shown for illustration in “M and V” cabinets.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.

For units equipped with a **DDS-TLU option**, specifications are modified as follows:

DDS Option	**H**	**K**
Phase-Continuous Switching Range	100 KHz thru 0.1 Hz digits (~1 MHz bandwidth)	10 KHz thru 0.1 Hz digits (~100 KHz bandwidth)
Frequency Resolution	0.1 Hz (0.2 Hz, 250-500 MHz)	0.1 Hz (0.2 Hz, 250-500 MHz)
Optional Phase Rotation	0-360° in .36° steps (in .72° steps, 250-500 MHz)	N/A
Switching Time	(within phase-continuous range) <1µs transient, 2µs delay	
Spurious Outputs Discrete:	-60 dBc	-70 dBc
Phase Noise:	-63 dBc	-63dBc



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PTS 620

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency	Range:	1.000 000 0 MHz to 619.999 999 9 MHz	
	Resolution:	0.1 Hz to 100 KHz, optional in decades	
	Accuracy	same as frequency standard	
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)	
Switching Time (to within 0.1 radian at new frequency)			
	100 MHz - 10 MHz digit:	20 µseconds	
	1 MHz - 0.1 Hz digit:	5 µseconds	
Output	Level:	+3 to +13 dBm (1V max, 50 Ω), metered in dBm and volts (rms)	
	Flatness:	±0.5 dB	
	Impedance:	50 Ω	
	Control:	manual by front panel control; remote by analog voltage	
Spurious Outputs		(at full power output, +13 dBm)	
	Discrete:	-70 dBc (-55 dBc, 1/2 & 3/2 f_{out} above 310 MHz)	
	Harmonics:	-30 dBc at full output (– 40 dBc at lower level)	
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz) including effects of internal standard	
	$\mathscr{L}$(1Hz):	100 Hz/ -100 dBc, 1 KHz/ -110 dBc, 10 KHz/ -120 dBc, 100 KHz/ -125 dBc	
	Noise Floor:	-135 dBc/Hz	
Frequency Standard	Internal:	OCXO or	TCXO
		3×10^{-9}/day	1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC	$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year	2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω	
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)	
General	Operating Ambient:	0 - 55ºC, 95% R.H.	
	Power:	105 - 125V, 50 - 400 Hz, 50W (100, 220, 240V optional)	
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)	
	Weight:	35 lbs	

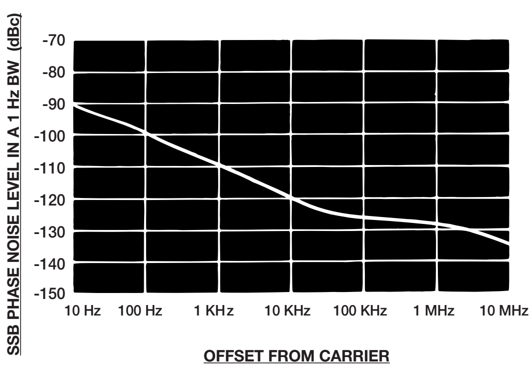
PTS 620 FREQUENCY SYNTHESIZER

- 1 MHz to 620 MHz
- + 3 to + 13 dBm output
- choice of resolution
- very low phase noise
- fast switching, 5 - 20µs
- fully programmable, BCD or GPIB
- modular flexibility, remote-only versions
- 7 decades of DDS resolution available with phase continuous switching

NOTE:
PTS 620 shown for illustration in “M” cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.

For units equipped with a **DDS-TLU option**, specifications are modified as follows:

DDS Option	**H**	**K**
Phase-Continuous Switching Range	100 KHz thru 0.1 Hz digits (~1 MHz bandwidth)	10 KHz thru 0.1 Hz digits (~100 KHz bandwidth)
Frequency Resolution	0.1 Hz (0.2 Hz, 310-620 MHz)	0.1 Hz (0.2 Hz, 310-620 MHz)
Optional Phase Rotation	0-360° in .36° steps (in .72° steps, 310-620 MHz)	N/A
Switching Time	(within phase-continuous range) <1µs transient, 2µs delay	
Spurious Outputs Discrete:	-60 dBc	-70 dBc
Phase Noise:	-63 dBc	-63 dBc



PTS 1600

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency

	Range:	1.000 000 MHz to 1599.999 999 MHz
	Resolution:	1 Hz
	Accuracy	same as frequency standard
	Control:	manual by keyboard and LCD; remote by TTL-level parallel entry BCD or GPIB (optional)

Switching Time (to within 0.1 radian at new frequency)

	1 GHz - 10 MHz digit:	20 µseconds
	1 MHz digit:	5 µseconds
	100 KHz - 1 Hz digit:	1 µsecond transient, 2 µsecond delay

Phase-Continuous Switching Range: 100 KHz through 1 Hz digits (~1 MHz bandwidth)

Output	Level:	+3 to +13 dBm (1V max, 50 Ω)
	Flatness:	±0.7 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
	Connector:	SMA female
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-60 dBc
	Harmonics:	-30 dBc
	Phase Noise:	-60 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	100 Hz/ -105 dBc, 1 KHz/ -114 dBc, 10 KHz/ -122 dBc, 100 KHz/ -124 dBc
	Noise Floor:	-136 dBc/Hz

Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year

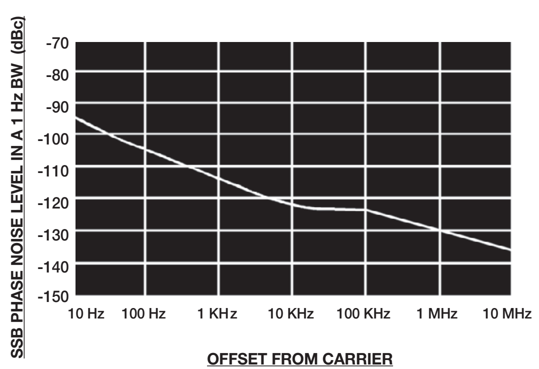
External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω	BNC Connector
Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω	BNC Connector
	(Note: internal or external standard required for operation)	

General	Operating Ambient:	10 - 45ºC, 95% R.H.
	Power:	105 - 125V, 50 - 400 Hz, 70W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	40 lbs
	Optional Phase Rotation:	0 - 360° in .36° steps

PTS 1600 FREQUENCY SYNTHESIZER

- 1 MHz to 1600 MHz
- + 3 to + 13 dBm output
- 1 Hz resolution with DDS
- low phase noise
- fast switching, 3 - 20μs
- fully remote control programmable, BCD or GPIB
- modular flexibility, remote-only versions

NOTE:
PTS 1600 shown for illustration in "D" cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.



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PTS 3200

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency

	Range:	1.000 000 MHz to 3199.999 999 MHz
	Resolution:	1 Hz
	Accuracy	same as frequency standard
	Control:	manual by keyboard and LCD; remote by TTL-level parallel entry BCD or GPIB (optional)

Switching Time (to within 0.1 radian at new frequency)

1 GHz - 10 MHz digit:	20 µseconds
1 MHz digit:	5 µseconds
100 KHz - 1 Hz digit:	1 µsecond transient, 2 µsecond delay

Phase-Continuous Switching Range:		100 KHz through 1 Hz digits (~1 MHz bandwidth)
Output	Level:	+3 to +13 dBm (1V max, 50 Ω)
	Flatness:	±0.7 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
	Connector:	SMA female
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-60 dBc 1 - 1600 MHz
		-55 dBc 1600 - 3200 MHz
	Harmonics:	-30 dBc (-35 dBc at lower power level)
	Phase Noise:	-60 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	100 Hz/-99 dBc, 1 KHz/ -108 dBc, 10 KHz/ -116 dBc, 100 KHz/ -118 dBc
	Noise Floor:	-130 dBc/Hz

Frequency Standard

Internal:	OCXO	or	TCXO
	3×10^{-9}/day		1×10^{-8}/day
	$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
	1×10^{-6}/year		2×10^{-6}/year

External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω	BNC Connector
Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω	BNC Connector
	(Note: internal or external standard required for operation)	

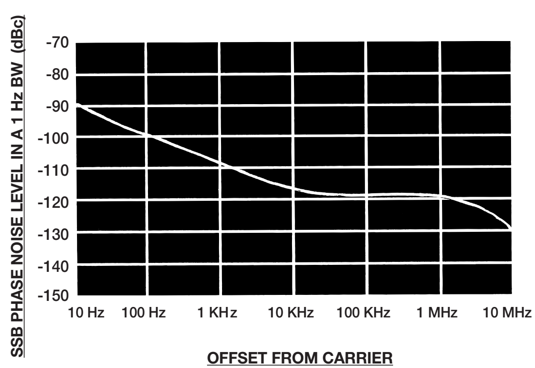
General

Operating Ambient:	10 - 45ºC, 95% R.H.
Power:	105 - 125V, 50 - 400 Hz, 70W (100, 220, 240V optional)
Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
Weight:	40 lbs
Optional Phase Rotation:	0 - 360° in .36° steps (in .72° steps,1600 - 3200 MHz)

PTS 3200 FREQUENCY SYNTHESIZER

- 1 MHz to 3200 MHz
- + 3 to + 13 dBm output
- 1 Hz resolution with DDS phase-continuous switching
- low phase noise
- fast switching, 3 - 20µs
- fully remote control programmable, BCD or GPIB
- modular flexibility, remote-only versions
- low power consumption, high reliability

NOTE:
PTS 3200 shown for illustration in “D” and “R” cabinets.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.



PTS 6400

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency		
	Range:	1.000 000 MHz to 6399.999 999 MHz
	Resolution:	1 Hz
	Accuracy	same as frequency standard
	Control:	manual by keyboard and LCD; remote by TTL-level parallel entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	1 GHz - 10 MHz digit:	20 μseconds
	1 MHz digit:	5 μseconds
	100 KHz - 1 Hz digit:	1 μsecond transient, 2 μsecond delay
Phase-Continuous Switching Range:		100 KHz through 1 Hz digits (~1 MHz bandwidth)
Output	Level:	-3 to +7 dBm (500mV max, 50Ω)
	Flatness:	±1.0 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
	Connector:	SMA female
Spurious Outputs		(at full power output, +7 dBm)
	Discrete:	-60 dBc 1 -3200 MHz
		-55 dBc 3200 -6400 MHz
	Subharmonics:	-45 dBc 1600 -6400 MHz
	Harmonics:	-30 dBc
	Phase Noise:	-60 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	
	1600 - 3200 MHz:	100 Hz/ -96 dBc, 1 KHz/-105 dBc, 10 KHz/-113 dBc, 100 KHz/-115 dBc
	Noise Floor:	
	1600 - 3200 MHz:	-126 dBc/Hz
	$\mathscr{L}$(1Hz) & Noise Floor:	
	0 - 1600 MHz:	improved by 6 dB
	3200 - 6400 MHz:	degraded by 6 dB

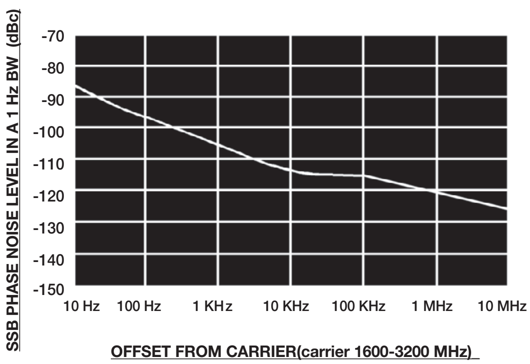
Frequency Standard	Internal:	OCXO	or TCXO
		3×10^{-9}/day	1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC	$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year	2×10^{-6}/year

	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω } BNC Connector
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω } BNC Connector
		(Note: internal or external standard required for operation)
General	Operating Ambient:	10 - 45ºC, 95% R.H.
	Power:	105 - 125V, 50 - 400 Hz, 70W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	40 lbs

PTS 6400 FREQUENCY SYNTHESIZER

- 1 MHz to 6400 MHz
- -3 to +7 dBm output
- 1 Hz resolution with DDS phase-continuous switching.
- low phase noise
- fast switching, 3 - 20μs
- fully remote control programmable, BCD or GPIB
- modular flexibility, remote-only versions
- low power consumption, high reliability

NOTE:
PTS 6400 shown for illustration in “D” cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.



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PTS x10

FREQUENCY SYNTHESIZERS

SPECIFICATIONS

Frequency		
	Range:	specified 10 MHz decade, 0.1-100 MHz (0.1-10, 10-20,...90-100 MHz)
	Resolution:	1 Hz (optional, 0.1 Hz under remote-control only)
	Accuracy	same as frequency standard
	Control:	manual by 10-position dial; remote by TTL-level parallel entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	1 MHz digit	
	non-phase-continuous:	5 µseconds
	phase-continuous:	<1 µsecond transient, 1 µsecond delay
	100 KHz - 1 Hz digits:	<1µsecond transient, 1µsecond delay, phase-continuous
Output	Level:	+3 to +13 dBm (1V max, 50 Ω)
	Flatness:	±0.25 dB
	Impedance:	50 Ω
	Control:	manual by front panel control; remote by analog voltage
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-60 dBc
	Harmonics:	-35 dBc
	Phase Noise:	-70 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	10 Hz/-110 dBc, 100 Hz/-122 dBc, 1 KHz/ -132 dBc, 10 KHz/ -133 dBc, 100 KHz/ -134 dBc
	Noise Floor:	-135 dBc/Hz

Frequency Standard	Internal:	OCXO	or	TCXO
		3 x 10^{-9}/day		1 x 10^{-8}/day
		±1 x 10^{-8}/0 - 50ºC		±1 x 10^{-6}/0 - 50ºC
		1 x 10^{-6}/year		2 x 10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 50 Ω; 5 MHz, 0.5-2.0 Vrms into 50 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		

General	Operating Ambient:	10 - 55ºC, 95% R.H.
	Power:	105 - 125V, 50 - 400 Hz, 30W (100, 220, 240V optional)
	Dimensions:	19 x 3.5 x 17.5 inches (relay rack or bench cabinet)
	Weight:	18 lbs
	Optional Phase Rotation:	0 - 360° in .225° steps

PHASE-CONTINUOUS SWITCHING

The PTS x10 sets new standards by offering users a 2 MHz bandwidth of ultra-low phase noise and low spurious phase-continuous switching range. Furthermore, the 2 MHz bandwidth can be switch-selected to span either ***even*** or ***odd*** MHz steps, guaranteeing phase-continuous coverage in the neighborhood of ***any*** selected output frequency.

Example:

Consider the **PTS x10** configured to cover the 40-50 MHz decade.

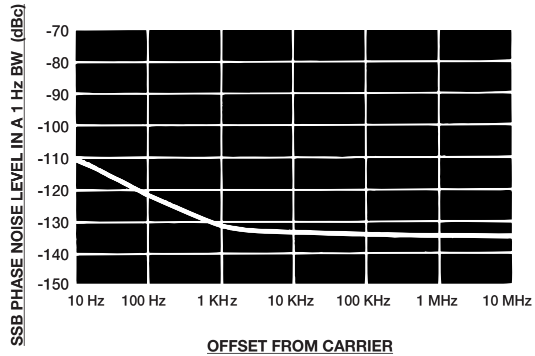
With switch-selected **even** coverage, phase-continuous spans are:	40-41.999999, 42-43.$\bar{9}$, 44-45.$\bar{9}$, 46-47.$\bar{9}$, 48-49.$\bar{9}$
With switch-selected **odd** coverage, phase-continuous spans are:	39-40.999999, 41-42.$\bar{9}$, 43-44.$\bar{9}$, 45-46.$\bar{9}$, 47-48.$\bar{9}$

PTS x10 FREQUENCY SYNTHESIZER

- 10 MHz bandwidth, configured to cover any specified decade 0.1 - 100 MHz (0.1-10, 10-20,...80-90, 90-100)
- 1 Hz resolution with DDS phase-continuous switching
- fully programmable, BCD or GPIB, with remote-only versions available.

The PTS x10 transfers the accuracy and stability of a frequency standard (built-in or external) to any output frequency within the configured 10 MHz decade specified by the user at the time of order (e.g., 20-30 MHz, 30-40 MHz, etc.). Additional optional field-installable replacement modules allow easy and rapid reconfiguration to another selected decade.

NOTE:
PTS x10 shown for illustration in “M” and “R” cabinets.
Consult pages 28, 29 for full cabinet style listing.
Consult page 27 for cabinet mechanical specifications



PTS D310

FREQUENCY SYNTHESIZERS

SPECIFICATIONS (apply to both independently programmable output channels)

Number of channels		2 fully independent output channels
Frequency	Range:	0.100 000 0 to 309.999 999 9 MHz
	Resolution:	0.1 Hz
	Accuracy	same as frequency standard
	Control:	remote by TTL-level parallel-entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	100 MHz -10 MHz digit:	20 µseconds
	1 MHz digit:	5 µseconds
	100 KHz - 0.1 Hz digit:	1 µsecond transient, 2 µsecond delay
Phase-Continuous Switching Range:		100 KHz through 0.1 Hz digits (~1 MHz bandwidth)
Output	Level:	+3 to +13 dBm (1V max, 50 Ω)
	Flatness:	±0.5 dB
	Impedance:	50 Ω
	Control:	preset and remote by analog voltage
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-70 dBc
	Harmonics:	-30 dBc at full power output,(-40 dBc at lower level)
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathcal{L}$(1Hz):	100 Hz/-105 dBc, 1 KHz/ -115 dBc, 10 KHz/ -123 dBc, 100 KHz/ -127 dBc
	Noise Floor:	-135 dBc/Hz

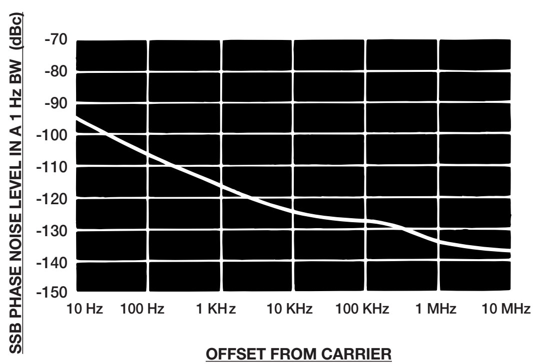
Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		

General	Operating Ambient:	0 - 50°C, 95% R.H.
	Power:	110 - 125V, 50 - 400 Hz, 75W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	40 lbs
	Optional Phase Rotation:	0 - 360° in .225° steps

PTS D310 FREQUENCY SYNTHESIZER

- two fully independent channels, each covering 0.1-310 MHz
- + 3 to + 13 dBm output
- low phase noise
- fast switching, 3 - 20μs
- fully programmable, BCD or GPIB
- DDS standard with phase-continuous switching
- low power consumption, high reliability

NOTE:
PTS D310 shown for illustration in "R" cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.



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PTS D620

FREQUENCY SYNTHESIZERS

SPECIFICATIONS (apply to both independently programmable output channels)

Number of channels		2 fully independent output channels
Frequency	Range:	1.000 000 0 to 619.999 999 8 MHz
	Resolution:	0.1 Hz, 1-310 MHz; 0.2 Hz, 310-620 MHz
	Accuracy	same as frequency standard
	Control:	remote by TTL-level parallel-entry BCD or GPIB (optional)
Switching Time (to within 0.1 radian at new frequency)		
	100 MHz -10 MHz digit:	20 µseconds
	1 MHz digit:	5 µseconds
	100 KHz - 0.1 Hz digit:	1 µsecond transient, 2 µsecond delay
Phase-Continuous Switching Range:		100 KHz through 0.1 Hz digits (~1 MHz bandwidth)
Output	Level:	+3 to +13 dBm (1V max, 50 Ω)
	Flatness:	±0.5 dB
	Impedance:	50 Ω
	Control:	preset and remote by analog voltage
Spurious Outputs		(at full power output, +13 dBm)
	Discrete:	-70 dBc 1-310 MHz -65 dBc 310-620 MHz (-55 dBc, 1/2 & 3/2 f_{out})
	Harmonics:	-30 dBc at full power output,(-40 dBc at lower level)
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz) including effects of internal standard
	$\mathscr{L}$(1Hz):	100 Hz/-100 dBc, 1 KHz/ -110 dBc, 10 KHz/ -120 dBc, 100 KHz/ -125 dBc
	Noise Floor:	-135 dBc/Hz

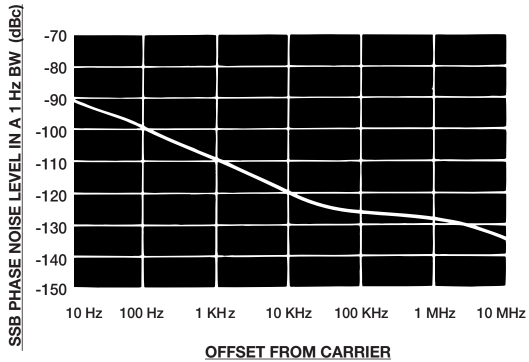
Frequency Standard	Internal:	OCXO	or	TCXO
		3×10^{-9}/day		1×10^{-8}/day
		$\pm 1 \times 10^{-8}$/0 - 50ºC		$\pm 1 \times 10^{-6}$/0 - 50ºC
		1×10^{-6}/year		2×10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		

General	Operating Ambient:	0 - 50°C, 95% R.H.
	Power:	110 - 125V, 50 - 400 Hz, 80W (100, 220, 240V optional)
	Dimensions:	19 x 5.25 x 18 inches (relay rack or bench cabinet)
	Weight:	40 lbs
	Optional Phase Rotation:	0 - 360° in .225° steps (in .450° steps, 310 - 620 MHz)

PTS D620 FREQUENCY SYNTHESIZER

- two fully independent channels, each covering 1-620 MHz
- + 3 to + 13 dBm output
- low phase noise
- fast switching, 3 - 20µs
- fully programmable, BCD or GPIB
- DDS standard with phase-continuous switching
- low power consumption, high reliability

NOTE:
PTS D620 shown for illustration in “R” cabinet.
Consult pages 28, 29 for full cabinet style listing.
Consult page 26 for cabinet mechanical specifications.



PTS 250..SX-51

FREQUENCY SYNTHESIZERS

PTS 250..SX-51 DUAL RANGE LOW-NOISE FREQUENCY SYNTHESIZER

(CONSULT FACTORY FOR PTS 160..SX-51 and PTS 310..SX-51 SPECIFICATIONS)

KEY SPECIFICATIONS

Standard Range

Frequency	Range	1.000 000 MHz to 249.999 999 MHz
	Wave Form:	sine wave
	Resolution	1 Hz to 100 KHz, optional in decades
Spurious		(at full power output, +13 dBm)
Outputs	Discrete:	-70 dBc
	Harmonics:	-30 dBc
	Phase Noise:	-63 dBc (0.5 Hz to 15 KHz, including effects of internal standard)
	L (1 Hz):	100 Hz/-105 dBc, 1 KHz/-115 dBc, 10 KHz/-123 dBc, 100 KHz/-127 dBc
	Noise Floor:	-135 dBc/Hz

Ultra-Low Noise Range

Frequency	Range:	1.000 000 0 MHz to 24.999 999 9 MHz
	Wave Form:	approximate square wave with 25 MHz low-pass filtering (harmonics: 2nd, -35 dBc, 3rd, -9 dBc, 4th, -35 dBc, 5th, -15 dBc or lower as a function of output frequency)
	Resolution:	0.1 Hz to 10 KHz, optional in decades
Spurious		(at full power output, +13 dBm)
Outputs	Discrete:	-75 dBc
	Harmonics:	-35 dBc even-order
	Phase Noise:	-73 dBc (0.5 Hz to 15 KHz, including effects of internal standard)
	L (1 Hz):	10 Hz/-120 dBc, 100 Hz/-135 dBc, 1 KHz/-140 dBc, 10 KHz/-142 dBc, 100 KHz/-145 dBc
	Noise Floor:	-147 dBc/Hz

GENERAL SPECIFICATIONS - Apply to both ranges

Frequency	Accuracy:	same as frequency standard		
	Control:	manual by 10-position dials; remote by TTL-level parallel entry BCD-encoded negative true logic or GPIB (optional)		
Switching		(to within 0.1 radian at new frequency)		
Time	100 MHz - 10 MHz digits:	20 µseconds		
	1 MHz - 0.1 Hz digits:	5 µseconds		
Output	Level:	+3 to +13 dBm (1V max., 50 Ω), metered in dBm and volts (rms)		
	Flatness:	±1.0 dB		
	Impedance:	50 Ω		
	Control:	manual by front panel control; remote by analog voltage		
Frequency	Internal:	OCXO	or	TCXO
Standard		3 x 10^{-9}/day		1 x 10^{-8}/day
		±1 x 10^{-8}/0 - 50ºC		±1 x 10^{-6}/0 - 50ºC
		1 x 10^{-6}/year		2 x 10^{-6}/year
	External:	10 MHz, 0.4-2.0 Vrms into 300 Ω; 5 MHz, 0.5-2.0 Vrms into 300 Ω		
	Aux. Output:	10.000 MHz, 0.4 Vrms into 50 Ω (Note: internal or external standard required for operation)		
General	Operating Ambient:	0 55°C, 95% relative humidity, altitude 0 - 2,000m.		
	Power:	120VAC ± 10%, 50 - 60 Hz, 45W (100V, 220-230V, 240V optional)		
	IEC Installation category:	I I		
	IEC Pollution degree:	2		
	Dimensions:	19 x 5.25 x 18 inches maximum (rack or bench cabinet)		
	Weight:	35 lbs.		

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OPTIONS AND ACCESSORIES

PTS prefers to concentrate on a standard product line which best serves our customers' needs and allows us to provide high-quality products. However, we do offer a number of options and accessories, described below. These options can be combined in a virtually limitless manner, resulting in a product not custom-built but still closely matching the customer's specifications, at a cost which is affordable. Alternatively, custom designs may be considered on a case-by-case basis.

GPIB Remote Control Interfaces — Option G, Option G(2)

GPIB-compatible remote control interface, replaces the standard parallel BCD interface. PTS 310, x10 GPIB includes phase rotation setting function.

Option G: IEEE 488.1 - 1987 compliant; allows the synthesizer to act as a basic listener device (no talk capabilities) and provides control of the two device-dependent functions output signal frequency and level. Output signal frequency can be programmed in 30 µseconds or less to the instrument's full resolution; signal level is programmed from +4 dBm to +13 dBm in 1 dB steps.

Option G(2): IEEE 488.2/SCPI compliant; allows complete control over all instrument functions and status. Switching speeds are 5 - 10 mseconds, or less than 250 µseconds in the LIST mode of operation.

Control: IEEE-488 connector
Available for: Option G: all models   Option G(2): all models *except* PTS x10 and PTS 310

Phase Rotation/Digital Phase Modulation — Option Y

Phase rotation of the main instrument output signal over the range 0º - 360º.

Phase Rotation Range: 0º – 360º
Resolution: 0.36° or 0.225° for "undoubled" range depending on model. Consult factory.
Switching Time: 2 µs

Control: 15-pin D-type connector, TTL-level parallel entry BCD-encoded negative true logic with latching capability. Optionally controllable by GPIB.
Available for: PTS 040, 120, 160, 250, 500, 620, (when equipped with option H)
PTS 310 type 2, x10, 1600, 3200
PTS D310, D620
(Note: PTS 310, Type 1, 0°, 90°, 180°, 270° in 90° steps)

DDS Load Strobe — Option X-26

For applications requiring asynchronously-timed phase-continuous switching. Used to control loading of frequency programming data for phase-continuous switching range.

Control: 1-pin BNC connector, TTL-level positive true logic
Available for: PTS 040, 120, 160, 250, 500, 620
PTS 1600, 3200, 6400 (equipped with option J)
PTS 310, x10
PTS D310, D620

Rack Mounting Slides

Standard 19" rack mount slides, for use on models with rack-mounting cabinet style. **Option X-14** **Option X-59**

Available for: all models

OPTIONS AND ACCESSORIES

Auxiliary Fixed Frequency Outputs

Extra 10 MHz Outputs — Option E

Replaces the normal single 10 MHz output with 3 passively decoupled outputs which deliver 0 dBm into 50 Ω and have maximum interaction (short circuit) of 1.5 dB.

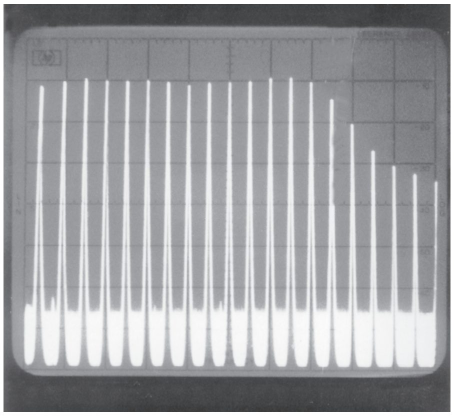
Available for: all models

Dual 10 MHz Square-Wave Outputs — Option M

Two 10 MHz square wave outputs, 1Vpp into 50 Ω, 2 Vpp open circuit.

Available for: all models

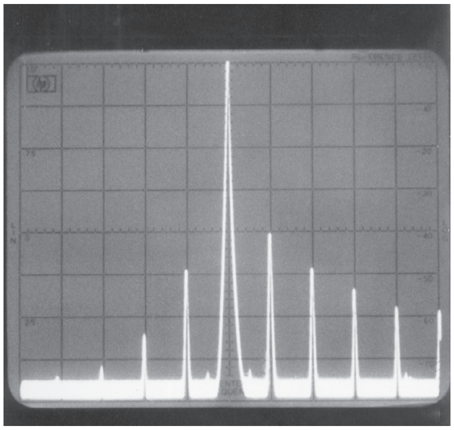
Comb (Picket Fence) Output — Option C



Pulse containing all 10 MHz multiples from 10 MHz to 140 MHz at a level of −5 dBm each. This option uses active isolation to protect internal signal purity.

Available for: PTS 040, 120, 160, 250, 500, 620, 1600, 3200, 6400

Filtered Comb or Internal Auxiliary Frequency — Option F (specify frequency)



Single, coherent n x 10 MHz frequency from 20 MHz to 140 MHz at a level of 0 dBm, with typical 10 MHz side-band suppression of 30 to 40 dBc,

or

(PTS 310 & x10 only) single n x 10 MHz frequency from 20 to 160 MHz with typical 10 MHz sideband suppression of 60 dBc or two n x 10 MHz frequencies with typical 10 MHz sideband suppression of 30 dBc

or

single coherent internal auxiliary frequency (consult factory for specific auxiliary frequencies available).

This option uses active isolation to protect internal signal purity.

Available for: all models

Filtered Comb & Dual 10 MHz Square-Wave Output Combination — Option FM (specify frequency)

Combines single filtered comb output (30 dBc 10 MHz sideband suppression) and dual 10 MHz square-wave outputs. See above for complete description of these options.

Available for: PTS 310, x10

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OPTIONS AND ACCESSORIES

Solid State Programmable Step Attenuator — Option A, A-1

Remote-control only (Option A) or manual and remote-control (Option A-1) attenuator providing 90 dB of total attenuation in 10 dB steps.

Attenuation Range:	90 dB in 10 dB steps
Frequency Range:	1-1000 MHz
Return Loss:	12 dB (VSWR 1.7) to 500 MHz 10 dB to 1000 MHz
Insertion Loss: (0 dB setting)	0 dB*
Output Level Flatness: (0 dB setting)	± 0.75 dB*
Accuracy of Attenuation 10 to 90 dB: (referenced to 0 dB setting)	± 1.0 dB at 500 MHz ± 1.5 dB at 1000 MHz
Accuracy, Incremental Step-to-Step:	± 1.0 dB typical to 1000 MHz
Harmonic Distortion: (where different from instrument spec.)	– 30 dBc
Switching Time:	5 µs (delay and rise time)

*The insertion loss will be "absorbed" by the instrument; frequency response of synthesizer plus attenuator will be ± 0.75 dB at the 0 dB attenuation setting.

Control: manual by 10-position front panel dial (available some models only, see model details below)
remote by TTL-level parallel-entry BCD, or GPIB on instruments equipped with GPIB interface
(see Notes 1 and 2, below)

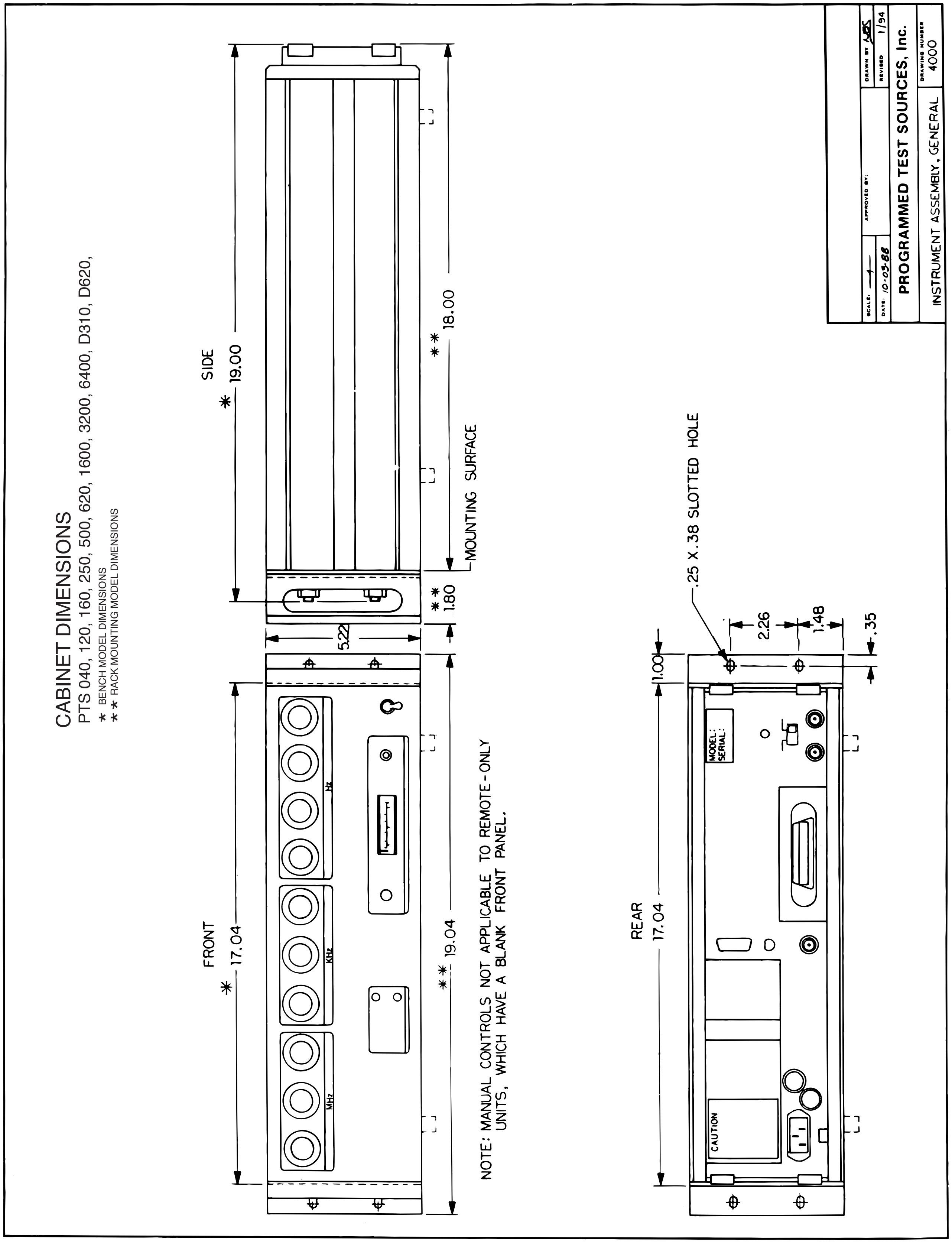
Available for: PTS 040, 120, 160, 250, 500, 620 (manual and remote-control or remote-control only)
PTS 310, x10 (remote-control only)

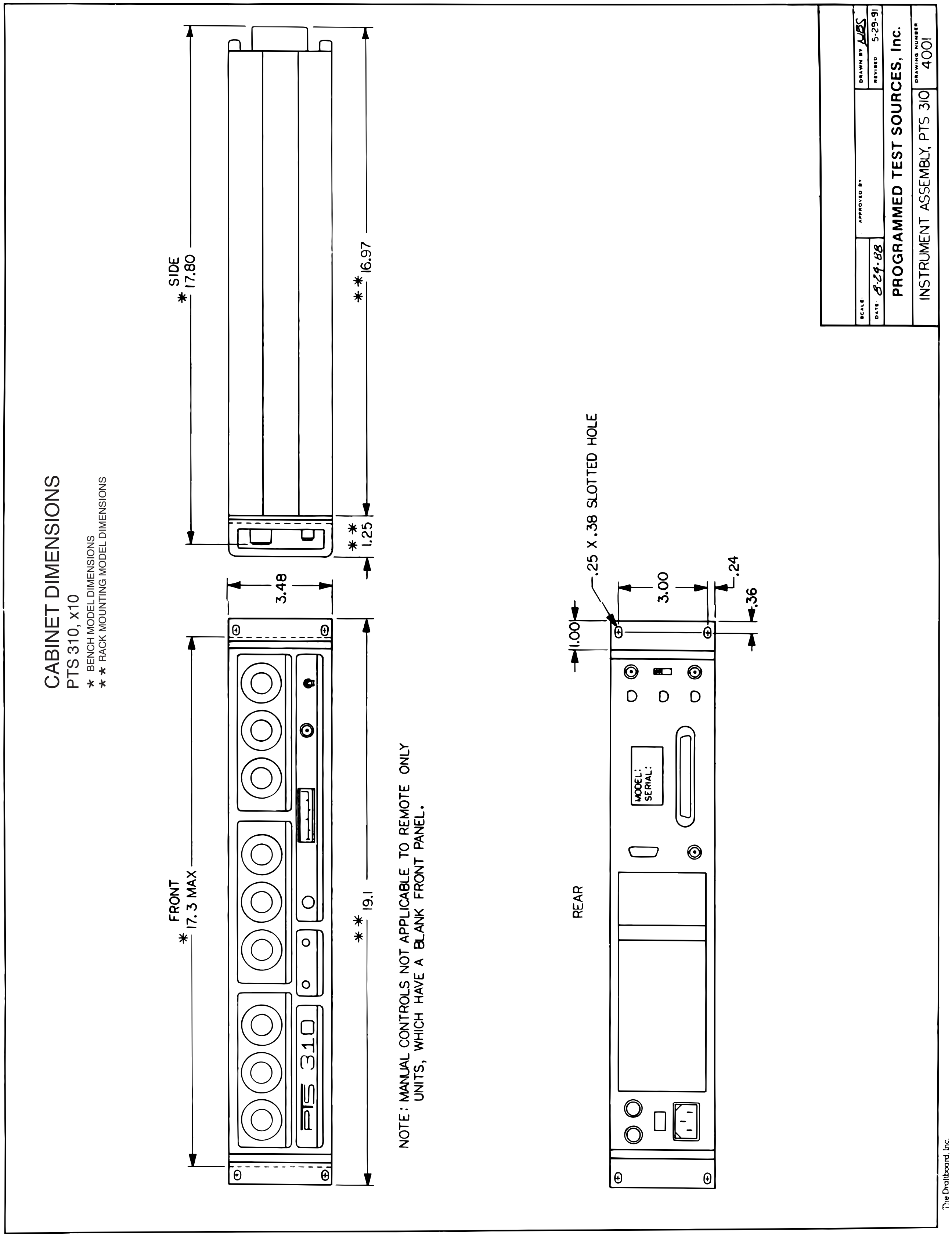
Note 1: On models PTS 040, 120, 160, 250, 500, and 620, attenuator TTL-level parallel-entry BCD remote control is through a 9-pin D-type connector, control logic **integrated** with the standard parallel remote control interface.
On models PTS 310, x10, attenuator TTL-level parallel-entry BCD remote control is through a 15-pin D-type connector, control logic **separate** from the standard parallel remote control interface.

Note 2: On instruments equipped with GPIB, attenuator remote control will produce 99 steps of 1 dB each.

MECHANICAL SPECIFICATIONS

All PTS synthesizer cabinets use substantial extrusion-reinforced frames for stability and long-term serviceability.




CABINET DIMENSIONS
PTS 310, x10
* BENCH MODEL DIMENSIONS
** RACK MOUNTING MODEL DIMENSIONS
SIDE
* 17.80
** 16.97
** 1.25
3.48
FRONT
* 17.3 MAX
** 19.1
PTS 310
NOTE: MANUAL CONTROLS NOT APPLICABLE TO REMOTE ONLY UNITS, WHICH HAVE A BLANK FRONT PANEL.
REAR
.25 X .38 SLOTTED HOLE
3.00
.24
.36
1.00
MODEL:
SERIAL:
SCALE:
DATE: 8-29-88
APPROVED BY
DRAWN BY
REVISED 5-29-91
PROGRAMMED TEST SOURCES, Inc.
INSTRUMENT ASSEMBLY, PTS 310
DRAWING NUMBER 4001

PTS PRODUCT CODE

The PTS product code is an alpha-numeric part number designed to fully specify your PTS synthesizer. Each product code contains the specification for frequency range, packaging option, resolution, frequency standard, line voltage and any miscellaneous options.

Example

PTS Code: 160M7O1C

Specifies: 0.1-160 MHz frequency range, manual controls, remote BCD control, front output, rack cabinet, 0.1 Hz resolution, OCXO frequency standard, 120V power supply and comb (picket fence) output.

160 — **M** — **7**

FREQUENCY RANGE

040	0.1-40 MHz
120	90-120 MHz
160	0.1-160 MHz
250	1-250 MHz
310	0.1-310 MHz
500	1-500 MHz
620	1-620 MHz
1600	1-1600 MHz
3200	1-3200 MHz
6400	1- 6400 MHz
x10	(user specified)
D310	0.1-310 MHz
D620	1-620 MHz

CABINET, CONTROLS, OUTPUT LOCATIONS

19" Rack Mounting	M	Manual & Remote Controls, Front Output
	S	Manual & Remote Controls, Rear Output
	D*	Keyboard/LCD & Remote Controls, Front Output
	R	Remote Control Only, Rear Output
Bench Cabinet	B	Manual & Remote Controls, Front Output
	U	Manual & Remote Controls, Rear Output
	V	Remote Control Only, Rear Output

*available on PTS 1600, 3200, 6400 only

RESOLUTION / PTS 310 TYPE / PTS x 10 FREQ. RANGE

Code	PTS 040/120/160/250/500/620/1600/3200/6400	PTS 310	PTS x10
0	________	________	0.1-10 MHz
1	100 KHz Resolution	Type 1	10-20 MHz
2	10 KHz Resolution	Type 2	20-30 MHz
3	1 KHz Resolution	________	30-40 MHz
4	100 Hz Resolution	________	40-50 MHz
5	10 Hz Resolution	________	50-60 MHz
6	1 Hz Resolution	________	60-70 MHz
7	0.1 Hz Resolution	________	70-80 MHz
H*	DDS with 0.1 Hz Resolution	________	
J**	DDS with 1 Hz Resolution	________	
K	DDS with 0.1 Hz Resolution	________	
8	________	________	80-90 MHz
9	________	________	90-100 MHz

*standard resolution on PTS D310, D620

standard resolution on PTS 1600, 3200, 6400; ***not available on other models*

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O

1

C

TYPE OF FREQUENCY STANDARD

O . . . . OCXO
- 3×10^{-9}/day
- $\pm 1 \times 10^{-8}$/0-50ºC
- 1×10^{-6}/year

T . . . . TCXO
- 1×10^{-8}/day
- $\pm 1 \times 10^{-6}$/0-50ºC
- 2×10^{-6}/year

N . . . . NONE

AC LINE VOLTAGE

1 . . . . . 120 V
2 . . . . . 120/220 V
3 . . . . . 120/240 V
5 . . . . . 120/100 V

MISCELLANEOUS OPTIONS (if none required, complete the model number with the letter "O")

A . . . . Programmable Step Attenuator (remote-control only)
(not available on PTS 1600, 3200, 6400, D310, D620)

A-1 . . Programmable Step Attenuator (manual and remote controls)
(not available on PTS 310, 1600, 3200, 6400, x10, D310, D620)

C . . . . Comb (Picket Fence) Output
(not available on PTS 310, x10, D310, D620)

E . . . . Extra 10 MHz Outputs

F . . . . Filtered Comb or Internal Auxiliary Frequency

FM . . . Filtered Comb & Dual 10 MHz Square-Wave Output Combination
(available on PTS 310, x10 only)

G . . . . GPIB Remote Control Interface (IEEE 488.1-1987 compliant)

G(2) . . GPIB Remote Control Interface (IEEE 488.2 SCPI compliant)
(not available on PTS 310, x10)

M . . . Dual 10 MHz Square-Wave Outputs

Y . . . . Phase Rotation / Digital Phase Modulation
(not available on PTS 6400)

X-6 . . Rack Cabinet with Rack Handles Removed

X-26 . DDS Load Strobe

SX-51 Dual Range Low Noise Frequency Synthesizer
(available on PTS 160, 250, 310 only)

Consult **Options and Accessories** section for complete specifications and availability.

IMPORTANT: FOR MISCELLANEOUS OPTIONS

Option:	Precludes:
*C	E, F or M
E	C or M
F	C or M
M	C, E or F

*If unit is equipped with manual controls and front output, this option available with "E" option.

ORDERING INFORMATION

The following describes how to construct the product code which will specify your synthesizer.

I. The product code begins with the model (frequency range) you are ordering:

040 (0.1-40 MHz)	310 (0.1-310 MHz)	D620 (2 @ 1-620 MHz)
120 (90-120 MHz)	D310 (2 @ 0.1-310 MHz)	1600 (1-1600 MHz)
160 (0.1-160 MHz)	500 (1-500 MHz)	3200 (1-3200 MHz)
250 (1-250 MHz)	620 (1-620 MHz)	6400 (1-6400 MHz)
		x10 (user-specified 10 MHz decade)

II. After the model number, use one letter to indicate type of controls, output location and cabinet choice:

*M:	Manual & Remote Controls	Front Output	Rack Cabinet
*S:	Manual & Remote Controls	Rear Output	Rack Cabinet
** D:	Keyboard/LCD & Remote Controls	Front Output	Rack Cabinet
R:	Remote Control Only	Rear Output	Rack Cabinet
*B:	Manual & Remote Controls	Front Output	Bench Cabinet
*U:	Manual & Remote Controls	Rear Output	Bench Cabinet
V:	Remote Control Only	Rear Output	Bench Cabinet

*not available on PTS 1600, 3200, 6400, D310, D620
**available on PTS 1600, 3200, 6400 only
note: rack cabinet instruments available without rack handles; specify X-6 option

III. Following this, use an alpha-numeric code to indicate either the resolution for models 040, 120, 160, 250, 500, 620, 1600, 3200, 6400, D310 & D620 **or** the type number of the PTS 310 **or** the frequency range of the PTS x10:

Code	PTS 040/120/160/250/500/620/1000/3200/D310/D620	PTS 310	PTS x10
0	________	________	0.1-10 MHz
1	100 KHz resolution	Type 1	10-20 MHz
2	10 KHz resolution	Type 2	20-30 MHz
3	1 KHz resolution	________	30-40 MHz
4	100 Hz resolution	________	40-50 MHz
5	10 Hz resolution	________	50-60 MHz
6	1 Hz resolution	________	60-70 MHz
7	0.1 Hz resolution	________	70-80 MHz
* H	DDS with 0.1 Hz resolution	________	
** J	DDS with 1 Hz resolution	________	
K	DDS with 0.1 Hz resolution	________	
8	________	________	80-90 MHz
9	________	________	90-100 MHz

*standard on PTS D310 & D620
standard on PTS 1600, 3200 & 6400 *(not available on other models)***

IV. Next, use a letter to indicate the frequency standard:

O: OCXO (3×10^{-9}/day) ($\pm 1 \times 10^{-8}$/0-50ºC) (1×10^{-6}/year)
T: TCXO (1×10^{-8}/day) ($\pm 1 \times 10^{-6}$/0-50ºC) (2×10^{-6}/year)
N: none required (external drive required)

V. Next, use a single digit to indicate the power supply: (all are 50-400 Hz, AC)

1: 120 V 2: 120/220 V 3: 120/240 V 5: 120/100 V

VI. Lastly, use a letter or letters to indicate any miscellaneous options (use letter O if no miscellaneous options are required):

A: Programmable Step Attenuator (remote control only; order A-1 for manual & remote controls)
C: Comb (Picket Fence) Output
E: Extra 10 MHz Outputs
F: Filtered Comb or Internal Auxiliary Frequency
FM: Filtered Comb & Dual 10 MHz Square-Wave Output Combination
G or G(2): GPIB Interface
M: Dual 10 MHz Square Wave Outputs
Y: Phase Rotation
X-6: Rack cabinet with rack handles removed
X-14: Rack Mounting Slides (5.25 inch instruments)
X-59: Rack Mounting Slides (3.50 inch instruments)
X-26: DDS Load Strobe
SX-51: Dual Range Low Noise Frequency Synthesizer

PRICE LIST
(DOMESTIC)

Basic Instrument without Frequency Standard or Other Options (Manual & BCD Remote)

RESOLUTION	PTS 040/120	PTS 160	PTS 250	PTS 500	PTS 620
100 KHz	$3,720	$5,000	$6,040	$7,450	$ 8,445
10 KHz	$4,025	$5,310	$6,350	$7,755	$ 8,750
1 KHz	$4,335	$5,615	$6,655	$8,065	$ 9,060
100 Hz	$4,645	$5,925	$6,965	$8,370	$ 9,365
10 Hz	$4,950	$6,230	$7,270	$8,680	$ 9,675
1 Hz	$5,260	$6,540	$7,580	$8,990	$ 9,985
0.1 Hz or DDS option H or K	$5,565	$6,850	$7,890	$9,295	$10,290

	PTS 310					
	Type 1	Type 2	PTS x10	PTS 1600	PTS 3200	PTS 6400
1 Hz (standard)	$6,465	$5,830	$2,695	$11,000	$14,080	$16,500

	PTS D310	PTS D620
0.1 Hz / 0.2 Hz, remote-only (standard)	$8,810	$13,960

NOTES:

1. For remote-only units (without manual controls) deduct $300 from prices above where applicable. ($200 for x10) ($800 for 1600, 3200, 6400)

****

CODE	BUILT-IN OPTIONS[1]	PTS 040/120/160/250/500/620/1600/6400/3200/D310/D620	PTS 310	PTSx10
	Frequency Standard[2]			
O	—OCXO	$605	$605	$605
T.	—TCXO	$300	$300	$300
	Remote-Control Interface			
	—BCD	No Charge	No Charge	No Charge
G	—GPIB	$440/($880 dual)	$440	$440
G(2) . .	—GPIB(2)	$825	N/A	N/A
	Extra Coherent Outputs (page 24)			
E.	—Extra 10 MHz	$ 45	$ 45	$ 45
M	—Dual 10 MHz Square Wave	$ 55	$110	$110
C	—Comb (Picket Fence)	$330	N/A	N/A
F.	—Filtered Comb (10 MHz multiple from 20-140 MHz)	$330	$385	$385
FM . . .	—Filtered Comb (10 MHz multiple, -30dB), plus Dual 10 MHz Square Wave Outputs	N/A	$385	$385
Y	Phase Rotation (requires PTS 310, x10 or option H or J)	$495	$495	$330
A	Programmable Step Attenuator (remote control only)	$660	$660	$660
A-1 . . .	Programmable Step Attenuator (manual/remote controls)	$770	N/A	N/A
X-26 . .	DDS Load Strobe	$ 55	$ 55	$ 55
X-6 . . .	Rack cabinet with rack handles removed	$ 45	$ 45	$ 45
X-14 . .	Rack Mounting Slides (5¼″ instruments)	$110	N/A	N/A
SX-51 .	PTS 160, 250, 310 only	$560	$560	N/A
X-59 . .	Rack Mounting Slides (3½″ instruments)	N/A	$110	$110

****

Notes

1. Some options not available on some instruments, or in some combinations. See **Options and Accessories** section of catalog for complete specification.
2. Units *without* a frequency standard are available and operate from an external 5 or 10 MHz standard. If no external standard is used, an internal standard is required to make the unit operational.

PROGRAMMED TEST SOURCES, INC.

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January 2008

FREQUENCY SYNTHESIZERS

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